United States Environmental Protection Agency

Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule

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Acknowledgements and Disclaimer

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Tetra Tech, Inc.

Contents

Exhibits

Chapter 1: Background

1.0 Introduction

This chapter provides background information on the development of 316(b) regulations including the proposed Existing Facilities rule. This chapter describes the goal of the proposed Existing Facilities rule and provides an overview of the legislative background, prior 316(b) rulemakings, and associated litigation history leading up to the proposed rulemaking. This document builds on and updates record support compiled for the Phase I rule, the remanded 2004 Phase II existing facility rule, and the Phase III rule, including the Technical Development Documents for each.

1.1 Purpose of Technical Development Document and Proposed Regulation

The purpose of this Technical Development Document is to provide record support for the proposed Existing Facilities rule and to describe the methods used by EPA to analyze various options. The goal of the proposed regulation is to establish national requirements for cooling water intake structures at existing facilities that implement Section 316(b) of the CWA. Section 316(b) of the CWA provides that any standard established pursuant to Section 301 or 306 of the CWA and applicable to a point source must require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available (BTA) for minimizing adverse environmental impact.

EPA first promulgated regulations to implement Section 316(b) in 1976. The U.S. Court of Appeals for the Fourth Circuit remanded these regulations to EPA which withdrew them, leaving in place a provision not remanded that directed permitting authorities to determine BTA for each facility on a case-by-case basis. In 1995, EPA entered into a consent decree establishing a schedule for taking final action on regulations to implement Section 316(b). Pursuant to a schedule in the amended decree providing for final action on regulations in three phases, in 2001, EPA published a Phase I rule governing new facilities. The U.S. Court of Appeals for the Second Circuit, while generally upholding the rule, rejected the provisions allowing restoration to be used to meet the requirements of the rule. *Riverkeeper, Inc. v. U.S. EPA*, 358 F. 3d 174, 181 (2d Cir.2004) ("*Riverkeepe*r I").

In 2004, EPA published the Phase II rule applicable to existing power plants. Following challenge, the Second Circuit remanded numerous aspects of the rule to the Agency, including the Agency's decision to reject closed-cycle cooling as BTA. The Agency made this determination, in part, based on a consideration of incremental costs and benefits. The Second Circuit concluded that a comparison of the costs and benefits of closed-cycle cooling was not a proper factor to consider in determining BTA. *Riverkeeper, Inc. v. U.S.EPA,* 475 F. 3d 83 (2d Cir. 2007) ("*Riverkeeper* II"). In 2008, the U.S, Supreme Court agreed to review the *Riverkeeper* II decision limited to a single issue: whether Section 316(b) authorizes EPA to balance costs and benefits in 316(b) rulemaking. In April 2009, in *Entergy Corp. v. Riverkeeper Inc.*, 129 S. Ct. 1498, 68 ERC 1001 (2009) (40 ER 770, 4/3/09), the Supreme Court ruled that it is permissible under Section 316(b) to consider costs and benefits in determining the best technology available to minimize adverse environmental impacts. The court left it to EPA's discretion to decide whether and how to consider costs and benefits in 316(b) actions, including rulemaking and BPJ determinations. The Supreme Court remanded the rule to the Second Circuit. Subsequently, EPA asked the Second Circuit to return the rule to the Agency for further review.

In 2006, EPA published the Phase III rule. The Phase III rule establishes 316(b) requirements for certain new offshore oil and gas extraction facilities. In addition, EPA determined that, in the case of electric generators with a design intake flow of less than 50 MGD and existing manufacturing facilities, 316(b) requirements should be established by NPDES permit directors on a case-by-case basis using their best professional judgment. In July 2010, the U. S. Court of Appeals for the Fifth Circuit issued a decision upholding EPA's rule for new offshore oil and gas extraction facilities. Further, the court granted the request of EPA and environmental petitioners in the case to remand the existing facility portion of the rule back to the Agency for further rulemaking. See section 1.2 below for a more detailed discussion of the history of EPA's actions to address standards for cooling water intake structures.

EPA is proposing requirements reflecting the best technology available for minimizing adverse environmental impact, applicable to the location, design, construction, and capacity of cooling water intake structures for existing facilities. EPA is treating existing power generating facilities and existing manufacturing and industrial facilities in one proceeding. This proposed rule applies to all existing power generating facilities and existing manufacturing and industrial facilities that have the design capacity to withdraw more than two million gallons per day of cooling water from waters of the United States and use at least twenty-five (25) percent of the water they withdraw exclusively for cooling purposes.

1.2 Background

The Federal Water Pollution Control Act, also known as the Clean Water Act (CWA), 33 U.S.C. 1251 et seq., seeks to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." 33 U.S.C. § 1251(a). Among the goals of the Act is

> "wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water…" 33 U.S.C. § 1251(a)(2).

In furtherance of these objectives, the CWA establishes a comprehensive regulatory program, key elements of which are (1) a prohibition on the discharge of pollutants from point sources to waters of the United States, except in compliance with the statute; (2) authority for EPA or authorized States or Tribes to issue National Pollutant Discharge Elimination System (NPDES) permits that authorize and regulate the discharge of pollutants; and (3) requirements for effluent limitations and other conditions in NPDES permits to implement applicable technology-based effluent limitations guidelines and standards and applicable State water quality standards.

Section 402 of the CWA authorizes EPA (or an authorized State or Tribe) to issue an NPDES permit to any person discharging any pollutant or combination of pollutants from a point source into waters of the United States. Forty-six States and one U.S. territory are authorized under Section 402(b) to administer the NPDES permitting program. NPDES permits restrict the types and amounts of pollutants, including heat that may be discharged from various industrial, commercial, and other sources of wastewater. These permits control the discharge of pollutants by requiring dischargers to meet technology-based effluent limitations guidelines (ELGs) or new source performance standards (NSPS) established pursuant to Section 301 or Section 306. Where such nationally applicable ELGs or NSPS exist, permit authorities must incorporate them into permit requirements. Where they do not exist, permit authorities establish effluent limitations and conditions, reflecting the appropriate level of control (depending on the type of pollutant) based on the best professional judgment of the permit writer. Limitations based on these guidelines, standards, or on best professional judgment are known as technology-based effluent limits. Where technology-based effluent limits are inadequate to meet applicable State water quality standards, Section 301(b)(1)(C) of the Clean Water Act requires permits to include more stringent limits to meet applicable water quality standards. NPDES permits also routinely include standard conditions applicable to all permits, special conditions, and monitoring and reporting requirements. In addition to these requirements, NPDES permits must contain conditions to implement the requirements of Section 316(b).

Section 510 of the Clean Water Act provides, that except as provided in the Clean Water Act, nothing shall preclude or deny the right of any State (or political subdivision thereof) to adopt or enforce any requirement respecting control or abatement of pollution; except that if a limitation, prohibition or standard of performance is in effect under the Clean Water Act, such State may not adopt any other limitation, prohibition, or standard of performance which is less stringent than the limitation, prohibition, or standard of performance under the Act. EPA interprets this to reserve for the States authority to implement requirements that are more stringent than the Federal requirements under state law. *PUD No. 1 of Jefferson County v. Washington Dep't of Ecology*, 511 U.S. 700, 705 (1994).

Sections 301, 304, and 306 of the CWA require that EPA develop technology-based effluent limitations guidelines and new source performance standards that are used as the basis for discharge requirements in wastewater discharge permits. EPA develops these effluent limitations guidelines and standards for categories of industrial dischargers based on the pollutants of concern discharged by the industry, the degree of control that can be attained using various levels of pollution control technology, consideration of various economic tests appropriate to each level of control, and other factors identified in Sections 304 and 306 of the CWA (such as non-water quality environmental impacts including energy impacts). EPA has promulgated regulations setting effluent limitations guidelines and standards under Sections 301, 304, and 306 of the CWA for more than 56 industries. See 40 CFR parts 405 through 471. EPA has established effluent limitations guidelines and standards that apply to most of the industry categories that use cooling water intake structures (e.g., steam electric power generation, paper and allied products, petroleum refining, iron and steel manufacturing, and chemicals and allied products).

Section 316(b) states, in full:

> Any standard established pursuant to Section 301 or Section 306 of [the Clean Water] Act and applicable to a point source shall require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

Section 316(b) addresses the adverse environmental impact caused specifically by the intake of cooling water, rather than discharges into water. Despite this special focus, the requirements of Section 316(b) remain closely linked to several of the core elements of the NPDES permit program established under Section 402 of the CWA to control discharges of pollutants into navigable waters. Thus, while effluent limitations apply to the discharge of pollutants by NPDES-permitted point sources to waters of the United States, Section 316(b) applies to facilities subject to NPDES requirements that also withdraw water from a water of the United States for cooling and that use a cooling water intake structure to do so.

The CWA does not describe the factors to be considered in establishing Section 316(b) substantive performance requirements that reflect the "best technology available for minimizing adverse environmental impact." The most recent guidance in interpreting 316(b) comes from the U.S. Supreme Court's decision in *Entergy Corp. v. Riverkeeper, Inc*. As noted, the decision was limited to the single question of whether Section 316(b) of the Clean Water Act authorizes EPA to compare costs and benefits of various technologies when setting national performance standards for cooling water intake structures under Section 316(b) of the Clean Water Act. In *Riverkeeper* II, the Second Circuit rejected EPA's determination that closed-cycle cooling was not BTA because it could not determine whether EPA had improperly considered costs and benefits in its 316(b) rulemaking. The Supreme Court reversed and remanded the Second Circuit ruling in a 6-3 opinion authored by Justice Scalia. The Court held that it is reasonable for EPA to conduct a cost-benefit analysis in setting national performance standards for cooling water intake structures under Section 316(b). The Court held that EPA has the discretion to consider costs and benefits under Section 316(b) but is not required to consider costs and benefits. The Court's discussion of the language of Section 316(b) – Section 316(b) is "unencumbered by specified statutory factors" -- and its critique of the Second Circuit's decision affirms EPA's broader discretion to consider a number of factors in standard setting under Section 316(b). While the Supreme Court's decision is limited to whether or not EPA may consider one factor (cost/benefit analysis) under Section 316(b), the language also suggests that EPA has wide discretion in considering factors relevant to 316(b) standard setting. ("It is eminently reasonable to conclude that § *1326b*'s silence is meant to convey nothing more than a refusal to tie the agency's hands as to whether cost-benefit analysis should be used, and if so to what decree." (*emphasis supplied)*, 129 S.Ct. 1498, 1508 (2009).

Regarding the other factors EPA may consider, Section 316(b) cross references Sections 301 and 306 of the CWA by requiring that any standards established pursuant to those sections also must require that the location, design, construction and capacity of intake structures reflect BTA. Thus, among the factors EPA may use to determine BTA, EPA may look to similar phrases used elsewhere in the CWA. See *Riverkeeper* v. *EPA,* (2nd Cir. Feb. 3, 2004). Section 306 directs EPA to establish performance standards for *new* sources based on the "best available demonstrated control technology" (BADT). 33 U.S.C. 1316(a)(1). In establishing BADT, EPA "shall take into consideration the cost of achieving such effluent reduction, and any non-water quality environmental impact and energy requirements." 33 U.S.C. 1316(b)(2)(B). The specific cross-reference in CWA Section 316(b) to CWA Section 306 "is an invitation to look to Section 306 for guidance in discerning what factors Congress intended the EPA to consider in determining the 'best technology available'" for new sources.

Similarly, Section 301 of the CWA requires EPA to establish standards known as "effluent limitations" for *existing* point source discharges in two phases. In the first phase, applicable to all pollutants, EPA must establish effluent limitations based on the "best practicable control technology currently available" (BPT). 33 U.S.C. 1311(b)(1)(A). In establishing BPT, the CWA directs EPA to consider the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, and shall also take into account the age of the equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impact (including energy requirements), and such other factors as [EPA] deems appropriate. 33 U.S.C. 1314(b)(1)(b).

In the second phase, EPA must establish effluent limitations for conventional pollutants based on the "best conventional pollution control technology" (BCT), and for toxic pollutants based on the "best available technology economically achievable" (BAT). 33 U.S.C. 1311(b)(2)(A), (E).

In determining BCT, EPA must consider, among other factors,

> "the relationship between the costs of attaining a reduction in effluents and the effluent reduction benefits derived, and the comparison of the cost and level of reduction of such pollutants from the discharge from publicly owned treatment works to the cost and level of reduction of such pollutants from a class or category of industry source…. and the age of equipment and facilities involved, the process employed, the engineering aspects …. of various types of control techniques, process changes, the cost of achieving such effluent reduction, non-water quality environmental impacts (including energy requirements), and such other factors as [EPA] deems appropriate." 33 U.S.C. 1314(b)(4)(B).

In determining BAT, the CWA directs EPA to consider "the age of equipment and facilities involved, the process employed, the engineering aspects …. of various types of control techniques, process changes, the cost of achieving such effluent reduction, non-water quality environmental impacts (including energy requirements), and such other factors as [EPA] deems appropriate." 33 U.S.C. 1314(b)(2)(B).

Section 316(b) expressly refers to Section 301, and the phrase "best technology available" is very similar to the phrases "best available technology economically achievable " and "best practicable control technology currently available" in that section. Thus, Section 316(b), Section 301(b)(1)(A) -- the BPT provision-- and Section 301(b)(1)(B) -- the BAT provision -- all include the terms "best," "technology," and "available," but neither BPT nor BAT goes on to consider minimizing adverse environmental impacts, as BTA does.

See 33 U.S.C. 1311(b)(1)(A) and (2)(A). These facts, coupled with the brevity of Section 316(b) itself, prompts EPA to look to Section 301 and, ultimately, Section 304 for further guidance in determining the "best technology available to minimize adverse environmental impact" of cooling water intake structures for existing facilities.

By the same token, however, there are significant differences between Section 316(b) and Sections 301 and 304. See *Riverkeeper, Inc.* v. *United States Environmental Protection Agency* (2nd Cir. Feb. 3, 2004) ("not every statutory directive contained [in Sections 301 and 306] is applicable" to a Section 316(b) rulemaking). Moreover, as the Supreme Court recognized, while the provisions governing the discharge of toxic pollutants must require the elimination of discharges if technically and economically achievable, Section 316(b) has the less ambitious goal of "minimizing adverse environmental impact." 129 S.Ct. 1498, 1506. In contrast to the effluent limitations provisions, the object of the "best technology available" is explicitly articulated by reference to the receiving water: to minimize adverse environmental impact in the waters from which cooling water is withdrawn. This difference is reflected in EPA's past practices in implementing Sections 301, 304, and 316(b). EPA has established BPT and BAT effluent limitations guidelines and NSPS based on the efficacy of one or more technologies to reduce pollutants in wastewater in relation to their costs without necessarily considering the impact on the receiving waters. This contrasts to 316(b) requirements, where EPA has previously considered the costs of technologies in relation to the benefits of minimizing adverse environmental impact in establishing 316(b) limits, which historically has been done on a case-by case basis. In *Re Public Service Co. of New Hampshire,* 10 ERC 1257 (June 17, 1977); *In Re Public Service Co. of New Hampshire,* 1 EAD 455 (Aug. 4, 1978); *Seacoast Anti-Pollution League* v. *Costle,* 597 F. 2d 306 (1st Cir. 1979) EPA concluded that, because both Section 301 and 306 are expressly cross-referenced in Section 316(b), EPA reasonably interpreted Section 316(b) as authorizing consideration of the same factors, including costs, as in those sections. EPA interpreted "best technology available" to mean the best technology available at an "economically practicable" cost. This approach squared with the limited legislative history of Section 316(b) which suggested the BTA was to be based on technology whose costs were "economically practicable." In debate on Section 316(b), one legislator explained that "[t]he reference here to 'best technology available' is intended to be interpreted to mean the best technology available commercially *at an economically practicable cost*." 118 Cong. Rec. 33,762 (1972) (statement of Rep. Clausen) (emphasis added).

For EPA's initial Phase II rulemaking, as it had during 30 years of BPJ Section 316(b) permitting, EPA therefore interpreted CWA Section 316(b) as authorizing EPA to consider not only the costs of technologies but also their effects on the water from which the cooling water is withdrawn.

Chapter 2: Summary of Data Collection Activities

2.0 Introduction

In developing the proposed rule, EPA used previously collected data from the Phase I, 2004 Phase II, and Phase III rulemakings in combination with newly collected data and information. This chapter first provides information on major data collection activities from the previous rulemakings and then provides summaries of information obtained through more recent data collection activities.

2.1 Primary Data Sourced from Previous 316(b) Rulemakings

This section summarizes the major data collection activities conducted during development of the Phase I, 2004 Phase II, and Phase III rulemakings that EPA also considered in developing this proposed rule. For additional, more detailed information on these previous activities, see the Phase I proposed rule (65 FR 49070), Phase I NODA (66 FR 28853), Phase II proposal (67 FR 17131), Phase II NODA (68 FR 13524), Phase III proposal (69 FR 68457), Phase III NODA (70 FR 71057), Phase III final (71 FR 35018), and Phase III final TDD (Chapter 3).

2.1.1 Survey Questionnaires

Industry characterization data, including facility-specific technical and financial information, for the proposed rule and EPA's Phase I, 2004 Phase II, and Phase III rulemakings was collected through an industry-wide survey conducted in 2000.[1] This information was fundamental to EPA's development of its previous rulemakings and is similarly fundamental to the proposed Existing Facilities rule. EPA has relied on the previously collected technical (e.g., cooling water system data and cooling water intake configuration specifications and intake flow rates) and financial information.[2, 3]

Two types of surveys were issued: detailed questionnaires (DQ) and short technical questionnaires (STQ). Detailed questionnaires were longer and requested more specific information about technologies, plant operations, and other characteristics. Short technical questionnaires were developed as a way to statistically sample a larger number of facilities while maintaining a manageable burden on the industry respondents; these surveys contained far less detailed information.

[1] For the Phase III rule, EPA issued industry questionnaires to offshore industries (see 69 FR 68458).
[2] Specific details about the questions are found in EPA's Information Collection Request (DCN 3– 3084-R2 in Docket W–00–03) and in the questionnaires (see DCN 3–0030 and 3– 0031 in Docket W–00–03 and the Docket for the proposed Existing Facilities rule); these documents are also available on EPA's web site (*http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/question_index.cfm*)
[3] EPA did update some of the financial information. For a discussion of financial data used, see the EBA.

2.1.2 Technology Efficacy Data

EPA compiled a database of cooling water intake structure technology performance information otherwise known as the Technology Efficacy Database (TED) (DCN 6-5000 and FDMS Document ID EPA-HQ-OW-2002-0049-1595). The Technology Efficacy Database was the result of an extensive literature search supplemented by information obtained through discussions with state and EPA regional staff, and meetings with nongovernmental organizations that had conducted national or regional data collection efforts (e.g., Electric Power Research Institute (EPRI) and Tennessee Valley Authority). EPA's goal in developing this database was to collect information and data to evaluate the performance of various impingement and entrainment control technologies. The resulting database contains over 150 records from over 90 documents that include narrative descriptions of biological sampling information and efficacies for a range of impingement and entrainment minimization technologies. See Chapter 4 of the TDD for the 2004 Phase II Final rule for a complete description of this database.

2.1.3 Existing Data Sources

In developing 316(b) regulations, EPA used existing data sources, where available and applicable. This includes information collected by other Federal agencies as well as data compiled by private companies. Additional details are found in the 2002 proposed Phase II rule at 67 FR17131, but the sources contacted include:

- Federal Energy Regulatory Commission (FERC);
- Energy Information Administration (EIA);
- Rural Utility Service (RUS);
- U.S. Nuclear Regulatory Commission (NRC);
- Utility Data Institute;
- NEWGen database;
- Electric Power Research Institute (EPRI); and
- Edison Electric Institute (EEI).

2.1.4 Public Participation Activities

Historically, EPA has worked extensively with stakeholders from industry, public interest groups, state agencies, and other Federal agencies in the development of previous 316(b) rulemakings, including numerous meetings with individual stakeholder groups. These public participation activities focused on various Section 316(b) issues including biology, technology, and implementation issues. For example, EPA has conducted public meetings focused on technology, cost and mitigation issues, a technical symposium sponsored by EPRI and a symposium on cooling water intake structure technologies. See the 2002 proposed Phase II rule (68 FR 17127) for a discussion of these and other public participation activities.

EPA has also issued nine Federal Register notices regarding the 316(b) regulation development process.[4] As a result, EPA has received over 350 public comments from environmental groups, industry associations, facility owners, state and Federal agencies, and private citizens.

2.2 New Data Collected

For the proposed Existing Facilities rule, EPA supplemented its previous data collection activities. EPA collected updated information on various aspects of the rulemaking. However, in an effort to better inform its BTA determination, EPA's main focus was on the performance of impingement and entrainment technologies.

2.2.1 Site Visits

As documented in the 2004 Phase II rule, EPA conducted site visits to 22 power plants in developing the 2004 rule. See 67 FR 17134. Since 2007, EPA has conducted over 50 site visits to power plants and manufacturing sites. The purpose of these visits was to: gather information on the intake technologies and cooling water systems in place at a wide variety existing facilities; better understand how the site-specific characteristics of each facility affect the selection and performance of these systems; gather data on the performance of technologies and affected biological resources; and to solicit perspectives from industry representatives.

While visiting certain sites, EPA also collected information on 7 additional facilities that staff did not physically visit; usually, these were other facilities that were owned by the parent company of a site visited by EPA. EPA further met with representatives of other companies or owners of specific power plant or manufacturing sites at EPA Headquarters in Washington DC.

In general, EPA visited a wide variety of sites representative of the industries and facilities subject to the proposed rule. Copies of the site visit reports (which provide an overall facility description as well as detailed information on electricity generation, the facility's cooling water intake structure and associated fish protection and/or flow reduction technologies, impingement and/or entrainment sampling and associated data, and a discussion of the possible application of cooling towers) for each site are provided in the docket for the proposed rule. Where possible, EPA made these reports publicly available well before publication of the proposed rule. A list of the facilities visited by EPA is provided below; Exhibit 2-1 shows the geographic representation of facilities visited by EPA as well as facilities for which EPA collected site-specific information.

[4] See 65 FR 49060, 66 FR 28853, 66 FR 65256, 67 FR 17122, 68 FR 13522, 69 FR 41576, 69 FR 68444, 70 FR 71057, and 71 FR 35006. Also see the EBA for a discussion of the Federal Register notices for economics-related issues.

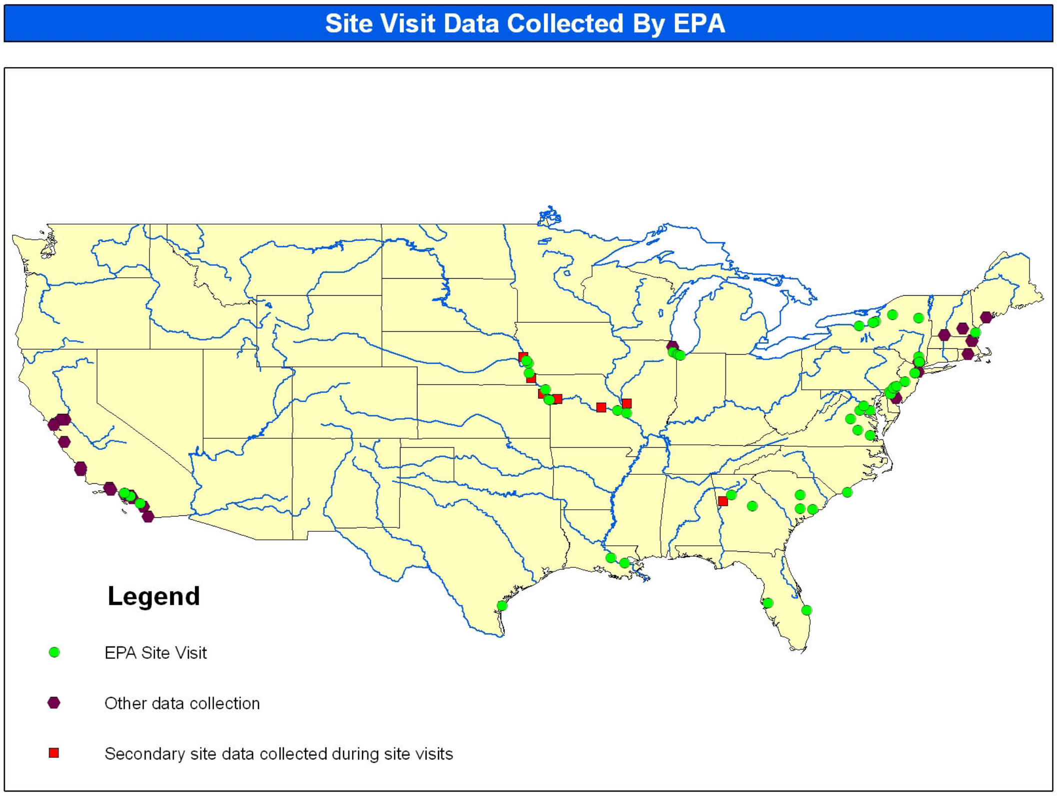
The sites visited by EPA include the following:

Facility Name	State	Date Of Visit
El Segundo	CA	9/1/2009
Haynes	CA	9/2/2009
San Onofre	CA	9/2/2009
Scattergood	CA	8/31/2009
Valero (Delaware City)	DE	7/15/2009
Big Bend	FL	3/27/2008
St. Lucie	FL	3/26/2008
Harlee Branch	GA	2/11/2009
McDonough	GA	2/11/2009
Council Bluffs	IA	3/2/2009
Crawford	IL	8/4/2009
Arcelor Mittal (Indiana Harbor)	IN	8/3/2009
Cargill (Hammond)	IN	8/3/2009
US Steel (Gary)	IN	8/4/2009
Nearman Creek	KS	3/3/2009
Quindaro	KS	3/3/2009
Dow (Louisiana Operations/Plaquemine)	LA	1/12/2010
Dow (St Charles)	LA	1/13/2010
Chalk Point	MD	12/3/2007
Labadie	MO	3/4/2009
Lake Road	MO	3/3/2009
Meramec	MO	3/4/2009
Brunswick	NC	1/28/2008
Nebraska City	NE	3/2/2009
North Omaha	NE	3/2/2009
Seabrook	NH	4/17/2008
Linden	NJ	5/26/2010
Logan	NJ	1/22/2008
Mercer	NJ	5/26/2010
Salem	NJ	1/22/2008
Beaver Falls	NY	4/1/2008
Danskammer	NY	4/16/2008
East River	NY	4/15/2008
Ginna	NY	4/3/2008
Nine Mile Point	NY	4/2/2008
Oswego	NY	4/2/2008
Wheelabrator Westchester	NY	4/16/2008
Eddystone	PA	1/23/2008
Sunoco (Marcus Hook)	PA	7/14/2009
Sunoco (Philadelphia)	PA	7/14/2009
Canadys	SC	2/10/2009
Wateree	SC	2/10/2009
Williams	SC	2/9/2009
Barney Davis	TX	3/3/2008
Chesterfield	VA	3/10/2009
North Anna	VA	4/28/2009
Possum Point	VA	3/10/2009
Potomac	VA	12/3/2007
Surry	VA	1/28/2008

Data was also provided by the following facilities:

Facility Name	State
Alamitos	CA
Contra Costa	CA
Diablo Canyon	CA
Encina	CA
Huntington Beach	CA
Mandalay	CA
Morro Bay	CA
Moss Landing	CA
Ormond Beach	CA
Pittsburg	CA
Potrero	CA
Redondo Beach	CA
South Bay	CA
Diablo Canyon	CA
Brayton Point	MA
General Electric (Lynn)	MA
Georgia Pacific	multiple
Hope Creek	NJ
Oyster Creek	NJ
Indian Point	NY
Elm Road	WI
Oak Creek	WI
Harbor	CA
Yates	GA
Fisk	IL
Callaway	MO
Hawthorn	MO
Iatan	MO
Sibley	MO
Sioux	MO
Cooper	NE
Fort Calhoun	NE
Winnetka	IL
Brooklyn Navy Yard	NY

Exhibit 2-1. Site Visit Locations and Locations of Other Site-Specific Data Collected



EPA used a wide variety of criteria in selecting the sites to visit including the following factors:

- **Industry sector:** In 2007, EPA met with several trade associations to discuss data and information sources that would be useful to EPA as it updated analyses. EPA solicited industry recommendations for criteria for selecting sites, as well as suggestions for specific sites. Among generators, EPA visited facilities owned by utilities, non-utilities, and municipalities. For manufacturers, EPA visited a steel mill, several petroleum refineries, several chemical manufacturers, and a food processing facility.[5]
- **Facility location:** EPA visited facilities in 8 EPA Regions and 20 states. Facilities were located on all types of waterbodies (ocean, estuary/tidal river, lake/reservoir, Great Lake and freshwater river). EPA also visited facilities on

[5] EPA was unable to schedule a visit to a pulp and paper facility prior to publishing the proposed rule, but based on the Agency's experience with other regulatory activities (including the Pulp and Paper Effluent Limitations Guideline) does not believe that this industry sector is remarkably different from other manufacturers in terms of cooling water intake structures. EPA also met with Georgia Pacific and the American Pulp and Paper Association to better understand the use of cooling water and cooling water intake structures for this industry sector.

major waterbodies, such as the Missouri/Mississippi Rivers, the Gulf of Mexico, the Chesapeake Bay, and both the Pacific and Atlantic Oceans.

- **Intake technology:** Selected sites employed a wide range of intake technologies, including coarse and fine mesh traveling screens, Ristroph traveling screens, coarse and fine mesh wedgewire screens, offshore velocity caps, and barrier nets. Sites also employed a variety of intake configurations, including shoreline, offshore, and intake canals.
- **Cooling system technology:** Most facilities visited employ once-through cooling, but EPA also visited multiple sites with closed-cycle cooling systems. Some facilities were designed and constructed as closed-cycle systems, while other sites retrofitted to closed-cycle cooling; some sites used combination cooling systems. EPA also visited sites with helper cooling towers.
- **Logistics:** Proximity to EPA Headquarters was a cost-effective way for multiple EPA staff to attend site visits. For non-local travel, proximity of sites to one another enabled clustered site visits, reducing travel costs and maximizing staff time onsite.
- **Biological data:** Most facilities were selected because they had conducted some form of impingement or entrainment study in recent years.
- **Fuel or generation type:** Selected sites used a variety of fuel types (coal, natural gas, nuclear, municipal waste). Most generated power through steam generation, but EPA also visited several combined cycle facilities.
- **Facility size:** EPA visited sites of all sizes, with a wide range of generating capacity (MW), intake flow, and land area. Additionally, EPA visited sites in rural areas, industrial areas, and in highly urbanized environments.

In summary, EPA learned the following from the site visits:

- A majority of facilities use coarse mesh screens. However, the screens are principally used to protect the facility from debris; as such facilities do not always optimize operation of the screens to protect fish;
- Costs are paramount to facility owners, as any costs could potentially impact planning and business decisions;
- While site-specific characteristics may set some facilities apart, most facilities were found to be very similar in how they use cooling water, how the intake technologies were selected and constructed, and challenges facilities faced in operating CWIS technologies;
- Long-term planning is important to facilities to maintain reliable energy supplies (issues such as repowering, air rules, increased energy demand, control of green house gas (GHG) emissions, and local transmission issues have long-term implications);
- Closed-cycle cooling, while potentially expensive for some sites, is technically feasible at most sites;

- Some manufacturing facilities may use cooling water for contact cooling (such as quench water). Contact cooling is rarely observed at power plants.
- Manufacturers have different opportunities to reduce and reuse cooling water. In some cases, manufacturers have reduced total water withdrawals by more than half.

During the site visits, EPA collected current facility information including power generation, capacity, and fuel source; permit status; cooling water usage; and cooling water intake structure and IM&E technologies and controls (including design, operation, and installation and operational cost information, where available). Through the site visits, EPA gained a more thorough understanding of the operation of the various IM&E technologies and controls including challenges, or lack thereof, and efficacy. EPA also gained more detailed information on any IM&E performance studies at each site, and, ultimately, the performance data. EPA additionally obtained information on the application of the suspended Phase II rulemaking. For example, EPA requested information on how each facility planned to comply with the suspended 2004 rule, and what challenges might have resulted from implementation of the suspended rule at each facility. Finally, EPA also gained a better understanding of the possible application of closed-cycle cooling at each facility. As a result of these site visits, EPA gained valuable information covering a wide range of topics. Several facilities provided National Pollutant Discharge Elimination System (NPDES) permit application data originally intended for submission under the 2004 Phase II rule. These studies typically included Proposals for Information Collection as well as portions of Comprehensive Demonstration Studies. Several facilities also provided technology efficacy data or impingement and entrainment data. Some provided IM&E feasibility studies as well.

Following each visit, EPA prepared a site visit report. These reports document the information EPA collected through each site visit and its discussions with facility representatives. Each facility was given the opportunity to review and comment on these reports. Where the information is not claimed to be confidential, these reports are available in the record.

EPA also visited Alden Laboratories in Holden, Massachusetts.

2.2.2 Data Provided to EPA by Industrial, Trade, Consulting, Scientific or Environmental Organizations or by the General Public

EPA has continued to work with various stakeholders in developing the proposed Existing Facilities rule. Through these interactions, EPA has received additional data and information including, but not limited to, the following: technology efficacy data, operating information, cost information, feasibility, and non-water quality related impact information.

EPRI and Industry

EPA met several times with representatives from EPRI and industry on topics ranging from the feasibility and cost of installing cooling towers at certain facilities, current studies of impingement on the Ohio River, and the latest advancements in fish protection technologies for traveling screens. Alden Laboratories also participated in some of these meetings and provided a status report on the latest advancements in fish protection at cooling water intake structures. EPA reviewed over 40 EPRI or EPRI-funded studies dated between 1985-2008, including multiple studies since the publication of the 2004 Phase II rule, including:[6]

- Fish Protection at Cooling Water Intakes: A Technical Reference Manual (2007) (DCN 10-6813)
- Net Environmental and Social Effects of Retrofitting Power Plants with Once-Through Cooling to Closed-Cycle Cooling (2008) (DCN 10-6927)
- Beaudrey Water Intake Protection (WIP) Screen Pilot-Scale Impingement Survival Study (2009) (DCN 10-6810)
- Comparison of Alternate Cooling Technologies for U.S. Power Plants: Economic, Environmental, and Other Tradeoffs (2004) (DCN 10-6961)
- Laboratory Evaluation of an Aquatic Filter Barrier for Protecting Early Life Stages of Fish (2004) (DCN 10-6815)
- Field evaluation of wedgewire screens for protecting early life stages at cooling water intake structures: Chesapeake Bay studies (2006) (DCN 10-6806)
- Laboratory evaluation of modified Ristroph traveling screens for protecting fish at cooling water intakes (2006) (DCN 10-6801)
- Design considerations and specifications for fish barrier net deployment at cooling water intake structures (2006) (DCN 10-6804)
- Laboratory evaluation of fine-mesh traveling water screens for protecting early life stages of fish at cooling water intakes (2008) (DCN 10-6802)
- Latent impingement mortality assessment of the Geiger Multi-Disc screening system at Potomac River Generating Station (2007) (DCN 10-6814)
- The role of temperature and nutritional status in impingement of clupeid fish species (2008) (DCN 10-6970)
- Cooling Water Intake Structure Area-of-Influence Evaluations for Ohio River Ecological Research Program Facilities (2007) (DCN 10-6971)

Materials from some of these meetings (e.g., PowerPoint presentations and demonstration movies) are available at DCNs 10-6816 to 10-6828.

[6] EPA also received Closed-Cycle Cooling System Retrofit Study: Capital and Performance Cost Estimates (2011) but it was received too late to be fully considered for the proposed rule.

Vendors

EPA also contacted cooling water intake structure technology vendors to investigate the use of several new technologies for potential application at existing facilities. EPA contacted the following technology vendors:

- Beaudrey screens (DCN 10-6606)
- Hydrolox screens (DCN 10-6807)
- Passavant (Geiger) screens (DCNs 10-6601A and B)
- Hendricks screens (DCNs 10-6601C and D)
- EIMCO screens
- Agreco (modular cooling towers) (DCNs 10-6647 and 6677)
- Blue Stream Services (modular cooling towers) (DCN 10-6677)
- EEA (substratum intakes) (DCN 10-6609)
- Gunderboom

Vendors provided information on design, operation, and efficacy of these technologies as well as capital and O&M costs. See the record for the proposed Existing Facilities rule for this information.

2.2.3 Updated Technology Database

As discussed in Section 2.1.2 and in the 2002 proposed Phase II rule (68 FR 13538-13539), EPA previously developed a Technology Efficacy Database in an effort to document and assess the performance of various technologies and operational measures (other than closed-cycle cooling[7]) designed to minimize the impacts of cooling water withdrawals (see DCN 6-5000 in the docket for the 2004 Phase II rule). EPA has since created an updated performance database. In creating the updated database, EPA's objective was to review the methods used to generate data in these studies and to combine relevant data across studies in order to produce statistical estimates of the overall performance of each of the technologies.

In developing the updated database, EPA considered data from over 150 documents. This includes documents previously contained in EPA's 316(b) rulemaking records as well as new documents obtained during development of the proposed Existing Facilities rule. Some of the documents are compilations of multiple studies, such as, EPRI's 2007 Fish Protection at Cooling Water Intakes: A Technical Reference Manual (DCN 10-6813), which includes results of over 100 studies. Others are facility-specific studies, or describe the results of research laboratory experiments conducted in a controlled setting. These documents contain information on the operation or performance of various forms and applications of these technologies, typically at a specific facility or controlled setting.

[7] EPA developed this database to evaluate possible BTA limitations for intake-based technologies. EPA did not include closed-cycle cooling in this database because these technologies operate through a reduction in flow, creating a different set of evaluation criteria.

The studies presented in these documents were performed by owners of facilities with cooling water intake structures, organizations that represent utilities and the electric power industry, and other research organizations.

To address EPA's objectives of bringing information from these documents together to better assess performance technology performance across different technology categories, EPA obtained and reviewed these documents for the presence of relevant data. Not all documents fulfilled this objective. While a document might present data that were acceptable for use in meeting the document's original objectives, this does not necessarily imply that these data will meet EPA's current objective to combine data across multiple sources to better assess performance of the different technology categories. Thus, it was necessary to establish some general criteria for accepting data from the documents:

- The data must be associated with technologies for minimizing impingement mortality or entrainment that are currently viable (as recognized by EPA) for use by industries with cooling water intake structures that are (or will be) subject to Section 316(b) regulation.
- The data must represent a quantitative measure (e.g., counts, densities, or percentages) that is related to the impingement mortality or entrainment of some life form of aquatic organisms within cooling water intake structures under the given technology.

For studies meeting the above criteria, EPA populated an MS Access database. Within this database, each document was distinguished by a unique document ID. The performance study database consisted of two primary data tables:

- A table containing specific information on a particular study, such as the document and study IDs, facility name, water body, data classification - (e.g., impingement mortality, entrainment), technology category, and other test conditions when specified (e.g., mesh size, intake velocity, flow rate, water temperature, conditions when the technology is in place, control conditions).
- A table containing the reported performance data for a given study. Each entry in this table contains one or more performance measures for a particular species along with other factors when they were specified (e.g., age category, dates or seasons of data collection, water temperature, velocity, elapsed time to mortality).

EPA used this database to develop performance estimates for certain intake technologies and to develop national performance based limits for impingement mortality. The screening criteria, methodology, and subsequent statistical analyses conducted to develop the proposed national performance limits are discussed in detail in Chapter XI of this technical development document.

2.2.4 Other Resources

EPA also collected information on cooling water system and cooling water intake structure-related topics from a variety of other sources.

a. State Cooling Water Policies

In recent years, several states have developed policies or regulations regarding cooling water use. EPA did not participate directly in the development of any of these state activities, but did closely monitor their progress. These state programs are summarized below.

California

California's Ocean Protection Council (OPC) adopted the April 20, 2006 resolution called *Regarding the Use of Once-Through Cooling Technologies in Coastal Waters* (2006 Resolution, DCN 10-6963) which urged state agencies to "implement the most protective controls to achieve a 90–95 percent reduction in [impingement and entrainment] impacts" and analyze the costs and constraints involved with the conversion of once-through cooling systems to an alternative technology. In February 2008, OPC completed a study entitled, *California's Coastal Power Plants: Alternative Cooling System Analysis,* (DCN 10-6964) which evaluates the feasibility of retrofitting coastal facilities to closed-cycle cooling towers to mitigate impingement and entrainment impacts at these sites. EPA reviewed this study to identify site-specific considerations involved in cooling tower retrofits.

California adopted its final Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling on May 4, 2010.
(See http://www.waterboards.ca.gov/water_issues/programs/npdes/cwa316.shtml for more information). Per the state website, the Policy "establishes technology-based standards to implement federal Clean Water Act Section 316(b) and reduce the harmful effects associated with cooling water intake structures on marine and estuarine life. The Policy will apply to the 19 existing power plants (including two nuclear plants) that currently have the ability to withdraw over 15 billion gallons per day from the State's coastal and estuarine waters using a single-pass system, also known as once-through cooling." The Policy requires that existing facilities reduce their intake flow to a level commensurate with a wet closed-cycle system; California established a 93 percent reduction in design flow as the minimum flow reduction, in addition to limiting intake velocities to 0.5 feet per second (fps).[8]

California has also proposed an amendment to the final Policy to provide additional flexibility, particularly with respect to combined-cycle generating units. The state solicited comments in November 2010, held a public meeting on December 14, 2010, and is currently evaluating the options.

[8] The Policy also contains a Track 2 that permits facilities to demonstrate that compliance with Track 1 (described above) is not feasible; these facilities must reduce impingement mortality and entrainment to at least 90 percent of the level achievable by compliance with Track 1.

Delaware

In March 2009, Delaware's House of Representatives introduced House Concurrent Resolution No. 7 (HCR 7)[9]; the resolution urges the Delaware Department of Natural Resources and Environmental Control (DNREC) to "declare that "Closed-cycle" cooling systems constitute the best technology available for water cooling intake structures" and "to require that all facilities that operate in Delaware waters and that use cooling water intake structures to adopt "Closed-cycle" cooling systems as quickly as possible." The resolution also notes the biological impacts associated with once-through cooling. The resolution was adopted (as amended) by the state Senate and the state House in June 2009. At the time of publication of the proposed rule, Delaware had not yet enacted a state regulation, but several facilities had made strides in reducing cooling water flows. A DNREC permit fact sheet[10] noted that the state's largest power plant (Indian River, located in Millsboro) is closing all three generating units that employ once-through cooling,[11] leaving Indian River with only a closed-cycle cooling system for Unit 4. During EPA's site visit to the (now closed) Valero refinery in Delaware City, facility representatives noted that their upcoming NPDES permit would require a substantial flow reduction.[12]

New York

In March 2010, New York proposed a policy that would require flow reduction equivalent to closed-cycle cooling at all existing facilities that withdraw more than 20 MGD.[13] New York also requires all new power plants to employ dry cooling systems, which reduce water withdrawals even further than wet cooling towers. At the time of publication of the proposed rule, the comment period for New York's proposal had closed[14] but the state had not taken any final action.

b. Individual NPDES Permit Renewals

In addition to state-wide cooling water policies, some recent individual NPDES permits have incorporated requirements for significant reductions in cooling water flow. The best-known example is Brayton Point in Somerset, Massachusetts. EPA Region I (which develops NPDES permits for several non-delegated New England states) issued a final NPDES permit in October 2003 that required a reduction in cooling water intake flow and thermal discharges of approximately 95 percent.[15] Following several years of

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[9] See http://legis.delaware.gov/LIS/LIS145.NSF/93487d394bc01014882569a4007a4cb7/674b902d7832ddd785257583005af947?OpenDocument.

[10] See http://www.wr.dnrec.delaware.gov/SiteCollectionDocuments/IRGS%20FactSheet_20100908.pdf.

[11] In December 2004, EPA Region III developed a Total Maximum Daily Load (TMDL) for temperature in the Indian River. The Indian River power plant is the only significant discharger to the receiving stream. See http://www.epa.gov/reg3wapd/tmdl/de_tmdl/IndianRiverTemp/IndianRiverEstablish.pdf and http://www.epa.gov/reg3wapd/tmdl/de_tmdl/IndianRiverTemp/IndianRiverReport.pdf.

[12] See DCN 10-6553.

[13] See http://www.dec.ny.gov/docs/fish_marine_pdf/drbtapolicy1.pdf.

[14] See http://www.dec.ny.gov/animals/66866.html for the comments received.

[15] See http://www.epa.gov/ne/braytonpoint/index.html.

appeals and litigation, the facility agreed in December 2007 to implement the requirements of the permit and is currently constructing two natural draft cooling towers at the facility.

EPA also visited a number of sites that had retrofitted to closed-cycle cooling for a variety of reasons.

- McDonough (GA), Yates (GA), Canadys (SC) and Wateree (SC) converted all generating units to closed-cycle cooling primarily to reduce thermal discharges. (See DCNs 10-6536, 10-6538, 10-6535, and 10-6534, respectively.)
- Nearman Creek (KS) converted its generating units to reduce the need for cooling water at times of the year when the source water level is low. (See DCN 10-6524.)
- Linden (NJ) constructed several new combined cycle units to replace retiring fossil units and uses grey water from a nearby treatment plant for its makeup water. (See DCN 10-6557.)

While the reasoning for some retrofits may not explicitly include consideration of 316(b), flow reduction is clearly an issue in the forefront of permitting and operational decisions at many facilities. Even in cases where 316(b) was not a consideration, the benefits to aquatic communities are realized nonetheless.

c. International Cooling Water Policy

EPA sought information on how other nations address the impacts from cooling water withdrawals. (See, e.g., DCNs 10-6620 and 6621). In general, EPA found that many countries lack an overarching regulatory structure analogous to Section 316(b), so efforts to address impacts from cooling water intake structures tend to be somewhat inconsistent. Some countries address the issue on a facility-by-facility basis, while others may make broader conclusions based on facility location. EPA's research did indicate a distribution of once-through and closed-cycle cooling systems similar to that found in the U.S. Lastly, EPA collected a European Union policy on cooling systems (see DCN 10-6846), which generally advocated that plant efficiency should be the primary decision criterion in determining the proper cooling system.

d. EPA's 1974 Steam Electric Effluent Limitation Guideline

EPA also reviewed a 1974 ELG for steam electric generators, as this was the Agency's first attempt at regulating cooling water withdrawals. In the 1974 final ELG (see 39 FR 36186), any existing electric generator built after 1970 with a capacity greater than 500 MW or any generating unit built after 1974 would have been required to retrofit to closed-cycle cooling; all new units were to be subject to the same standard. EPA's rationale at the time was that these facilities were relatively new, operated as baseload facilities, and would be in service for an extended period, thereby justifying the costs to retrofit. EPA considered many of the same factors in the ELG that it did in developing the current proposed Existing Facilities rule. The rule was remanded on administrative grounds and the subsequent revised ELG (see 47 FR 52290) was silent on cooling water withdrawals and cooling system types.

2.2.5 Implementation Experience

Following promulgation of the 2004 Phase II rule, states and EPA Regions began to implement the rule. During that time, EPA worked to assist states in understanding the rule, develop guidance materials, and support the review of the documentation of the new requirements. As a result, EPA became aware of certain elements of the 2004 rule that had become particularly troublesome to implement; as a result, EPA has considered these challenges and crafted a regulatory framework that the Agency believes is simpler for all stakeholders to understand and implement.

1. Calculation Baseline

The 2004 Phase II rule required that facilities reduce impingement mortality and entrainment from the calculation baseline. The calculation baseline was intended to represent a "typical" Phase II facility and outlined a configuration for a typical CWIS (See 69 FR 41590). EPA defined the calculation baseline as follows:

> "an estimate of impingement mortality and entrainment that would occur at your site assuming that: the cooling water system has been designed as a once-through system; the opening of the cooling water intake structure is located at, and the face of the standard 3/8 inch mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody; and the baseline practices, procedures, and structural configuration are those that [a] facility would maintain in the absence of any structural or operational controls, including flow or velocity reductions, implemented in whole or in part for the purposes or reducing impingement mortality and entrainment."

In doing so, a facility that had undertaken efforts to reduce impingement and entrainment impacts (e.g., by installing a fine mesh screen or reducing intake flow) would be able to "take credit" for its past efforts and only be required to incrementally reduce impingement mortality or entrainment to meet the performance standards.

In practice, both permittees and regulatory agencies encountered difficulty with the calculation baseline, specifically how a facility should determine what the baseline represented and how a particular facility's site-specific configuration or operations compared to the calculation baseline. For facilities whose site configuration conforms to the calculation baseline, it was relatively easy to determine impingement mortality and entrainment at the conditions representing calculation baseline. However, for facilities that have a different configuration, estimating a hypothetical calculation baseline could be difficult. For example, facilities with intake configuration that differed significantly from the calculation baseline (e.g., a submerged offshore intake) were unsure as to how to translate their biological and technological data to represent a shoreline CWIS. Oftentimes facilities encountered difficulty in determining the appropriate location for monitoring to take place. Other facilities were unsure as to how to take credit for retired generating units and other flow reductions practices. In site visits, EPA learned that facilities with little or no historical biological data encountered a particularly difficult and time-intensive task of collecting appropriate data and developing the calculation baseline. As a result, EPA has developed a new approach to the technology-based requirements proposed today that does not incorporate a calculation baseline.

2. Entrainment Exclusion Versus Entrainment Survival

As EPA worked towards revising the existing facility rules, EPA discovered a nuance to the performance based requirements of the 2004 Phase II rule: entrainment exclusion versus entrainment survival. As discussed in section III.C below, EPA re-reviewed the data on the performance of intake technologies and conducted statistical analysis of the data. From this analysis, it became apparent that the 2004 Phase II rule did not fully consider the true performance of intake technologies in affecting "entrainable" organisms.

By definition, entrainment is the incorporation of aquatic organisms into the intake flow, which passes through the facility and is then discharged. In order to pass through the technologies located at the CWIS (e.g., intake screens, nets, etc.), the organisms must be smaller than the smallest mesh size.[16] For coarse mesh screens (3/8" mesh size), most "entrainables" simply pass through the mesh (and through the facility) with only some contact with the screen.[17] In this situation the mortality of organisms passing through the facility was assumed to be 100 percent, although some facilities have since collected data showing survival of certain hardier species and lifestages of aquatic organisms. However, as mesh sizes are reduced,[18] more and more entrainables will actually become impinged on the screens (i.e., "converted" from entrainable to impingeable) and would then be subjected to spray washes and return along with larger impinged organisms as well as debris from the screens. Under the 2004 Phase II rule, these "converts" would be classified as a reduction in entrainment, since the entrainment performance standard simply required a reduction in the number (or mass) of entrained organisms entering the cooling system. However, for some facilities the low survival rate of converts resulted in the facility have difficulty complying with the impingement mortality limitations. By comparison, the performance standard for impingement was measured as impingement mortality. Organisms that were impinged (i.e., excluded) from the CWIS were typically washed into a return system and sent back to the source water. In this case, impingement mortality is an appropriate measure of the biological performance of the technology.

Through EPA's review of control technologies, the Agency found that the survival of "converts" on fine mesh screens was very poor, and in some extreme cases comparable to the extremely low survival of entrained organisms that are allowed to pass entirely

[16] In the case of many soft-bodied organisms such as eggs and larvae, the force of the intake flow can be sufficient to bend organisms that are actually larger than the screen mesh and pull them into the cooling system.
[17] Eggs are generally smaller than 2 millimeters in diameter, while larvae head capsids are much more variable in size, increasing as they mature to the juvenile stage.
[18] Fine mesh screens were considered to be one technology that could be used to meet the entrainment performance standards under the 2004 Phase II rule. EPA also reviewed performance data for screens with mesh sizes as small as 0.5 mm, as described in section III.C.

through the facility.[19] More specifically, EPA found that most eggs were entrained unless the mesh slot size was 2.0 mm or less, and mortality of eggs "converted" to impingement approached 20 to 30 percent. More telling, the mortality of larvae off a fine mesh screen was rarely less than 80 percent. As a result, a facility with entrainment exclusion technologies such as fine mesh screens could approach 90 percent performance, but the subsequent survival of these organisms overall ranged from 0 to 52 percent, and the facility's impingement mortality rates increased. In other words, a facility that simply excluded entrainable organisms (with no attention being paid to whether they survive or not) could be deemed to have met its entrainment requirements under the 2004 Phase II rule, when in fact it may be causing the same level of mortality as a facility with no entrainment controls at all.

3. Cost-Cost Test

In the 2004 Phase II rule, EPA developed facility-specific cost estimates, and published those costs in Appendix A (69 FR 41669). The 2004 Phase II rule also included a cost-cost test (see 69 FR 41644) where a facility could demonstrate that its costs to comply with the 2004 rule were significantly greater than those that EPA had considered. Since initial implementation of the July 9, 2004 316(b) Phase II rule, EPA has identified several concerns with the facility-specific cost as well as the use of that cost in Appendix A. First, EPA has identified numerous inconsistencies between facility permit applications, responses in the facility's 316(b) survey, and overall plant capacity as reported in the most recent EIA database. These inconsistencies resulted in Appendix A costs that were not comparable to many facility's own compliance cost estimates. In addition, as described more fully in Chapter 2 of the Technical Development Document, EPA does not have available technical data for all existing facilities. EPA obtained the technical data for facilities through industry questionnaires. In order to decrease burden associated with these questionnaires, EPA requested detailed information from a sample, rather than a census, of facilities. EPA has concluded that the costs provided in Appendix A are not appropriate for use in a facility-level cost-cost test. As a result, EPA is not providing a framework similar to Appendix A in the proposed Existing Facilities rule. (See section III.C below and VII for more information about how EPA developed compliance costs.) The impingement mortality requirements of the proposed Existing Facilities rule are economically achievable,[20] and the low variability in the costs of IM controls at a facility makes such a provision ineffectual. Furthermore, the proposed Existing Facilities rule requirements for entrainment mortality requires facilities to submit facility-specific compliance cost estimates. The determination of whether the cost of specific entrainment mortality technologies is too high is made by the Director on a case-by-case basis; accordingly a cost-cost provision is unnecessary.

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[19] Through-plant entrainment survival has been studied extensively, with EPRI's Review of Entrainment Survival Studies being amongst the most comprehensive. See DCN 2-017A-R7 from the Phase I docket.
[20] The Phase II rule found impingement mortality (plus entrainment on certain waterbodies) was economically achievable; EPA has not identified any reason this revising this conclusion. See Response to Comment 316bEFR.330.009 in the Phase II Response to Comment Document (DCN 6-5049).

2.2.6 New or Revised Analyses

In addition to collecting new information, EPA has re-evaluated some existing data and analyses.

1. Review of Study Data/New Performance Database

The standards of the 2004 Phase II regulation required impingement mortality reduction for all life stages of fish and shellfish of 80 to 95 percent from the calculation baseline (for all Phase II facilities) and entrainment reduction requirements of 60 to 90 percent (for certain Phase II facilities). EPA based these performance requirements on a suite of technologies and compliance alternatives.

For the proposed Existing Facilities rule, EPA reanalyzed BTA. This includes, but is not limited to, a re-analysis of candidate BTA technologies, their effectiveness, their costs, and their application. This section highlights some of the major changes resulting from this re-analysis. See Section VI of the preamble for a thorough discussion of EPA's updated BTA analysis and determination.

<u>a. New Performance Database</u>

As described above, in its Section 316(b) rule development efforts to date, EPA has gathered industry documents and research publications with information from studies which evaluated the performance of a range of technologies for minimizing impingement or entrainment.

EPA subsequently used this database in an attempt to develop impingement mortality and entrainment limits. However, as described in section VI, the performance data for screens and other intake technologies did not indicate that those technologies were nearly as effective at minimizing impingement and entrainment as closed-cycle cooling.

<u>b. Impingement Mortality and Entrainment Technology Performance Estimates</u>

To evaluate the effectiveness of different control technologies and the extent to which the various regulatory options considered for the proposed Existing Facilities rule minimize adverse environmental impacts associated with cooling water intake structures, EPA used the data collected in the new analysis to develop impingement mortality and entrainment reduction estimates. For some technologies, the proposed Existing Facilities rule reflects updated information or a different methodology for estimating effectiveness.

1. Cooling Towers

In the 2004 Phase II rule, EPA estimated facilities employing freshwater cooling towers and saltwater cooling towers would achieve flow reductions, and therefore associated entrainment and impingement mortality reductions, of 98 percent and 70-96 percent, respectively.[21] At that time, EPA's record demonstrated that saltwater cooling towers typically operated at 1.1-2.0 cycles of concentration. However, more recent information demonstrates that, as a result of advances in design and operation, saltwater cooling towers typically operate at 1.5 cycles of concentration or more. This equates to a 94.9 percent reduction in flow over a once through cooling system. To better reflect the advances in cooling tower design, EPA now estimates that freshwater cooling towers and saltwater cooling towers reduce impingement mortality and entrainment by 97.5 percent and 94.9 percent, respectively.

2. Exclusion Technologies

As discussed in chapter 6 of the TDD, screens and other technologies operate using a principle of excluding organisms from entering the cooling system. For technologies other than cooling towers, EPA generally calculated their efficacy as the mean percent efficacy of the available data. Because EPA has sufficient data to evaluate impingement *mortality*, its impingement mortality technology efficacy calculation account for mortality. However, because EPA has data on entrainment exclusion but lack sufficient entrainment *mortality* data to calculate exclusion technology entrainment mortality efficacy, EPA's calculated mean entrainment percent efficacy does not account for mortality. In reality, whether or not an organism is excluded from the cooling water intake does not minimize entrainment-related environmental impacts unless the excluded organisms survive and ultimately are returned back to the waterbody. Available data on the proposed technology basis demonstrate that entrainment reductions associated with fine mesh technologies vary depending on life stage and mesh size.

In the 2004 Phase II rule, EPA made the assumption that any entrained organism entrained died (i.e., 100 percent mortality for organisms passing through the facility) and any organism not entrained survived. In other words, if a technology reduced entrainment by 60 percent, then EPA estimated 40 percent of the organisms present in the intake water would die in comparison to 100 percent in the absence of any entrainment reduction. As explained in Section VI, EPA has not received any new data on this issue and, as such, has not altered its conclusion that entrainment leads to 100 percent mortality.

EPA analyzed the limited data on the survivability of organisms that are "converted" from entrained to impinged on fine mesh screens. These data show that under most operational conditions, many, if not all, larvae may die as a result of the impact on fine mesh screens. In the case of eggs, the data indicate that some species may die, but many survive. The data also demonstrate that if the organisms can withstand impingement on the fine mesh screen, the majority survive after passing through a fish return and returning to the source water. EPA requests additional data on the survivability (or mortality) of organisms that are converted from entrained to impinged on fish mesh screens.

[21] As discussed in Section VI.B of the preamble, impingement mortality and entrainment reductions are proportional to flow reductions.

2. Compliance Cost Methodology

To assess the economic impact of various regulatory control options, EPA estimates the costs associated with regulatory compliance. These costs of compliance may include initial fixed and capital costs, annual operating and maintenance costs, downtime costs, recordkeeping, monitoring, studies, and reporting costs. The costs estimates reflect the incremental costs attributed only to the proposed Existing Facilities rule.

For the purposes of estimating incremental compliance costs attributable to regulatory requirements, EPA traditionally develops either facility-specific or model facility costs. Facility-specific compliance costs require detailed process information, including production, capacity, water use, overall management, monitoring data, geographic location, financial conditions, and other industry specific data for each facility. When facility-specific data are not available, EPA develops model facilities to provide a reasonable representation of the industry.

As discussed in the preamble and the TDD, model facility costs were developed for facilities that completed a detailed industry questionnaire (and therefore the facilities for which EPA had the best and most detailed information) and national costs were estimated by multiplying model facility costs by a weighting factor.

EPA has also adopted a new methodology for estimating costs for retrofitting to closed-cycle cooling. EPRI developed a cost model that incorporates facility-specific data and reflects state-of-the-art cooling tower design. This model was based on a number of site-specific engineering design studies at facilities across the U.S. and incorporates a wide variety of site conditions and facility characteristics. The model is also capable of incorporating design features such as plume abatement.

EPA also made other changes to its costing assumptions and approaches. For a summary discussion of these revisions, see the preamble and Chapter 8 of the TDD.

3. Case Studies (Environmental Impacts, Thermal Impacts)

a. Review of NPDES 316(a) and (b) Permits

Addressing Section 316(a) Permit Provisions

The various methods used to address relevant CWA Section 316(s) provisions in permit limitations for thermal discharges are compared in Exhibit 2-2.[22] Of the 103 permits reviewed, approximately half (53 percent) had some form of effluent temperature limitations. These were divided between facility permits with some form of an EPA-approved 316(a) variance (33 percent) and those with temperature limits based on either State temperature standards or a State-approved model or mixing zone study (20 percent).

[22] For a description of the entire analysis, see DCN 10-6623.

Exhibit 2-2. Methods used to address Section 316(a) Requirements by EPA Region

EPA Region[1]	Permits	None Given (Towers in place)		Not Specified		No Temp. Limits/ No Monitoring		Temp. Guidance/ Monitoring Only		Application of State Temp. Limits/ Mixing Zone (No 316(a) Req.)		316(a) Variance Study	
2	8							2	(25%)	3	(38%)	3	(38%)
3	15	1	(7%)			1	(7%)	3	(20%)	2	(13%)	8	(53%)
4	23					3	(13%)	6	(26%)	4	(17%)	10	(43%)
5	20							10	(50%)	3	(15%)	7	(35%)
6	19	3	(16%)	2	(11%)	5	(26%)	3	(16%)	6	(32%)		
7	5							3	(60%)	1	(20%)	1	(20%)
9	5	1	(20%)									4	(80%)
10	8			3	(38%)	1	(13%)	1	(13%)	2	(25%)	1	(13%)
Total	103	5	(5%)	5	(5%)	10	(10%)	28	(27%)	21	(20%)	34	(33%)

[1] No permits from Regions 1 or 8 were included in the permit review

For the 47 percent of the facilities with no temperature limits in their permit; approximately 27 percent had temperature monitoring and reporting requirements. The remaining 20 percent of the facilities had no permit-based temperature limitations (this included 5 percent with existing cooling towers).

Of the 34 permits with approved 316(a) variances, 17 were approved with historic evaluation studies that were typically 15-25 years old or of indeterminate vintage (i.e., insufficient evidence to date effort), with two of these scheduled for a re-evaluation during the next permit cycle. For 10 of the 13 permits with historic variance studies, the regional PQR material indicated that documentation of the study was not available as part of the permit package. Seventeen facilities had updated 316(a) studies that had been completed within the last five years.

A comparison was made of the Section 316(a) permit provisions between electrical power generating plants and manufacturers nationwide. The large majority (77 percent) of the twenty-two manufacturing facilities had either no effluent temperature limitations or monitoring and reporting requirements. None of manufacturers had an approved 316(a) variance study whereas 42 percent of the power plants did.

Addressing Section 316(b) Permit Provisions

The various methods used to address relevant Section 316(b) provisions in permit limitations are compared in Exhibit 2-3. A breakdown of the compliance categories indicates that 51 percent of the facilities' permit conditions contained little or no references to 316(b) regulations. Further analysis of the 316(b) provision status nationwide indicates that none of the manufacturing facilities had 316(b) requirements specified in their permits, while 36 percent of the generators had none.

Exhibit 2-3. Methods used to address Section 316(b) Requirements by EPA Region

EPA Region	Permits	Not Specified	None	CDS, not initiated	CDS, ongoing	Approved permit conditions		New Facility (subject to Phase I)	None Given (Tower in place)
						Historic Evaluations	Current Re-evaluation		
2	8	4 (50%)		1 (13%)			3 (38%)		
3	15	3 (20%)		4 (27%)	3 (20%)	1 (7%)		2 (13%)	2 (13%)
4	23	15 (65%)		2 (9%)		3 (13%)	2 (9%)		1 (4%)
5	20	5 (25%)		3 (15%)	4 (20%)	4 (20%)	4 (20%)		
6	19	13 (68%)	2 (11%)		2 (11%)		2 (11%)		
7	5	2 (40%)		3 (60%)					
9	5			4 (80%)					1 (20%)
10	8	8 (100%)							
Total	**103**	**50 (49%)**	**2 (2%)**	**17 (17%)**	**9 (9%)**	**8 (8%)**	**11 (11%)**	**2 (2%)**	**4 (4%)**

Approximately 19 percent of the facilities had an approved 316(b) demonstration; which included 11 percent that were scheduled for a re-evaluation during the next permit cycle. Nine percent of the facilities reportedly had initiated a CDS investigation while 17 percent were required to conduct the CDS within the current 5-year permit cycle but had not started at the time of permit issuance. The current status of these CDS activities is uncertain due to the remand of the Phase II facility 316(b) regulations in midst of the current permit cycle. Specifically, on July 9, 2007 (72 FR 37107), EPA suspended the bulk of the Phase II 316(b) regulation and announced that, pending further rulemaking (currently ongoing), permit requirements for cooling water intake structures at Phase II facilities should be established on a case-by-case, best professional judgment (BPJ) basis.

Of the 103 facilities reviewed, eleven facilities had cooling towers already installed with an additional six facilities in the process of installing cooling towers.

Overview of New or Revised Analyses

A review of 103 NPDES permits, together with corresponding factsheets and relevant EPA PQR documents, identified permit effluent limitations and/or operating conditions pertaining to how generation and manufacturing facilities dealt with potential Sections 316(a) and 316(b) permit provisions. Based on this review:

- Of the permits reviewed, 53 percent had effluent temperature limitations either based on EPA-approved 316(a) variance (33 percent of all facilities) or state-approved models or mixing zone studies (20 percent). The remaining facilities either had no temperature limits (20 percent) or monitoring only (27 percent):
- For facilities with approved 316(a) variances, about half were based on historic studies or required re-evaluation the following permit cycle, while half were based on updated 316(a) studies conducted within the last five years;
- Permit temperature limitations for maximum temperature varied widely between states and environmental settings. Permit limits for allowable deviation from

ambient conditions generally adhered to States water quality temperature standards;

- Over half (51 percent) of the NPDES permits reviewed did not contain any reference to Section 316(b) requirements. However, inclusion of 316(b) compliance requirements varied widely between permits for manufacturing facilities (0 percent included 316(b) requirements) and generators (64 percent); and
- Cooling towers were installed in 11 or scheduled to be installed at six of the 103 or 16 percent of all facilities considered.

4. Closed-cycle Cooling

EPA considered a wide variety of technical aspects associated with retrofitting cooling towers, including (but not limited to) the availability of land, noise and plume effects, evaporative losses, and nuclear safety concerns.

As discussed in Chapter 10 of the TDD, EPA had previously conducted analyses for these effects; Chapter 10 provides the updated analyses.

Chapter 3: Scope/Applicability of Proposed Rule

3.0 Introduction

The proposed Existing Facilities rule includes all existing facilities that were previously subject to the 2004 Phase II and 2006 Phase III rules, including existing power producers and manufacturers with a design intake flow of more than 2 MGD that withdraw at least 25 percent of water for cooling purposes. The proposed rule also clarifies the definition and requirements for new units at existing facilities. The applicable requirements are summarized in Exhibits 3-1 and 3-2.

Exhibit 3-1. Applicability by Phase of the 316(b) Rules

Facility Characteristic	Applicable Rule
New power generating or manufacturing facility	Phase I rule
New offshore oil and gas facility	Phase III rule
New unit at an existing power generating or manufacturing facility	This proposed rule
Existing power generating or manufacturing facility	This proposed rule
Existing offshore oil and gas facility, seafood processing vessel or LNG import terminal	Case-by-case, Best professional judgment

Exhibit 3-2. Applicable Requirements of the Proposed Rule for Existing Facilities

Facility Characteristic	Applicable Requirements
Existing facility with a DIF >125 MGD	Impingement mortality requirements at 125.94(c) and Entrainment Characterization Study requirements at 125.94(b)
Existing facility with a DIF >2 MGD	Impingement mortality requirements at 125.94(c) (no entrainment requirements)
New unit at an existing facility	Impingement mortality requirements at 125.94(c) and Entrainment Characterization Study requirements at 125.94(b)
Facility with a cooling water intake structure that does not meet the criteria in 125.91	Case-by-case, Best professional judgment

Initially, EPA divided the 316(b) rulemaking into three phases; however, as EPA's analysis progressed, it became clear that cooling water intake structures are operated similarly at most industrial facilities (i.e., both power producing and manufacturing facilities). From a biological perspective, the effect of intake structures on impingement and entrainment does not differ depending on whether an intake structure is associated with a power plant or a manufacturer. Instead the impingement and entrainment impacts associated with intakes of the same type are generally comparable, and these impacts are addressed without discriminating which facilities are behind the intake structure. Thus, EPA is consolidating the universe of potentially regulated facilities from the 2004 Phase II rule with the existing facilities in the 2006 Phase III rule for purposes of the proposed Existing Facilities rule. This consolidation also provides a "one-stop shop" for information related to the proposed rulemaking, as all existing facilities would be addressed in an equitable manner by the same set of technology-based requirements.

3.1 General Applicability

This rule would apply to owners and operators of existing facilities that meet all of the following criteria:

- The facility is a point source that uses or proposes to use one or more cooling water intake structures, including a cooling water intake structure operated by an independent supplier that withdraws water from waters of the United States and provides cooling water to the facility by any sort of contract or other arrangement;
- The total design intake flow of the cooling water intake structure(s) is more than 2 MGD; and
- The cooling water intake structure(s) withdraw(s) cooling water from waters of the United States and at least twenty-five (25) percent of the water withdrawn is used exclusively for cooling purposes measured on an average annual basis for each calendar year.

EPA is proposing to continue to adopt provisions to ensure that the rule does not discourage the reuse of cooling water for other uses such as process water. The definition of cooling water at 40 CFR 125.93 provides that cooling water used in a manufacturing process either before or after it is used for cooling is considered process water for the purposes of calculating the percentage of a facility's intake flow that is used for cooling purposes. Therefore, water used for both cooling and non-cooling purposes does not count towards the 25 percent threshold. EPA notes this definition is the same definition used for new facilities in the Phase I rule at 40 CFR 125.83. Examples of water withdrawn for non-cooling purposes includes water withdrawn for warming by liquefied natural gas facilities and water withdrawn for public water systems by desalinization facilities. Further, the proposed rule at 40 CFR 125.91(c) specifies that cooling water obtained from a public water system or using treated effluent (such as wastewater treatment plant “gray” water) as cooling water does not constitute use of a cooling water intake structure for purposes of this rule.

The proposed Existing Facilities rule focuses on those facilities that are significant users of cooling water; only those facilities that use more than 25 percent of the water withdrawn for cooling purposes are subject to requirements. Using 25 percent as the threshold for the percent of flow used for cooling purposes at power plants ensures that almost all cooling water withdrawn from waters of the U.S. is addressed by requirements for minimizing adverse environmental impact. While manufacturing facilities often withdraw water for more than cooling purposes, the majority of the water is withdrawn from a single intake structure.[1] Once water passes through the intake, water can be apportioned to any desired use, including uses that are not related to cooling. Similarly, because power generating facilities typically use far more than 25 percent of the water they withdraw for cooling

[1] Facilities may also use groundwater wells or municipal water for various uses, but the volume of these withdrawals is usually much smaller than the volume withdrawn from surface waters.

purposes, EPA proposes to establish the 25 percent threshold to ensure that nearly all cooling water and the largest existing facilities using cooling water intake structures are addressed by the proposed requirements. As a result, EPA estimates that approximately 68 percent of manufacturers and 93 percent of power-generating facilities that meet the other proposed thresholds for the rule use more than 25 percent of intake water for cooling.

EPA is proposing that the Director, using BPJ, establish BTA impingement and entrainment mortality standards for an existing offshore oil and gas facility, a seafood processing vessel, or an offshore liquefied natural gas import terminal. Such a facility would be subject to permit conditions implementing CWA Section 316(b) where the facility is a point source that uses a cooling water intake structure and has, or is required to have, an NPDES permit. Permit writers may further determine that an intake structure that withdraws less than 25 percent of the intake flow for cooling purposes should be subject to Section 316(b) requirements, and set appropriate requirements on a case-by-case basis, using best professional judgment. The proposed Existing Facilities rule is not intended to constrain permit writers, including those at the Federal, State, or Tribal level, from addressing such cooling water intake structures. EPA also recognizes that facilities may reuse water within their facility; any volume of cooling water that is reused may be subtracted from the total withdrawal of cooling water by the facility when determining if a facility is subject to the proposed rule.

3.1.1 What is an "Existing Facility" for Purposes of the Section 316(b) Existing Facility Rule?

In the proposed Existing Facilities rule, EPA is defining the term "existing facility" to include any facility that commenced construction before January 18, 2002, as provided for in 40 CFR 122.29(b)(4).[2] EPA is proposing to establish January 17, 2002 as the date for distinguishing existing facilities from new facilities because that is the effective date of the Phase I new facility rule. In addition, EPA is defining the term "existing facility" in this proposed rule to include modifications and additions to such facilities, the construction of which commences after January 17, 2002, that do not meet the definition of a new facility at 40 CFR 125.83, the definition used to define the scope of the Phase I rule. That definition states:

> "*New facility* means any building, structure, facility, or installation that meets the definition of a 'new source' or 'new discharger' in [other NPDES regulations] and is a greenfield or stand-alone facility; commences construction after January 17, 2002; and uses either a newly constructed cooling water intake structure, or an existing cooling water intake structure whose design capacity is increased to accommodate the intake of additional cooling water. New facilities include only 'greenfield' and 'stand-alone' facilities. A greenfield facility is a facility that is constructed at a site at which no other source is located or that totally replaces the process or production equipment at an existing facility (see 40 CFR 122.29(b)(1)(i) and (ii). A stand-alone facility is a new, separate facility that is constructed on

[2] Construction is commenced if the owner or operator has undertaken certain installation and site preparation activities that are part of a continuous on-site construction program, and it includes entering into certain specified binding contractual obligations as one criterion (40 CFR 122.29(b)(4)).

> property where an existing facility is located and whose processes are substantially independent of the existing facility at the same site (see 40 CFR 122.29(b)(1)(iii) and are not used for the same industrial purpose. New facility does not include new units that are added to a facility for purposes of the same general industrial operation (for example, a new peaking unit at an electrical generating station)."[3]

The preamble to the final Phase I rule discusses this definition at 66 FR 65256; 65258 - 65259; 65285 - 65287, December 18, 2001. EPA's definition of an "existing facility" in the proposed Existing Facilities rule is intended to ensure that all sources excluded from the definition of new facility in the Phase I rule are captured by the proposed definition of existing facility.

A point source would be subject to Phase I or the proposed Existing Facilities rule even if the cooling water intake structure it uses is not located at the facility.[4] In addition, modifications or additions to the cooling water intake structure (or even the total replacement of an existing cooling water intake structure with a new one) do not convert an otherwise unchanged existing facility into a new facility, regardless of the purpose of such changes (e.g., to comply with the proposed rule or to increase capacity). Rather, the determination as to whether a facility is new or existing focuses on whether it is a green field or stand-alone facility and whether there are changes to the cooling water intake to accommodate it.

3.1.2 What is "Cooling Water" and What is a "Cooling Water Intake Structure?"

EPA has not revised the definition of cooling water intake structure for the proposed Existing Facilities rule. A cooling water intake structure is defined as the total physical

[3] The Phase I rule also listed examples of facilities that would be "new" facilities and facilities that would "not be considered a 'new facility' in two numbered paragraphs. These read as follows:
"(1) Examples of 'new facilities' include, but are not limited to: the following scenarios:
(i) A new facility is constructed on a site that has never been used for industrial or commercial activity. It has a new cooling water intake structure for its own use.
(ii) A facility is demolished and another facility is constructed in its place. The newly-constructed facility uses the original facility's cooling water intake structure, but modifies it to increase the design capacity to accommodate the intake of additional cooling water.
(iii) A facility is constructed on the same property as an existing facility, but is a separate and independent industrial operation. The cooling water intake structure used by the original facility is modified by constructing a new intake bay for the use of the newly constructed facility or is otherwise modified to increase the intake capacity for the new facility.
(2) Examples of facilities that would not be considered a 'new facility' include, but are not limited to, the following scenarios:
(i) A facility in commercial or industrial operation is modified and either continues to use its original cooling water intake structure or uses a new or modified cooling water intake structure.
(ii) A facility has an existing intake structure. Another facility (a separate and independent industrial operation), is constructed on the same property and connects to the facility's cooling water intake structure behind the intake pumps, and the design capacity of the cooling water intake structure has not been increased. This facility would not be considered a 'new facility' even if routine maintenance or repairs that do not increase the design capacity were performed on the intake structure."

[4] For example, a facility might purchase its cooling water from a nearby facility that owns and operates a cooling water intake structure.

structure and any associated constructed waterways used to withdraw cooling water from waters of the United States. Under the definition in the proposed Existing Facilities rule, the cooling water intake structure extends from the point at which water is withdrawn from the surface water source up to, and including, the intake pumps. The proposed Existing Facilities rule puts forth for existing facilities the same definition of a "cooling water intake structure" that applies to new facilities under Phase I. The proposed Existing Facilities rule also adopts the new facility rule's definition of "cooling water" as water used for contact or noncontact cooling, including water used for equipment cooling, evaporative cooling tower makeup, and dilution of effluent heat content. The definition specifies that the intended use of cooling water is to absorb waste heat rejected from the processes used or auxiliary operations on the facility's premises. The definition also indicates that water used in a manufacturing process either before or after it is used for cooling is process water for both cooling and non-cooling purposes and would not be considered cooling water for purposes of determining whether 25 percent or more of the flow is cooling water. This clarification is necessary because cooling water intake structures typically bring water into a facility for numerous purposes, including industrial processes; use as circulating water, service water, or evaporative cooling tower makeup water; dilution of effluent heat content; equipment cooling; and air conditioning. EPA notes that this clarification does not change the fact that only the intake water used exclusively for cooling purposes is counted when determining whether the 25 percent threshold in 40 CFR 125.91(a)(3) is met.

3.1.3 Would My Facility Be Covered if it is a Point Source Discharger?

The proposed Existing Facilities rule would apply only to facilities that are point sources (i.e., have an NPDES permit or are required to obtain one). This is the same requirement EPA included in the Phase I new facility rule at 40 CFR 125.81(a)(1). Requirements for complying with Section 316(b) will continue to be applied through NPDES permits.

Based on the Agency's review of potential existing facilities that employ cooling water intake structures, the Agency anticipates that most existing facilities subject to the proposed Existing Facilities rule will control the intake structure that supplies them with cooling water, and discharge some combination of their cooling water, wastewater, or storm water to a water of the United States through a point source regulated by an NPDES permit. Under these circumstances, the facility's NPDES permit will include the requirements for the cooling water intake structure. In the event that an existing facility's only NPDES permit is a general permit for storm water discharges, the Agency anticipates that the Director would write an individual NPDES permit containing requirements for the facility's cooling water intake structure. Alternatively, requirements applicable to cooling water intake structures could be incorporated into general permits. If requirements are placed into a general permit, they must meet the requirements set out at 40 CFR 122.28.

As EPA stated in the preamble to the final Phase I rule (66 FR 65256 (December 18, 2001)), the Agency encourages the Director to closely examine scenarios in which a facility withdraws significant amounts of cooling water from waters of the United States but is not required to obtain an NPDES permit. As appropriate, the Director will necessarily apply other legal requirements, where applicable, such as Section 404 or 401 of the Clean Water Act, the Coastal Zone Management Act, the National Environmental

Policy Act, the Endangered Species Act, or similar State or Tribal authorities to address adverse environmental impact caused by cooling water intake structures at those facilities.

3.1.4 Would My Facility Be Covered if it Withdraws Water From Waters of the U.S.? What if My Facility Obtains Cooling Water from an Independent Supplier?

The requirements in the proposed Existing Facilities rule apply to cooling water intake structures that have the design capacity to withdraw amounts of water more than 2 MGD from "waters of the United States." Waters of the United States include the broad range of surface waters that meet the regulatory definition at 40 CFR 122.2, which includes lakes, ponds, reservoirs, nontidal rivers or streams, tidal rivers, estuaries, fjords, oceans, bays, and coves. These potential sources of cooling water may be adversely affected by impingement and entrainment.

Some facilities discharge heated water to manmade cooling ponds, and then withdraw water from the ponds for cooling purposes. EPA recognizes that cooling ponds may, in certain circumstances, constitute a closed-cycle cooling system and therefore may already comply with some or all of the technology-based requirements in the proposed rule. However, facilities that withdraw cooling water from cooling ponds that are waters of the United States and that meet the other criteria for coverage (including the requirement that the facility has or will be required to obtain an NPDES permit) would be subject to the proposed Existing Facilities rule. In some cases, water is withdrawn from a water of the United States to provide make-up water for a cooling pond. In many cases, EPA expects such make-up water withdrawals are commensurate with the flows of a closed-cycle cooling tower, and again the facility may already comply with requirements to reduce its intake flow under the proposed rule. In those cases where the withdrawals of make-up water come from a waters of the United States, and the facility otherwise meets the criteria for coverage (including a design intake flow of more than 2 million gallons per day), the facility would be subject to the proposed Existing Facilities rule requirements.

EPA does not intend this rule to change the regulatory status of cooling ponds. Cooling ponds are neither categorically included nor categorically excluded from the definition of "waters of the United States" at 40 CFR 122.2. EPA interprets 40 CFR 122.2 to give permitting authorities the discretion to regulate cooling ponds as "waters of the United States" where cooling ponds meet the definition of "waters of the United States." The determination whether a particular cooling pond is, or is not, a water of the United States is to be made by the permitting authority on a case-by-case basis. The EPA and the U.S. Army Corps of Engineers have jointly issued jurisdictional guidance concerning the term "waters of the United States" in light of the Supreme Court's decision in *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 (2001) (SWANCC). A copy of that guidance was published as an Appendix to an Advanced Notice of Proposed Rulemaking on the definition of the phrase "waters of the U.S.," see 68 FR 1991 (January 15, 2003), and may be obtained at (http://www.epa.gov/owow/wetlands/pdf/ANPRM-FR.pdf).

The Agency recognizes that some facilities that have or are required to have an NPDES permit might not own and operate the intake structure that supplies their facility with cooling water. In addressing facilities that have or are required to have an NPDES permit that do not directly control the intake structure that supplies their facility with cooling water, revised 40 CFR 125.91 provides (similar to the new facility rule) that facilities that obtain cooling water from a public water system or use treated effluent are not deemed to be using a cooling water intake structure for purposes of the proposed Existing Facilities rule. However, obtaining water from another entity that is withdrawing water from a water of the US would be counted as cooling water intake water for purposes of determining whether an entity meets the threshold requirements of the rule. For example, facilities operated by separate entities might be located on the same, adjacent, or nearby property(ies); one of these facilities might take in cooling water and then transfer it to other facilities prior to discharge of the cooling water to a water of the United States. 40 CFR 125.91(b) specifies that use of a cooling water intake structure includes obtaining cooling water by any sort of contract or arrangement with one or more independent suppliers of cooling water if the supplier or suppliers withdraw water from waters of the United States but that is not itself an existing facility subject to Section 316(b).

As a practical matter, existing facilities are the largest users of cooling water, and typically require enough cooling water to warrant owning the cooling water intake structures. In some cases, such as at nuclear power plants or critical baseload facilities, the need for cooling water includes safety and reliability reasons would likely preclude any independent supplier arrangements. Therefore, EPA does not expect much application of this provision. EPA is nevertheless retaining the provision in order to prevent facilities from circumventing the requirements of the proposed Existing Facilities rule by creating arrangements to receive cooling water from an entity that is not itself subject to the proposed rule, and is not exempt from the proposed rule (such as drinking water or treatment plant discharges reused as cooling water).

3.1.5 What Intake Flow Thresholds Result in an Existing Facility Being Subject to the Proposed Existing Facilities Rule?

There are two ways in which EPA determines the cooling water flow at a facility. The first way is based on the design intake flow (DIF), which reflects the maximum intake flow the facility is capable of withdrawing. While this normally is limited by the capacity of the cooling water intake pumps, other parts of the cooling water intake system could impose physical limitations on the maximum intake flow the facility is capable of withdrawing. The second way is based on the actual intake flow (AIF), which reflects the actual volume of water withdrawn by the facility. EPA has defined AIF to be the average water withdrawn each year over the preceding 3 years. Both of these definitions are in the proposed Existing Facilities rule.

EPA considered requirements based on the intake flow at the existing facility. The proposed Existing Facilities rule applies to facilities that have a total design intake capacity of more than 2 MGD (see 40 CFR 125.91).[5] At 2 MGD, 99.7 percent of the total water withdrawals would be covered while 58 percent of the manufacturers, 70 percent of the non-utilities, and 100 percent of the utilities would be covered. EPA also chose the 2 MGD threshold to be consistent with the applicability criteria in the Phase I rule.[6] EPA continues to believe that this threshold ensures that the largest users of cooling water will be subject to the proposed rule.

EPA proposes to continue to use a threshold based on design intake flow as opposed to actual intake flow for several reasons. In contrast to actual intake flow, design intake flow is a fixed value based on the design of the facility's operating system and the capacity of the circulating and other water intake pumps. This provides clarity, as the design intake flow does not change, except in limited circumstances, such as when a facility undergoes major modifications. On the other hand, actual flows can vary significantly over sometimes short periods of time. For example, a peaking power plant may have an actual intake flow close to the design intake flow during times of full energy production, and may be zero during periods of standby. Use of design intake flow provides clarity to regulatory status, is indicative of the possible magnitude of environmental impact, and would avoid the need for monitoring to confirm a facility's status. Also see 69 FR 41611 for more information about these thresholds.

Under current NPDES permitting regulations at 40 CFR 122.21, all existing facilities greater than 2 MGD DIF must submit basic information describing the facility, source water physical data, source water biological characterization data, and cooling water intake system data. Under the proposed Existing Facilities rule, all facilities greater than 2 MGD DIF would be required to submit additional facility-specific information including the proposed impingement mortality reduction plan, relevant biological survival studies, and operational status of each of the facility's units. Certain facilities withdrawing the largest volumes of water for cooling purposes would have additional information and study requirements such as the Entrainment Characterization Study as described below.

EPA seeks to clarify that for some facilities, the design intake flow is not necessarily the maximum flow associated with the intake pumps. For example, a power plant may have redundant circulating pumps, or may have pumps with a name plate rating that exceeds the maximum water throughput of the associated piping. EPA intends for the design intake flow to reflect the maximum volume of water that a plant can physically withdraw from a source waterbody over a specific time period. This also means that a plant that has permanently taken a pump out of service or has flow limited by piping or other physical limitations should be able to consider such constraints when reporting its DIF.

[5] The 2004 Phase II rule applied to existing power-generating facilities with a design intake flow of 50 MGD or greater. Facilities potentially in scope of the Phase III rule had a DIF of greater than 2 MGD.
[6] See 65 FR 49067/3 for more information.

3.1.6 Are Offshore Oil and Gas Facilities, Seafood Processing Vessels or LNG Import Terminals Addressed Under the Proposed Existing Facilities Rule?

Under the proposed Existing Facilities rule, existing offshore oil and gas facilities, seafood processing facilities and LNG import terminals would be subject to 316(b) requirements on a best professional judgment basis. In the Phase III rule, EPA studied offshore oil and gas facilities and seafood processing facilities[7] and could not identify any technologies (beyond the protective screens already in use) that are technically feasible for reducing impingement or entrainment in such existing facilities.[8] As discussed in the Phase III rule, known technologies that could further reduce impingement or entrainment would result in unacceptable changes in the envelope of existing platforms, drilling rigs, mobile offshore drilling units (MODUs), seafood processing vessels (SPVs), and similar facilities as the technologies would project out from the hull, potentially decrease the seaworthiness, and potentially interfere with structural components of the hull. EPA also believes that for many of these facilities, the cooling water withdrawals are most substantial when the facilities are operating far out at sea – and therefore not withdrawing from a water of the U.S. The EPA is aware that LNG facilities may withdraw hundreds of MGD of seawater for warming (re-gasification). However, some existing LNG facilities may still withdraw water where 25 percent or more of the water is used for cooling purposes. As discussed in section V of the preamble, EPA has not identified a uniformly applicable and available technology for minimizing impingement and entrainment (I&E) mortality at these facilities. However, technologies may be available for some existing LNG facilities. LNG facilities that withdraw any volume of water for cooling purposes would be subject to case-by-case, best professional judgment BTA determinations.

EPA has not identified any new data or approaches that would result in a different determination. Therefore, the proposed Existing Facilities rule would continue to require that the BTA for existing offshore oil and gas extraction facilities and seafood processing facilities is through conditions established by NPDES permit directors on a case-by-case basis using best professional judgment.

3.1.7 What is a "New Unit" and How Are New Units Addressed Under This Proposed Rule?

The Phase I rule did not distinguish between new stand-alone facilities and new units where the units are built on a site where a source is already located and does not totally replace the existing source. Because EPA is not changing the new facility rule definitions, and is only proposing clarifying revisions to the existing facility rule, this proposed provision is not intended to otherwise reopen the Phase I rule. Today's proposed rule establishes requirements for new units added to an existing facility that are not a "new

[7] EPA studied naval vessels and cruise ships as part of its development of a general NPDES permit for discharges from ocean-going vessels. (See http://cfpub.epa.gov/npdes/home.cfm?program_id=350 for more information.) EPA studied seafood processing vessels and oil and gas exploration facilities in the 316(b) Phase III rule.

[8] As discussed in the preamble, requirements for new offshore facilities set forth in the Phase III rule remain in effect.

facility" as defined at 40 CFR 125.83. Today's proposal seeks to clarify the definitions of "new" versus "existing" by first noting that, for purposes of section 316(b), a facility cannot be defined as a new facility and an existing facility at the same time. In this rule, while EPA will continue to treat replacement and new units for the same industrial purpose as existing facilities, EPA intends to have different requirements for the *addition* of new units. A replacement unit or repowered unit, as distinct from constructing an additional unit, would not be treated as a new unit. The requirements for new units are modeled after the requirements for a new facility in the Phase I rule.

For a complete discussion of how new units are addressed, refer to section V.H of the preamble.

Chapter 4: Industry Description

4.0 Introduction

This chapter presents a profile of the facilities potentially regulated under the proposed Existing Facilities rule. The proposed rule would apply national requirements to existing facilities that use cooling water intake structures to withdraw water for cooling from waters of the U.S. Specifically, the proposed rule would apply to owners and operators of existing facilities that meet all of the following criteria:

- The facility is a point source that uses or proposes to use one or more cooling water intake structures, including a cooling water intake structure operated by an independent supplier that withdraws water from waters of the United States and provides cooling water to the facility by any sort of contract or other arrangement;
- The total design intake flow of the cooling water intake structure(s) is more than 2 MGD; and
- The cooling water intake structure(s) withdraw(s) cooling water from waters of the United States and at least twenty-five (25) percent of the water withdrawn is used exclusively for cooling purposes measured on an average annual basis for each calendar year.

The proposed Existing Facilities rule would apply to all existing power plants and all existing manufacturing facilities that meet the above criteria. This chapter presents information characterizing the categories of facilities subject to the proposed rule.

Much of the information presented in this chapter is based on data from the U.S. Department of Energy's (DOE) "Annual Electric Generator Report" (Form EIA-860) and "Annual Electric Power Industry Report" (Form EIA-861), and EPA's Section 316(b) 2000 Industry Surveys (the Industry Short Technical Questionnaire [STQ] and the Detailed Industry Questionnaire [DQ] for Phase II Cooling Water Intake Structures). For more information on aspects of the industry that may influence the nature and magnitude of economic impacts of the proposed Existing Facilities rule, see the Economic and Benefits Analysis for the Proposed Section 316(b) Existing Facilities Rule (EBA).

The electric power industry and the other industries subject to the proposed Existing Facilities rule are studied extensively by many organizations and government agencies. DOE's Energy Information Administration (EIA), among others, publishes a multitude of reports, documents, and studies on an annual basis. This chapter profile is not intended to duplicate those efforts. Rather, this profile compiles, summarizes, and presents those industry data that are important in the context of the technical analysis for the proposed Existing Facilities rule. For more information on general concepts, trends, and developments in the electric power industry and other industries affected by the proposal, see the "References," section of this chapter.

EPA first described the electricity industry in its April 2002 Phase II Proposed Rule (see 67 FR 17135-17136). A profile of other industries and existing manufacturers was developed to support the proposed Phase III Rule (see Phase III Proposed Rule TDD; EPA-821-R-04-015, DCN 7-0004 in the Phase III docket, available at EPA-HQ-OW-2004-0002-0025 to -0029). While these general descriptions still apply, EPA has updated some of its earlier estimates to reflect a more current and comprehensive industry profile for facilities subject to the proposed Existing Facilities rule.

The glossary located at the end of this chapter provides definitions for all terms that are ***bolded and italicized*** throughout this chapter.

4.1 Industry Overview

This section provides a brief overview of the industry, including descriptions of major industry sectors and types of generating facilities.

4.1.1 Major Industry Sectors

In 1997, EPA estimated that over 400,000 facilities could potentially be subject to a cooling water intake regulation. Given the large number of facilities potentially subject to regulation, EPA decided to focus its data collection efforts on six industrial categories that, as a whole, are estimated to account for over 99 percent of all cooling water withdrawals. These six sectors are: ***Utility*** Steam Electric, ***Nonutility*** Steam Electric, Chemicals & Allied Products, Primary Metals Industries, Petroleum & Coal Products, and Paper & Allied Products. EPA's data collection efforts (via the 1998 industry questionnaire) focused on the electric generators (both ***utility*** and ***nonutility*** steam electric) and the four manufacturing industry groups that were identified as significant users of cooling water. These industries are presented below, as described by the Standard Industrial Classification (SIC) system, and are intended to represent all electric generators and manufacturers with a DIF greater than 2 MGD.

Electric Services

This industry sector is classified under SIC Major Group 49. This major group includes establishments engaged in the ***generation***, ***transmission***, and/or ***distribution*** of electricity or gas or steam. A detailed discussion of the electricity industry is provided in section 4.2 of this chapter.

Chemical and Allied Products

This industry sector is classified under SIC Major Group 28. This major group includes establishments producing basic chemicals and establishments manufacturing products by predominantly chemical processes. Establishments classified in this major group manufacture three general classes of products: (1) basic chemicals, such as acids, alkalies, salts, and organic chemicals; (2) chemical products to be used in further manufacture, such as synthetic fibers, plastics materials, dry colors, and pigments; and (3) finished chemical products to be used for ultimate consumption, such as drugs, cosmetics, and soaps; or to be used as materials or supplies in other industries, such as paints, fertilizers, and explosives.

Primary Metals Industries

This industry sector is classified under SIC Major Group 33. This major group includes establishments engaged in smelting and refining ferrous and nonferrous metals from ore, pig, or scrap; in rolling, drawing, and alloying metals; in manufacturing castings and other basic metal products; and in manufacturing nails, spikes, and insulated wire and cable.

Paper and Allied Products

This industry sector is classified under SIC Major Group 26. This major group includes establishments primarily engaged in the manufacture of pulps from wood and other cellulose fibers, the manufacture of paper and paperboard, and the manufacture of paper and paperboard into converted products.

Petroleum and Coal Products

This industry sector is classified under SIC Major Group 29. This major group includes establishments primarily engaged in petroleum refining, manufacturing paving and roofing materials, and compounding lubricating oils and greases from purchased materials.

Other Industries

EPA sent industry questionnaires to individual facilities from a number of other industries outside of the four listed above and incorporated that data into the analysis for the proposed Existing Facilities rule. In 2004, EPA also collected information on land-based liquefied natural gas (LNG) facilities.

The following sections describe the electricity industry and the other manufacturing sectors and describe how cooling water is withdrawn and used at these facilities. In many cases, the facility data has been aggregated into two major groups; Electric Generators (Electric Services) and Manufacturing Facilities. The Manufacturing Facilities group includes all industrial facilities described above that are not classified as Electric Generators (i.e., Chemical and Allied Products, Primary Metals Industries, Paper and Allied Products, Petroleum and Coal Products, and Other Industries).

4.1.2 Number of Facilities and Design Intake Flow Characteristics

EPA estimates that approximately 1,263 facilities in the major industrial categories would be subject to regulation under the proposed Existing Facilities rule. These facilities combine to account for a design intake flow of over 409 billion gallons per day of cooling water from approximately 1,836 cooling water intake structures. While electric generators account for just over 53 percent of the number of facilities, they account for approximately 90 percent of the total estimated design intake flow. See Exhibit 4-1 below.

Exhibit 4-1. Cooling Water Use in Surveyed Industries

	Estimated Number of Facilities	Percent of Total Number of Facilities	Estimated Total Design Intake Flow (MGD)	Percent of Total Design Intake Flow
Facilities Potentially Regulated Under Proposed Existing Facilities Rule (all existing facilities that withdraw more than 2 MGD)	1,263	100	409,600	100
Existing electric generators	671	53	370,126	90
Existing manufacturers	592	47	39,473	10

Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).

Note: All values are weighted and include facilities identified as baseline closures. Design intake flow for Short Technical Survey Facilities was imputed from average intake flow.

Exhibit 4-2 shows the geographic distribution of the estimated facilities subject to 316(b). For illustrative purposes, manufacturers and electric generators are separated; generators are further separated by the former designations of Phase II and Phase III facilities, which is no longer relevant.

Exhibit 4-2. Map of Facilities Subject to 316(b)

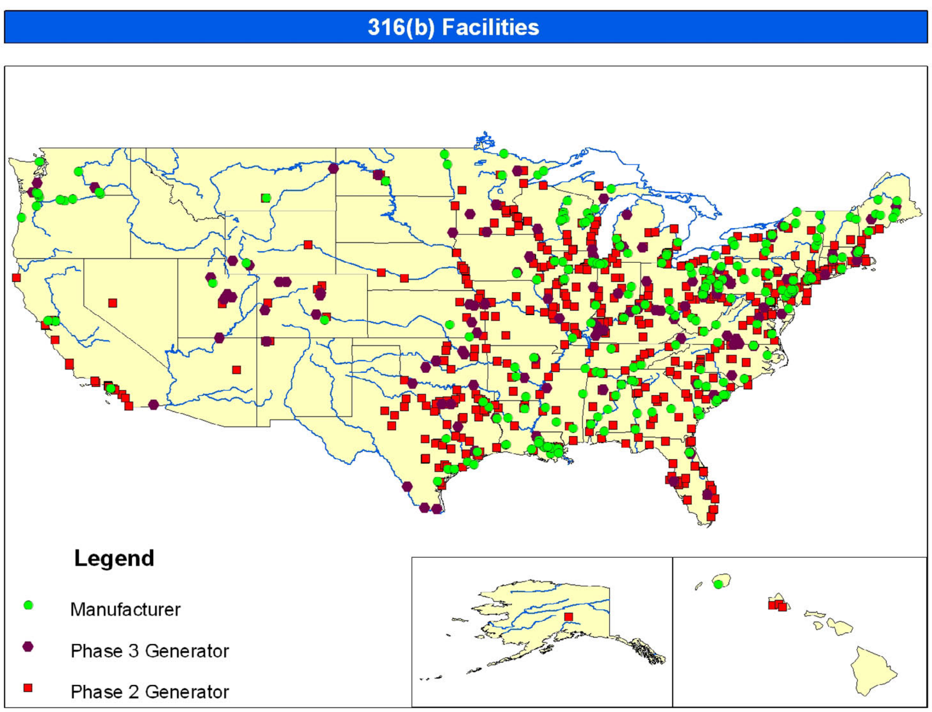


Exhibit 4-3 illustrates the range and distribution of the number of facilities by design intake flows (DIF).

Exhibit 4-3. Distribution of Facilities by Design Intake Flows

	Electric Generators		Manufacturers	
Design Intake Flow (MGD)	Estimated Number of Facilities	Percent of Number of Facilities	Estimated Number of Facilities	Percent of Number of Facilities
2 - 10	37	5	139	24
10 - 20	29	4	95	16
20 - 50	51	8	196	33
50 - 100	56	8	84	14
100 - 200	90	13	44	7
200 - 500	152	23	23	4
500 – 1,000	145	22	7	1
>1,000	112	17	3	0.5
Total	671	100	592	100

Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).

Note: All values are weighted and include those facilities identified as baseline closures. Design intake flow for Short Technical Survey Facilities was imputed from average intake flow.

Exhibit 4-3 shows that the majority of electric generator facilities have a DIF >100 MGD while the majority of manufacturers have a DIF in the 2 to 50 MGD range.

Exhibit 4-4 shows the estimated total DIF and average intake flow (AIF) for each flow range shown in Exhibit 4-2. The percent AIF/DIF shows the relative volume of AIF to DIF for each flow range.

Exhibit 4-4. Relative Volumes of Design Intake Flow and Average Intake Flow

	Electric Generators			Manufacturers		
Design Intake Flow (MGD)	Total weighted DIF MGD	Total weighted AIF MGD	Percent AIF/DIF	Total weighted DIF MGD	Total weighted AIF MGD	Percent AIF/DIF
2 - 10	178	71	40%	719	321	45%
10 - 20	449	175	39%	1,322	667	50%
20 - 50	1,745	830	48%	6,217	3,158	51%
50 - 100	4,087	2,010	49%	5,887	3,341	57%
100 - 200	12,464	6,042	48%	6,355	3,043	48%
200 - 500	49,946	26,501	53%	7,883	4,247	54%
500 - 1,000	103,672	61,995	60%	4,606	2,767	60%
>1,000	197,586	118,970	60%	6,484	3,696	57%
Total	370,126	216,593	59%	39,473	21,239	54%

Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).

Exhibit 4-4 shows that facilities with larger design flows tend to withdraw a higher proportion of their design flow on a daily basis and the trend is more pronounced for electric generators.

Exhibit 4-5 shows design intake flow values by industry type.

Exhibit 4-5. Design Intake Flow by Industry Type

Industry Type	Estimated Number of Facilities	Total Design Intake Flow (MGD)	Percent of Total Design Intake Flow of All Facilities	Average Design Intake Flow (MGD)[a]
Chemical and Allied Products	185	12,400	3	126
Primary Metals	95	9,444	2	131
Paper and Allied Products	227	11,944	3	69
Petroleum and Coal Products	39	3,259	1	96
Food Products	38	2,073	0.5	52
Other Manufacturing	7	353	0.1	81
Total Manufacturers	592	39,473	10	95
Electric Generators	671	370,126	90	555
Total	1,262	409,600	100	434

[a] Average based on surveyed facilities. May not be reflective of actual industry-wide average design intake flows.
Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).
Note: All values are weighted and include facilities identified as baseline closures. Design intake flow for Short Technical Survey Facilities was imputed from average intake flow.

4.1.3 Source Waterbodies

Facilities potentially regulated under the proposed Existing Facilities rule can be found on all waterbody types, but are predominantly located on freshwater rivers and streams. Exhibit 4-6 below illustrates the distribution of facilities by waterbody type.

Exhibit 4-6. Distribution of Source Waterbodies for Existing Facilities

Source of Surface Water	Electric Generators		Manufacturers	
	Estimated Number of Facilities	Percent of Facilities	Estimated Number of Facilities	Percent of Facilities
Freshwater River or Stream	349	52	454	77
Lake or Reservoir	134	20	42	7
Great Lakes	48	7	46	8
Estuary or Tidal River	117	17	39	7
Ocean	22	3	11	2
Total	671	100	592	100

Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).
Note: All values are weighted and include those facilities identified as baseline closures.

Exhibit 4-7 focuses on facilities located on freshwater rivers and streams. In the 2004 Phase II rule, any freshwater facility whose DIF exceeded 5 percent of its source river's mean annual flow (MAF) would have been subject to both impingement mortality and entrainment requirements. The exhibit shows the withdrawal volumes for all facilities that completed a detailed technical questionnaire.

Exhibit 4-7. Facility Intake Flows as a Percentage of Mean Annual Flow

		DIF				AIF			
	Intake Flow as a % of MAF	**No. of Facilities**	**% of No. of Fac.**	**No. of Wgtd. Fac.**	**% of No. of Wgtd.**	**No. of Facilities**	**% of No. of Fac.**	**No. of Wgtd. Fac.**	**% of No. of Wgtd.**
Electric Generators	No Data	10	6.06%	10	5.95%	10	6.06%	10	5.95%
	1-5%	91	55.15%	93.31	55.50%	117	70.91%	119.45	71.05%
	5-10%	19	11.52%	19	11.30%	20	12.12%	20	11.90%
	10-20%	23	13.94%	23.14	13.76%	8	4.85%	8.23	4.90%
	20-40%	11	6.67%	11.39	6.77%	5	3.03%	5.17	3.08%
	40-60%	4	2.42%	4	2.38%	2	1.21%	2.14	1.27%
	60-80%	1	0.61%	1	0.59%	1	0.61%	1	0.59%
	80-100%	3	1.82%	3	1.78%	0	0.00%	0	0.00%
	>100%	3	1.82%	3.28	1.95%	2	1.21%	2.14	1.27%
	Total	165	100.00%	168.12	100.00%	165	100.00%	168.13	100.00%
		DIF				**AIF**			
	Percent Range	**No. of Facilities**	**% of No. of Fac.**	**No. of Wgtd. Fac.**	**% of No. of Wgtd.**	**No. of Facilities**	**% of No. of Fac.**	**No. of Wgtd. Fac.**	**% of No. of Wgtd.**
Manufacturers	No Data	7	3.93%	21.03	4.63%	7	3.93%	21.03	4.63%
	1-5%	143	80.34%	372.41	82.06%	151	84.83%	391.46	86.26%
	5-10%	6	3.37%	16.03	3.53%	6	3.37%	15.38	3.39%
	10-20%	8	4.49%	16.53	3.64%	6	3.37%	9.53	2.10%
	20-40%	7	3.93%	11.09	2.44%	2	1.12%	2.81	0.62%
	40-60%	0	0.00%	0	0.00%	3	1.69%	4.97	1.10%
	60-80%	1	0.56%	1.67	0.37%	1	0.56%	2.75	0.61%
	80-100%	4	2.25%	9.19	2.02%	0	0.00%	0	0.00%
	>100%	2	1.12%	5.88	1.30%	2	1.12%	5.88	1.30%
	Total	178	100.00%	453.83	100.00%	178	100.00%	453.81	100.00%

Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).

Note: All values are weighted and include those facilities identified as baseline closures.

Note: Extremely large withdrawal percentages may reflect flawed data or may represent facilities that withdraw as much as 100% of the waterbody's flow (see, for example, the discussion on Monroe Power Plant in the Case Study Analysis [DCN 4-0003] in the Phase II docket).

4.1.4 Cooling Water System Configurations

Facilities potentially regulated under the proposed Existing Facilities rule employ a variety of cooling water system (CWS) types. Exhibit 4-8 shows the distribution of cooling water system configurations.

Exhibit 4-8. Distribution of Cooling Water System Configurations

	All Facilities		Electric Generators		Manufacturers	
CWS Configuration	Estimated Number of CWS[a]	Percent of Total CWS	Estimated Number of CWS for	Percent of Total CWS	Estimated Number of CWS	Percent of Total CWS
Once-through	1049	62	599	66	450	57
Once-through with Non-recirculating Pond	127	8	67	7	60	8
Once-through with Non-recirculating Tower	44	3	30	3	14	2
Recirculating with Tower	406	24	182	20	224	28
Recirculating with Pond	119	7	64	7	55	7
Combination	167	10	70	8	97	12
Other	156	9	35	4	121	15
Total	1,704	100	912	100	793	100

[a] Some facilities have more than one cooling water system. Some cooling systems have more than one type of CWS configuration.

Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).

Note: All values are weighted and include facilities identified as baseline closures.

Exhibit 4-9 shows the distribution of cooling water systems and the waterbody type from which they withdraw.

Exhibit 4-9. Distribution of Facilities by Cooling Water System and Waterbody Type

Waterbody Type	Recirculating		Once Through		Combination		Total	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Freshwater Stream/River	226.7	80%	461.8	58%	114	65%	**803**	**64%**
Lake/Reservoir	47	17%	109.3	14%	19.6	11%	**176**	**14%**
Estuary/Tidal River	6.1	2%	124.3	16%	26.3	15%	**156**	**12%**
Ocean	0	0%	33.1	4%	0	0%	**33**	**3%**
Great Lake	4	1%	74.4	9%	15.9	9%	**94**	**7%**
Total	**74**	**100%**	**405**	**100%**	**57**	**100%**	**1262**	**100%**

Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).

Exhibit 4-10 shows the distribution of cooling water system types at nuclear facilities.

Exhibit 4-10. Distribution of Cooling Water System Configurations at Nuclear Facilities by Waterbody Type

CWS Type	Waterbody Type	Number of Facilities
Combination	Ocean	0
	Estuary/ Tidal River	0
	Great Lake	1
	Freshwater River	3
	Lake/ Reservoir	4
Closed-Cycle	Ocean	0
	Estuary/ Tidal River	2
	Great Lake	3
	Freshwater River	14
	Lake/ Reservoir	4
Once-Through	Ocean	5
	Estuary/ Tidal River	8
	Great Lake	6
	Freshwater River	5
	Lake/ Reservoir	7

Exhibit 4-10 shows that nuclear facilities (which are virtually always baseload generators) with closed-cycle or combination cooling systems are most frequently located on freshwater rivers and lakes. Also, there are no nuclear facilities with closed-cycle cooling that withdraw from an ocean.

Exhibit 4-11 illustrates the intake structure arrangements for facilities potentially regulated under the Proposed Rule.

Exhibit 4-11. Distribution of Cooling Water Intake Structure Arrangements

Intake Arrangement	Electric Generators		Manufacturers	
	Estimated Number of Facilities	Percent of Arrangements	Estimated Number of Facilities	Percent of Arrangements
Canal or Channel Intake	185	28	112	19
Bay or Cove Intake	59	9	43	7
Submerged Shoreline Intake	216	32	179	30
Surface Shoreline Intake	212	32	128	22
Submerged Offshore Intake	105	16	186	32
Total	671	100	592	100

Note: The sum of facilities for each arrangement exceeds the total since some facilities employ multiple intake arrangements.

Source: Survey Data from Detailed and Short Technical Industry Questionnaires: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).

Note: All values are weighted and include facilities identified as baseline closures.

Exhibit 4-12 illustrates the distribution of cooling water system configurations as a function of facility age. EPA does not have similar data on age of the cooling water system, or age of the power producing equipment.

Exhibit 4-12. Estimated Distribution of Cooling Water System Configurations as a Function of Age

CWS age (Years)	CWS Configuration	Electric Generators		Manufacturers	
		Estimated Number of CWSs	Percent of CWSs	Estimated Number of CWSs	Percent of CWSs
< 10	Once-through	4	0.5%	18	2%
	Recirculating	9	1%	10	1%
	Combination	4	1%	16	2%
	Other	0	0%	0	0%
	Total	17	2%	44	6%
10 to 20	Once-through	21	3%	27	4%
	Recirculating	24	3%	41	5%
	Combination	1	0.1%	31	4%
	Other	0	0%	3	0.4%
	Total	47	6%	102	13%
20 to 40	Once-through	224	29%	82	11%
	Recirculating	63	8%	36	5%
	Combination	29	4%	53	7%
	Other	3	0.4%	12	2%
	Total	319	41%	183	24%
>40	Once-through	332	43%	221	29%
	Recirculating	21	3%	60	8%
	Combination	37	5%	101	13%
	Other	5	0.7%	49	6%
	Total	396	51%	431	57%
All	Once-through	581	75%	348	46%
	Recirculating	117	15%	147	19%
	Combination	71	9%	201	26%
	Other	9	1%	64	8%
	Total	779	100%	760	100%

Based on detailed technical survey data. Numbers are estimated using weighting factors. Estimated total CWSs do not match those in Exhibit 1-6 which are based on weighted detailed and short technical survey responses.
Source: Survey Data from Detailed and Short Technical Industry Questionnaire: (DCN 4-0016F-CBI).

Exhibit 4-13 presents the distribution of in-scope facilities by the number of separate cooling water systems at each facility.

Exhibit 4-13 shows that both electric generators and manufacturers have a similar distribution of number of cooling water systems and that the majority use a single CWS.

Exhibit 4-13. Estimated Distribution of In-Scope Facilities by the Number of Cooling Water Systems

Number of Cooling Water Systems	Electric Generators		Manufacturers	
	Estimated Number of Facilities	Percent of Facilities	Estimated Number of Facilities	Percent of Facilities
1	506	75%	463	78%
2	115	17%	103	17%
3	33	5%	4	1%
4	12	2%	9	1%
5 or more*	5	1%	12	2%
Total	**671**	100%	**592**	100%

* The largest number of cooling water systems was 7.
Source: Survey Data from Detailed and Short Technical Industry Questionnaire: (DCN 4-0016F-CBI).

4.1.5 Design and Operation of Cooling Water Intake Structures

Each CWS may be serviced by more than one cooling water intake structure (CWIS). Exhibit 4-14 provides an estimate of the number and percent of facilities that have multiple CWISs.

Exhibit 4-14. Estimated Distribution of In-Scope Facilities by the Number of Cooling Water Intake Structures

Number of Cooling Water Intake Structures	Electric Generators		Manufacturers	
	Estimated Number of Facilities	Percent of Facilities	Estimated Number of Facilities	Percent of Facilities
1	450	67%	452	76%
2	146	22%	101	17%
3	45	7%	18	3%
4	16	2%	9	2%
5 or more*	14	2%	12	2%
Total	**671**	100%	592	100%

* The largest number of cooling water intake structures was 8.
Source: Survey Data from Detailed and Short Technical Industry Questionnaire: (DCN 4-0016F-CBI).

Exhibit 4-14 shows that both electric generators and manufacturers have a similar distribution of number of CWISs and that the majority of both use a single CWIS.

For those power generators with multiple intake structures, Exhibit 4-15 illustrates the number of facilities that utilize closed-cycle cooling for at least some portion of the facility's cooling system (i.e., a "combination" CWS).

Exhibit 4-15. Electric Generators with Multiple CWISs

CWS Type	Flow Range	Number of Facilities
Once-through only	<50 MGD	7
Once-through only	50-250 MGD	35
Once-through only	>250 MGD	150
Closed-cycle + once-through	<50 MGD	0
Closed-cycle + once-through	50-250 MGD	2
Closed-cycle + once-through	>250 MGD	5

Source: Survey Data from Detailed and Short Technical Industry Questionnaire: (DCN 4-0016F-CBI).

Both mesh size and intake velocity affect impingement and entrainment reductions. In particular, screen mesh size is an important factor affecting impingement and entrainment rates. Exhibit 4-16 provides a national estimate of the number and percentage of facilities utilizing different mesh size screens.

Exhibit 4-16. Estimated Distribution of Screen Mesh Size

Mesh Size (mm)	Electric Generators		Manufacturers	
	Estimated Number of CWISs	Percent of CWISs	Estimated Number of CWISs	Percent of CWISs
≤5 mm (1/5 in)	21	2%	115	18%
>9.5–19 mm (3/8 – 3/4 in)	885	88%	347	55%
Other/Missing Data	97	10%	171	27%
Total	1002	100%	633	100%

Includes data for multiple CWISs and multiple screens at many facilities.
Assumes "other" and "missing" is >9.
Source: Survey Data from Detailed and Short Technical Industry Questionnaire: (DCN 4-0016F-CBI).

These data show that at the time the technical survey was conducted, only a small percentage of electric generators utilized fine mesh screens. EPA is aware that since then, additional facilities have installed fine mesh screens.

Exhibit 4-17 below illustrates the wide range of design intake velocities at facilities potentially regulated under the proposed rule.

Exhibit 4-17. Distribution of Cooling Water Intake Structure (CWIS) Design Through-Screen Velocities

	Electric Generators		Manufacturers	
Velocity (feet per second)	Estimated Number of CWIS	Percent of CWIS	Estimated Number of CWIS	Percent of CWIS
0 - 0.5	148	17	165	38
0.5 - 1	200	22	85	20
1 - 2	316	35	84	19
2 - 3	162	18	57	13
3 - 5	35	4	27	6
5-7	10	1	6	1
>7	23	3	13	3
Total	893	100	436	100

Distribution of Cooling Water Intake Structure (CWIS) Design Through-Screen Velocities (continued)

	Electric Generators		Manufacturers	
Velocity (feet per second)	Estimated Number of CWIS	Percent of CWIS	Estimated Number of CWIS	Percent of CWIS
Average (fps Unweighted	1.9		1.6	
Median (fps Unweighted)	1.4		1.0	

Based on survey responses that provided data.

Note: The average design through-screen velocity for all surveyed cooling water intake structures (unweighted) is 1.8 feet per second. The median design through-screen velocity for all surveyed facilities is 1.3 feet per second.

Source: Survey Data from Detailed and Short Technical Industry Questionnaire: (DCN 4-0016F-CBI).

Note: All values are weighted and include those facilities identified as baseline closures.

Exhibit 4-18 provides a national estimate of the number and percentage of cooling water intake structures by average number of days operating for all intakes for which data was reported. Data provided is based on a "typical" year for short technical survey facilities and the year 1998 for the detailed technical survey facilities.

Exhibit 4-18. Estimated Distribution of Intakes by Average of CWIS Operating Days

Average Intake Operating Days	Electric Generators		Manufacturers	
	Estimated Number of Facilities	Percent of Facilities	Estimated Number of Facilities	Percent of Facilities
<60 days	81	8.0%	37	4.6%
60 – 180 days	113	11.1%	23	2.9%
180 – 270 days	81	8.0%	26	3.2%
>270 days	684	67.2%	676	82.6%
Unknown	58	5.7%	56	6.8%
Total	1,017	100.0%	819	100.0%

Source: Survey Data from Detailed and Short Technical Industry Questionnaires.

Exhibit 4-18 shows that the intakes for manufacturers tend to operate more days per year than electric generators. Nearly 75 percent of both types of facilities operate more than 270 days per year. For electric generators, the number of operating days is a component of the ***capacity utilization rate*** (CUR); the other component is the proportion of the total generating capacity actually generated during the operating period. The number of operating days also gives an indication of the general amount of operational downtime that may be available to help defray costs of compliance technology construction downtime.

4.1.6 Existing Intake Technologies

Most facilities potentially regulated under the proposed Existing Facilities rule have intake technologies already in place. Exhibit 4-19 illustrates the number of existing facilities utilizing different types of intake technologies. EPA notes that not all intake technologies may be sufficient to meet the performance standards or the requirements of the rule. While not using an intake technology per se, facilities with cooling towers have also been included in this table to demonstrate the usage of flow reduction as a method to reduce impingement mortality and entrainment.

Exhibit 4-19. Distribution of Intake Technologies

	Electric Generators		Manufacturers	
Intake Technology Type	Estimated Number of Technologies	Percent of Facilities	Estimated Number of Technologies	Percent of Facilities
Bar Rack/Trash Rack	281	42	403	68
Screening Technologies	623	93	431	73
Passive Intake Technologies	130	19	205	35
Fish Diversion or Avoidance System	44	7	36	6
Fish Handling or Return System	145	22	23	4
No Intake Technologies	6	1	14	2
Cooling Tower	191	28	209	35
Total	671	100	592	100

Note: The total number of technologies exceeds the total number of facilities, since many facilities employ multiple intake technologies.

Source: Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures (DCN 4-0016F-CBI).

Note: All values are weighted and include those facilities identified as baseline closures.

4.1.7 Age of Facilities

Exhibit 4-20 shows the age of existing generating units. As discussed in Chapter 5, this data may not be entirely representative of the actual age of equipment used, as power plants and manufacturers tend to be long-lived facilities that commonly add new units or replace existing units.[1]

[1] As a result, the age of the facility as a whole may not be representative of the age of its units; original units may have been retired or replaced.

Exhibit 4-20. Age of Electric Generating Units by Fuel Type

Unit Age (years)	Coal		Natural Gas		Nuclear		Oil		Other	
	Units	%	Units	%	Units	%	Units	%	Units	%
> 60	22	2	11	1	0	0	8	2	0	0
51-60	275	29	119	14	0	0	27	6	6	26
41-50	271	28	137	16	0	0	123	27	1	4
31-40	218	23	276	33	49	50	241	53	0	0
11-30	167	17	121	14	49	50	41	9	13	57
< 10	9	1	180	21	0	0	16	4	3	13
Total	**962**		**844**		**98**		**456**		**23**	

Source: EIA Form 860 Database, year 2008 data.

Note: Data was not available for approximately 34 facilities.

As shown in Exhibit 4-20, over eighty percent of the coal-fired units are at least 30 years of age and more than 31 percent of coal units are at least 50 years of age. Natural gas facilities tend to be much newer and most nuclear powered units continue to operate under a recently renewed 20 year operating license or are in the process of seeking such renewals.[2]

4.1.8 Water Reduction Measures at Manufacturers

During EPA's site visits to manufacturing facilities, EPA noted many flow reduction and/or water reuse practices being employed. Flow reductions were demonstrated through process innovations, internal audits and leak checks, reengineering to capture lost resources (e.g., water, heat), water reuse or conservation initiatives, process changes as a result of effluent limitations guideline (ELG) requirements, and other similar activities. EPA also reviewed specific ELG requirements and other incentive programs to identify water reduction requirements and approaches. A summary of the findings is presented below.

Site Visits

An overview of flow reduction information from the manufacturing site visits follows below.[3]

[2] As discussed in DCN 10-6876, there are indications that some nuclear units may operate well beyond the initial projections for useful life.

[3] For a complete discussion of EPA's site visits, see Chapter 2 of this Technical Development Document.

Manufacturing Site	Notes on Intake Flow Reductions
ArcelorMittal—Indiana Harbor	East side recirculates an estimated 569 MGD via underground tunnel system and also has extensive cooling tower usage. West side uses a mix of once-through and CCRS, with power plant using most of once-through flow.
Cargill—Hammond	Reuses 10-15% of cooling water as process water. Other Cargill sites reuse higher percentages. Cargill formed a corporate water reduction team and has a company-wide goal of reducing water use by 5% by 2012.
Dow Chemical—Louisiana Operations (Plaquemine)	60% of the heat load is processed through cooling towers, leading to a commensurate reduction in flow.
Dow Chemical—St. Charles Operations (SCO)	4% of the heat load is processed through cooling towers.
Sunoco—Marcus Hook	Historical intake capacity (DIF) is 134 MGD, permitted limit (from DRBC) is 43 MGD, and AIF is 17 MGD. Significant use of cooling towers.
Sunoco—Philadelphia	Converted several process lines to CCRS in the 1980s and has significant water reuse and use of cooling towers. Actual flow reductions not available, but AIF is very low.
US Steel—Gary	A cooling tower recirculates approximately 148 MGD. Blast furnaces and steel shop also converted to CCRS.
Valero—Delaware City	Added dry and wet cooling systems to new process lines. Withdrawals are limited by DRBC; added towers in 1990s to expand production without increasing heat load.

Effluent Limitations Guidelines (ELGs)

In addition to conducting site visits to observe water reduction practices, EPA also researched ELGs to identify incentives and requirements for water reduction. ELGs are technology-based regulations and are intended to represent the greatest pollutant reductions that are economically achievable for a particular industrial category. As part of the regulatory development process that EPA uses in developing technology-based ELGs for industrial categories, EPA first gathers extensive information and data on the industry's processes, discharge characteristics, technologies and practices used to treat, minimize, or prevent wastewater discharges, as well as economic information.

Pollution prevention, management, and minimization practices have become a greater focus in the ELG development process, especially since EPA has been establishing ELGs for industrial categories and facilities that are not typical production facilities (i.e., airport deicing, construction and development, and concentrated aquatic animal production (aquaculture) facilities among others). EPA is also required by the CWA to reexamine existing ELGs to ensure they are still representative of the industrial category and meet the current levels of treatment technology (BAT, BCT, BPT, NSPS, PSES, and PSNS). For those industrial categories whose ELGs are being revised, new pollution prevention practices are thoroughly examined in addition to the traditional end-of-pipe treatment technologies.

As part of developing ELGs for various industry sectors, EPA typically assesses water use, technologies in place, and industry trends. The documents developed by EPA as part of this process provide the most accurate description of historic changes in water withdrawals on an industry or process/subcategory level.

For example, the factors used in developing the subcategories for the revised iron and steel ELG included:

- Age of equipment and facilities;
- Location;
- Size of the site;
- Manufacturing processes employed;
- Wastewater characteristics; and
- Non-water quality environmental impacts

Of the areas mentioned above, EPA determined that manufacturing processes and the resultant wastewater characteristics were the most significant factors for possible subcategorization of the industry. Detailed discussions of water use, pollutants generated, and production-normalized flow rates are found throughout the technical development document (TDD). As part of the iron and steel regulatory development effort, EPA examined the following:

- In-process technologies and process modifications;
- Process water recycle technologies;
- Process water discharge flow rates;
- End-of-pipe wastewater treatment technologies; and
- Treated process wastewater effluent quality

Section 8 of the iron and steel TDD[4] provides examples of wastewater minimization technologies. For example, high-rate recycling can recycle approximately 95 percent or more from a process for reuse. As with other metal processes, countercurrent cascade rinsing can reduce water use by up to 90 percent while other discussions demonstrate process modifications that can result in the reduction of process water volumes by either extending the amount of time water can be utilized within a process or reducing the volume of process water required.

In the metal products and machinery ELG, a section of the TDD[5] discusses pollution prevention practices and wastewater reduction technologies. EPA estimated in the TDD, Section 8, that the use of flow reduction technologies can reduce water use by as much as 50 to 90 percent at applicable facilities.

[4] Iron and Steel Manufacturing Point Source Category Final Rule: Development Document. EPA 821-R-02-004. Available at http://water.epa.gov/scitech/wastetech/guide/ironsteel/tdd.cfm.
[5] Effluent Guidelines, Metal Products and Machinery: Final Rule Development Document. EPA-821-B-03-001. Available at http://water.epa.gov/scitech/wastetech/guide/mpm/tdd_index.cfm.

In the organic chemicals, plastics, and synthetic fibers TDD,[6] water conservation and reuse technologies are described although no estimates in reducing flow volumes are presented.

Economic considerations play a large role in the efficient utilization of water within many industrial sectors. Recovering chemicals from waste streams can lower chemical costs but can also greatly reduce treatment expenses for wastewater discharges. In addition, efficient use of water within processes, cooling water for example, can improve process efficiencies throughout the rest of the facility (heated water can then be utilized by other processes in the plant). Leaks and spills at industrial facilities not only present productivity issues, but can possibly lead to health and safety issues.

Incentive Programs

EPA has also developed voluntary incentive programs for facilities that wish to go beyond the minimum regulatory requirements established in the applicable ELG. An example is the Voluntary Advanced Technology Incentives Program (VATIP) established as part of the revised National Emissions Standards for Hazardous Air Pollutants for Source Category: Pulp and Paper Production; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboards (also known as the Pulp and Paper Cluster Rule). EPA established the VATIP to encourage facilities subject to the Bleached Papergrade Kraft and Soda Subcategory to achieve greater pollutant reductions by implementing pollution prevention controls. Pulp and paper mills that enroll in the VATIP receive additional time to comply with the regulation and have reduced monitoring requirements, among other incentives.

The VATIP comprises three tiers that represent increasingly more effective levels of environmental protection. Mills enrolled in the program have extended compliance dates in which to meet the requirements for each tier. Facilities that enter in to VATIP are required to prepare a milestone plan that reflects how the mill will achieve the limitations for their selected tier. This milestone plan can assist permitting authorities in developing interim limitations and requirements in NPDES permits. EPA established three phases to measure a facility's progress in complying with permit requirements and to ensure compliance with the tier limitations. The three phases include:

- Initial limitations
- Intermediate milestones; and
- Ultimate limitations

The initial limitations must reflect either the existing effluent quality or the current technology-based limits in the mill's current permit, whichever is more stringent. This is for those pollutants (or flows) that are part of the VATIP. Under the Clean Water Act (CWA), facilities must comply with best available technology economically achievable

[6] Development Document for 1987 Effluent Limitations Guidelines and Standards for OCPSF. EPA 440-1-87-009. Available at http://water.epa.gov/scitech/wastetech/guide/ocpsf/index.cfm.

(BAT) effluent limitations promulgated after March 31, 1989 immediately (CWA §301(b)(2)). Under the VATIP, the limitations for the various tiers eventually become the BAT limits for those facilities. The pulp and paper ELG requires immediate compliance with ELG limits, but only if they have become enforceable BAT limits.

The intermediate milestones include the establishment of intermediate BAT limitations and the possible inclusion of interim milestones reflective of the facility moving forward to achieve the required limitations for the respective tier.

The ultimate limitations require the facility to meet the final effluent limitations for the applicable tier no later than the date specified in the regulation.

In addition to the time to allow participating facilities to meet the more stringent effluent limits, facilities participating in the VATIP is the reduction in monitoring requirements. Based on the tier chosen, monitoring frequencies are reduced once the facility has demonstrated it has reached the intermediate milestones (stage 2).

4.1.9 Land-based Liquefied Natural Gas Facilities

EPA's research also indicates that there are five existing land-based liquefied natural gas (LNG) facilities in the United States, all on the East coast. LNG facilities may withdraw hundreds of MGD of seawater for warming (re-gasification). Some existing LNG facilities may withdraw water and use 25 percent or more of the for cooling purposes. As discussed in section V of the preamble to the proposed Existing Facilities rule, EPA has not identified a uniformly applicable and available technology for minimizing impingement and entrainment mortality at these facilities. However, technologies may be available for some existing LNG facilities. LNG facilities that withdraw any volume of water for cooling purposes would be subject to case-by-case, best professional judgment BTA determinations under the proposed rule.

4.2 Electricity Industry

The electricity industry is made up of three major functional service components or sectors: ***generation***, ***transmission***, and ***distribution***. Each of these terms is defined as follows (Beamon, 1998; Joskow, 1997):

- The ***generation*** sector includes power plants that produce, or "generate," electricity.[7] Electric energy is produced using a specific generating technology, for example, internal combustion engines and turbines. Turbines can be driven by wind, moving water (hydroelectric), or steam from fossil fuel-fired boilers or nuclear reactions. Other methods of power ***generation*** include geothermal or photovoltaic (solar) technologies.
- The ***transmission*** sector can be thought of as the interstate highway system of the business – the large, high-voltage power lines that deliver electricity from power plants to ***distribution*** centers using a complex system. ***Transmission*** requires: interconnecting and integrating a number of generating facilities into a stable,

[7] The terms "plant" and "facility" are used interchangeably throughout this profile and document.

synchronized, alternating current (AC) network; scheduling and dispatching all connected plants to balance the demand and supply of electricity in real time; and managing the system for equipment failures, network constraints, and interaction with other ***transmission*** networks.

- The ***distribution*** sector can be thought of as the local delivery system – the relatively low-voltage power lines that take power from a ***distribution*** center and bring it to homes and businesses. Electricity ***distribution*** relies on a system of wires and transformers along streets and underground to provide electricity to the ultimate end user: residential, commercial, and industrial consumers. The ***distribution*** system involves both the provision of the hardware (for example, lines, poles, transformers) and a set of retailing functions, such as metering, billing, and various demand management services.

Of the three industry sectors, only electricity ***generation*** uses cooling water and is, therefore, subject to Section 316(b) regulations.

4.2.1 Domestic Production

This section presents an overview of U.S. generating capacity and electricity ***generation*** for the year 2007.[8] The rating of a generating unit is a measure of its ability to produce electricity.[9] Generator ratings are expressed in megawatts (MW). ***Nameplate capacity*** and net ***capability*** are the two common measurements (U.S. DOE, 2000a) and are defined as follows:

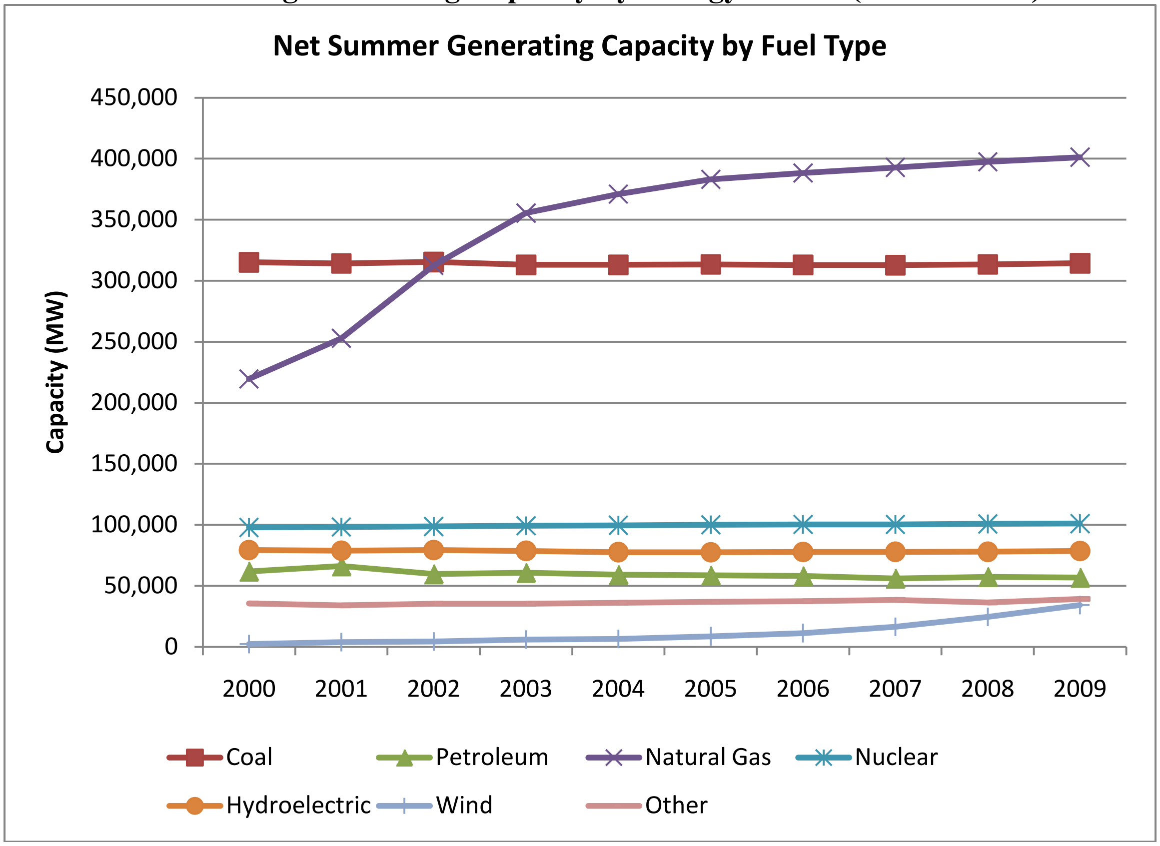
Nameplate capacity is the full-load continuous output rating of the generating unit under specified conditions, as designated by the manufacturer.

Net capability is the steady hourly output that the generating unit is expected to supply to the system load, as demonstrated by test procedures. The ***capability*** of the generating unit in the summer is generally less than in the winter due to higher ambient-air and cooling-water temperatures, which cause generating units to operate less efficiently. The ***nameplate capacity*** of a generating unit is generally greater than its net capability.

Exhibit 4-21 shows the net US generating capacity from 2000 to 2009 by fuel type.

[8] 2007 is the most recent year that detailed data is available. EPA has updated this information since the 2002 proposed Phase II rule, which used data from 1999.
[9] The numbers presented in this section are *capability* for utility facilities and *capacity* for nonutilities. For convenience purposes, this section will refer to both measures as "capacity."

Exhibit 4-21. Existing Generating Capacity by Energy Source (2000 to 2009)



Note 1: Data reflects summer month capacity, during peak consumption.

Note 2: "Other" is a combination of the following: other gases (e.g., blast furnace gas, propane gas); solar; wood; and other renewables.

Source: DOE 2010. Table ES-1.

Exhibit 4-21 shows that the majority of capacity increases over the past 10 years have been fueled by natural gas, with a minor increase in wind power in recent years.

4.2.2 Prime Movers

Electric power plants use a variety of ***prime movers*** to generate electricity. The type of prime mover used at a given plant is determined based on the type of load the plant is designed to serve, the availability of fuels, and energy requirements. Most ***prime movers*** use fossil fuels (coal, petroleum, and natural gas) as an energy source and employ some type of turbine to produce electricity. The six most common ***prime movers*** are (U.S. DOE, 2000a):

- ***Steam Turbine:*** Steam turbine or "steam electric" units require a fuel source to boil water and produce steam that drives the turbine. Either the burning of fossil fuels or a nuclear reaction can be used to produce the heat and steam necessary to generate electricity. These units are often ***baseload*** units that are run continuously to serve the constant load required by the system. Steam electric units generate the majority of electricity produced at power plants in the U.S.[10]

- ***Gas Combustion Turbine:*** Gas turbine units burn a combination of natural gas and distillate oil in a high pressure chamber to produce hot gases that are passed directly through the turbine. Units with this prime mover are generally less than 100 megawatts in size, less efficient than steam turbines, and used for ***peakload*** operation serving the highest daily, weekly, or seasonal loads. Gas turbine units have quick startup times and can be installed at a variety of site locations, making them ideal for peak, emergency, and reserve-power requirements. These units do not use a steam loop and do not use cooling water; waste heat is discharged to the atmosphere.
- ***Combined-Cycle Turbine:*** Combined-cycle units utilize both steam and gas turbine prime mover technologies to increase the efficiency of the gas turbine system. After combusting natural gas in gas turbine units, the hot gases from the turbines are transported to a waste-heat recovery steam boiler where water is heated to produce steam for a second steam turbine.[3] The steam may be produced solely by recovery of gas turbine exhaust or with additional fuel input to the steam boiler. Combined-cycle generating units are generally used for ***intermediate loads.*** These units use a steam loop in the steam turbine portion of the process and use cooling water to convert the steam back to water.
- ***Internal Combustion Engines:*** Internal combustion engines contain one or more cylinders in which fuel is combusted to drive a generator. These units are generally about 5 megawatts in size, can be installed on short notice, and can begin producing electricity almost instantaneously. Like gas turbines, internal combustion units are generally used only for peak loads. These units do not use a steam loop and do not use cooling water; waste heat is discharged to the atmosphere.
- ***Water Turbine:*** Units with water turbines, or "hydroelectric units," use either falling water or the force of a natural river current to spin turbines and produce electricity. These units are used for all types of loads. These units do not use a steam loop and do not use cooling water, as they typically do not generate excess waste heat.
- ***Other Prime Movers:*** Other types of ***prime movers*** include binary cycle turbine (geothermal), photovoltaic (solar), wind turbine, and fuel cell ***prime movers.*** The contribution of these ***prime movers*** is small relative to total power production in the U.S., but the role of these ***prime movers*** may expand in the future because recent legislation includes incentives for their use. Generally, with the exception of binary cycle turbines, these movers do not generate excess waste heat. Binary cycle turbines generally use cooling towers to dissipate waste heat.

Exhibit 4-22, which is based on DOE's Form EIA-860, provides data on existing power generating plants by prime mover. This exhibit includes all facilities in the electric power

[10] The steam is contained in a steam loop that is separate from the cooling water system and is, therefore, not the focus of this rule. Cooling water is used to convert steam back to water.

industry (i.e., not just facilities subject to 316(b)) that have at least one non-retired unit and that submitted Form EIA-860 (Annual Electric Generator Report) in 2007.[11] For this analysis, EPA classified facilities as "steam turbine" or "***combined-cycle***" if they had at least one generating unit of that type; facilities with both steam turbine- and combined-cycle-based capacity were classified by the largest capacity generating unit. Facilities that had no steam electric units were classified under the prime mover of the largest capacity generating unit.

Section 316(b) is only relevant for electric generators that use cooling water. However, not all ***prime movers*** require cooling water. Only ***prime movers*** with a steam-electric generating cycle use large enough amounts of cooling water to fall under the scope of the proposed rule. EPA identified the two types of ***prime movers*** (steam turbine and ***combined-cycle*** steam turbine) that constitute the steam electric ***prime movers*** of interest.[12]

Using this list of steam electric ***prime movers*** and DOE's Annual Electric Generator Report (which collects data to create an annual inventory of utilities and operating status of units), EPA identified the facilities that have at least one generating unit with a steam electric prime mover. The rest of this profile will focus on the generating plants with a steam electric prime mover (i.e., steam turbine or ***combined-cycle***).

Exhibit 4-22. Number of Existing Utility and Nonutility Facilities by Prime Mover, 2007

Prime Mover	Number of Facilities
Steam Turbine	1,349
Combined-Cycle	453
Gas Turbine	834
Internal Combustion	1,005
Hydroelectric	1,368
Other	365
Total	**5,374**

[a] Facilities are listed as steam electric if they have at least one steam electric generating unit.

[b] Facility counts are weighted estimates generated using the original 316(b) survey weights.

Sources: U.S. EPA, 2000; U.S. DOE, 2007.

[11] Note that EPA's technology assessments and compliance cost estimates are based upon data that EPA collected through industry questionnaires. This technology data represents the year 2000. Since EPA has not collected any new information on intake technologies, intake flows, etc. for the Existing Facilities proposed rule, EPA is continuing to use the 2000 questionnaire data for some analyses as it reflects the best information available. However, because more recent economic information is available through existing sources, EPA conducted the economic analyses using 2007 data to more accurately account for possible impacts. As a result, some of the information presented in this chapter reflects the year 2000 while other reflects the year 2007.

[12] EIA identifies 11 other categories of prime mover, but these categories are not subject to 316(b).

4.2.3 Steam Electric Generators

Exhibit 4-23 provides summary data concerning the number of utilities/operators, number of plants, generating units, and total ***nameplate capacity.*** The table provides information for the industry as a whole, for the steam electric part of the industry, and for the part of the industry potentially subject to the proposed Existing Facilities rule.

Exhibit 4-23. Summary of 316(b) Electric Power Facility Data

	Total[f]	Steam Electric[f]		316(b)[b,c]	
		Number	% of Total	Number	% of Total
Utilities/Operators[d]	2,537	1,158	46%	233	9%
Plants[d]	5,374	1,805	34%	559	10%
Units[e]	17,250	4,828	28%	2,132	12%
Nameplate Capacity (MW)	1,072,497	790,690	74%	480,388	45%

[a] Data are for regulated and non-regulated entities.

[b] Number of units and capacity include steam and non-steam units and capacity, respectively, at 316(b) electric power facilities.

[c] Number of plants, number of units, and capacity are weighted estimates and are generated using the original 316(b) survey weights.

[d] Utilities/operators and plants are listed as steam electric if they have at least one non-retired steam electric unit.

[e] Total number of units includes non-steam generating units at facilities previously considered for the 316(b) regulation that have retired all of their steam generating units. Because these facilities no longer have steam operations they are excluded from the currently analyzed 316(b) universe.

[f] Estimates exclude facilities that have retired all of their operations - steam and non-steam - according to the 2010 base-case IPM run.

From the universe of facilities with a steam electric prime mover and based on data collected from EPA's industry technical questionnaires and the compliance requirements for the proposed rule, EPA has identified 559 facilities to which the proposed rule is expected to apply.[13] All of these facilities are in the set of 554 facilities that were expected to comply with the suspended 2004 Phase II Final Rule and 117 electric generators with design intake flow between 2 and 50 MGD excluded from the 2006 Phase III Final Rule; however, based on 2007 ***EIA*** data and IPM data, a total of 93 of the 671 Phase II and Phase III facilities will have retired by 2012.[14] In addition, 19 coastal facilities are subject to the California "Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling."[15] Exhibit 4-24 provides a summary of the estimated number of facilities considered in the economic analysis under previous and current 316(b) regulation development.

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[13] EPA developed the estimates of the number and characteristics of facilities expected to be within the scope of the proposed rule using the facility sample weights that were developed for the suspended 2004 Phase II rule and the 2006 Phase III Rule. These weights provide comprehensive estimates of the total number of in-scope facilities based on the full set of facilities sampled in EPA's industry questionnaires. See the preamble to the proposed rule and the EBA for further discussion of the sample weights used in this analysis.

[14] Individual values do not sum to reported totals due to rounding as the result of the application of statistical weights.

[15] As described in the EBA, these 19 facilities were not included in the economic analysis for the proposed rule, as they are subject to requirements under the state's cooling water policy, which contains similar requirements to the proposed rule.

Exhibit 4-24. Number of 316(b) Regulated Facilities

	Unweighted			Weighted[a]		
	Phase II	Phase III	Total	Phase II	Phase III	Total
Phase II/III	543	113	656	554	117	671
EIA-Retired[b,c]	41	11	52	43	11	54
IPM-Retired[b]	31	8	39	31	8	39
Coastal CA	17	0	17	19	0	19
Currently Analyzed	454	94	548	461	98	559

[a] Facility counts generated using the original 316(b) survey weights.

[b] A facility is considered retired if it no longer has any steam operations even though it may still operate non-steam units.

[c] Includes facilities that have already retired and those that will do so before 2012 (i.e., the rule promulgation).

Sources: U.S. EPA, 2000; U.S. DOE, 2007 (GenY07); U.S. EPA Analysis, 2010.

Exhibit 4-25 presents the estimated number of 316(b) facilities by fuel type and prime mover category.

Facilities have multiple generating units and each unit uses only one type of prime mover. However, many facilities operate units with different types of ***prime movers.*** EPA estimates that 12 of the 525 steam turbine facilities also operate ***combined-cycle*** generating units and that 10 of the 33 ***combined-cycle*** facilities also operate steam turbine generating units. The data shown in Exhibit 4-23 are based on total capacity by prime mover type and do not necessarily indicate which prime mover type predominates with regard to annual power ***generation.***

Exhibit 4-25. 316(b) Electric Power Facilities by Plant Type and Prime Mover

Plant Type[a]	Prime Mover	Number of 316(b) Electric Generators[b,c]
Coal Steam	Steam Turbine	342
Gas	Steam Turbine	73
Nuclear	Steam Turbine	56
Oil	Steam Turbine	29
Other Steam	Steam Turbine	25
Total Steam	Steam Turbine	525
Combined-Cycle	Combined-Cycle	33
Total		559

[a] Facilities are listed as steam electric if they have at least one steam electric generating unit.

[b] Facility counts are weighted estimates generated using the original 316(b) survey weights.

Sources: U.S. EPA, 2000; U.S. DOE, 2007 (GenY07); U.S. EPA Analysis, 2010

[c] Individual values do not sum to reported total due to rounding as the result the application of statistical weights.

4.3 Manufacturers

4.3.1 Electric Generation at Manufacturers

Some manufacturing facilities also produce electricity (cogeneration). According to data from the 316(b) questionnaire, 164 manufacturing facilities responded that they had produced electricity in 1996, 1997, or 1998.[16] One hundred eleven (111) facilities responded that they did not generate electricity during the survey period. Twelve (12) facilities did not respond to the question.

Exhibit 4-26 shows the proportion of the 38 manufacturers that use coal as their primary fuel source.

Exhibit 4-26. Manufacturers with Coal-Fired Generation

Total Facility Coal-fired Generation Capacity (MW)	Number of Facilities
0-25	15
25-50	8
50-100	9
100-200	4
>200	2
Total	**38**

The six largest manufacturers (i.e., those with a generating capacity above 100MW) came from 5 industry sectors: steel works (SIC 3312), iron ore (1011), electric services/non-ferrous metals (4911/3339), chemical (2800), and sanitary paper (2676).

4.4 Glossary

Baseload: The minimum amount of electric power delivered or required over a given period of time at a steady rate.

Baseload Generating Unit: A baseload generating unit is normally used to satisfy all or part of the minimum or base load of the system and, as a consequence, produces electricity at an essentially constant rate and runs continuously. Baseload units are generally the newest, largest, and most efficient of the three types of units. (http://www.eia.doe.gov/cneaf/electricity/page/prim2/chapter2.html)

Capacity Utilization Rate: 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.

Combined-Cycle: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

[16] Answered yes to Question 15(a) of the 31(6)b detailed industry questionnaire for manufacturers, which requested information on whether the facility generated electricity during the time period covered by the survey.

Combined-Cycle Unit: An electric generating unit that consists of one or more combustion turbines and one or more boilers with a portion of the required energy input to the boiler(s) provided by the exhaust gas of the combustion turbine(s).

Distribution: The delivery of energy to retail customers (including homes, businesses, etc…).

Distribution System: The portion of an electric system that is dedicated to delivering electric energy to an end user.

EIA: The Energy Information Administration (EIA), created by Congress in 1977, is a statistical agency of the U.S. Department of Energy.

Electricity Available to Consumers: Power available for sale to customers. Approximately 8 to 9 percent of net ***generation*** is lost during the ***transmission*** and distribution process.

Gas Turbine Plant: A plant in which the prime mover is a gas turbine. A gas turbine typically consisting of an axial-flow air compressor and one or more combustion chambers, where liquid or gaseous fuel is burned and the hot gases are passed to the turbine and where hot gases expand to drive the generator and are then used to run the compressor.

Generation: The process of producing electric energy or the amount of electric energy produced by transforming other forms of energy, commonly expressed in ***kilowatt***-hours (kWh) or megawatt-hours (MWh).

Gross Generation: The total amount of electric energy produced by the generating units at a generating station or stations, measured at the generator terminals.

Internal Combustion Plant: A plant in which the prime mover is an internal combustion engine. An internal combustion engine has one or more cylinders in which the process of combustion takes place, converting energy released from the rapid burning of a fuel-air mixture into mechanical energy. Diesel or gas-fired engines are the principal fuel types used in these generators. The plant is usually operated during periods of high demand for electricity.

Kilowatt (kW): One thousand watts (W).

Kilowatt-hour (kWh): One thousand watt-hours (Wh).

Megawatt (MW): One thousand kilowatts (kWh).

Megawatt-hour (MWh): One thousand kilowatt-hours (kWh)

Nameplate Capacity: The amount of electric power delivered or required for which a generator, turbine, transformer, ***transmission*** circuit, station, or system is rated by the manufacturer.

Net Capacity (Capability): The amount of electric power delivered or required for which a generator, turbine, transformer, ***transmission*** circuit, station, or system is rated by the manufacturer, exclusive of station use, and unspecified conditions for given time interval.

Net Generation: Gross generation minus plant use from all electric ***utility*** owned plants. The energy required for pumping at a pump storage plant is regarded as plant use and must be deducted from the gross equation.

Nonutility Power Producer: A corporation, person, agency, authority, or other legal entity or instrumentality that owns electric generating capacity and is not an electric utility. Nonutility power producers include qualifying cogenerators, qualifying small power producers, and other nonutility generators (including independent power producers) without a designated franchised service area that do not file forms listed in the Code of Federal Regulations, Title 18, Part 141. (http://www.eia.doe.gov/emeu/iea/glossary.html)

Peakload: The maximum load during a specified time period.

Peakload Generating Unit: A peakload generating unit, normally the least efficient of the three unit types, is used to meet requirements during the periods of greatest, or peak, load on the system. (http://www.eia.doe.gov/cneaf/electricity/page/prim2/chapter2.html)

Prime Movers: The engine, turbine, water wheel or similar machine that drives an electric generator; or, for reporting purposes, a device that directly converts energy to electricity directly (e.g., photovoltaic solar, and fuel cell(s)).

Regulated Entity: For the purpose of ***EIA***'s data collection efforts, entities that either provide electricity within a designated franchised service area and/or file forms listed in the Code of Federal Regulations, Title 18, part 141 are considered regulated entities. This includes investor-owned electric utilities that are subject to rate regulation, municipal utilities, federal and state power authorities, and rural electric cooperatives. Facilities that qualify as cogenerators or small power producers under the Public Utility Regulatory Power Act (PURPA) are not considered regulated entities.

Reliability: Electric system reliability has two components: adequacy and security. Adequacy is the ability of the electric system to supply customers at all times, taking into account scheduled and unscheduled outages of system facilities. Security is the ability of the electric system to withstand sudden disturbances, such as electric short circuits or unanticipated loss of system facilities. The degree of reliability maybe measured by the frequency, duration, and magnitude of adverse effects on consumer services. (http://www.eia.doe.gov/cneaf/electricity/epav1/glossary.html)

Steam Electric Power Plant: A plant in which the prime mover is a steam turbine. The steam used to drive the turbine is produced in a boiler where fossil fuels are burned.

Transmission: The movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers, or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer.

Utility: A corporation, person, agency, authority, or other legal entity or instrumentality that owns and/or operates facilities within the United States, its territories, or Puerto Rico for the generation, transmission, ***distribution***, or sale of electric energy primarily for use by the public, with a dedicated service area, and files forms listed in the Code of Federal Regulations, Title 18, Part 141. Facilities that qualify as cogenerators or small power producers under the Public Utility Regulatory Policies Act (PURPA) are not considered electric utilities. (http://www.eia.doe.gov/emeu/iea/glossary.html)

Water Turbine: A unit in which the turbine generator is driven by falling water.

4.5 References

Beamon, J.A. 1998. Competitive Electricity Prices: An Update. From the Phase I Rule Record. DCN 1-2110-EA.

Joskow, P. L. 1997. Restructuring, Competition and Regulatory Reform in the U.S. Electricity Sector. DCN1-2118-EA.

U.S. Department of Energy (U. S. DOE). 2009. Energy Information Administration (EIA). *Electric Power Annual 2009.* Released: November 23, 2010. Table ES1 at: http://www.eia.doe.gov/cneaf/electricity/epa/epaxlfilees1.pdf

U.S. Department of Energy (U.S. DOE). 2007. Form EIA-860 (2007). Annual Electric Generator Report.

U.S. Department of Energy (U.S. DOE). 2002. Energy Information Administration (EIA). *Status of State Electric Industry Restructuring Activity as of March 2002*. At: http://www.eia.doe.gov/cneaf/electricity/chg_str/regmap.html.

U.S. Department of Energy (U.S. DOE). 2001. Energy Information Administration (EIA). *Annual Energy Outlook 2002 With Projections to 2020*. DOE/EIA-0383(2002). December 2001.

U.S. Department of Energy (U.S. DOE). 2000a. Energy Information Administration (EIA). *Electric Power Industry Overview.* At: http://www.eia.doe.gov/cneaf/electricity/page/prim2/toc2.html.

U.S. Department of Energy (U. S. DOE). 2000b. Energy Information Administration (EIA). *Electric Power Annual 1999 Volume I.* DOE/EIA-0348(99)/1.

U.S. Department of Energy (U. S. DOE). 2000c. Energy Information Administration (EIA). *Electric Power Annual 1999 Volume II.* DOE/EIA-0348(99)/2.

U.S. Department of Energy (U.S. DOE). 1999a. *Form EIA-860A (1999). Annual Electric Generator Report – Utility.*

U.S. Department of Energy (U.S. DOE). 1999b. *Form EIA-860B (1999). Annual Electric Generator Report – Nonutility*.

U.S. Department of Energy (U.S. DOE). 1999c. *Form EIA-861 (1999). Annual Electric Utility Data*.

U.S. Department of Energy (U.S. DOE). 1999d. *Form EIA-759 (1999). Monthly Power Plant Report.*

U.S. Department of Energy (U.S. DOE). 1998a. Energy Information Administration (EIA). *Electric Power Annual 1997 Volume I*. DOE/EIA-0348(97/1).

U.S. Department of Energy (U.S. DOE). 1998b. Energy Information Administration (EIA). *Electric Power Annual 1997 Volume II*. DOE/EIA-0348(97/1).

U.S. Department of Energy (U.S. DOE). 1998c. *Form EIA-861 (1998). Annual Electric Utility Data*.

U.S. Department of Energy (U.S. DOE). 1996a. Energy Information Administration (EIA). *Electric Power Annual 1995 Volume I.* DOE/EIA-0348(95)/1.

U.S. Department of Energy (U.S. DOE). 1996b. Energy Information Administration (EIA). *Electric Power Annual 1995 Volume II*. DOE/EIA-0348(95)/2.

U.S. Department of Energy (U. S. DOE). 1996c. Energy Information Administration (EIA). *Impacts of Electric Power Industry Restructuring on the Coal Industry*. At: http://www.eia.doe.gov/cneaf/electricity/chg_str_fuel/html/chapter1.html.

U.S. Department of Energy (U.S. DOE). 1995a. Energy Information Administration (EIA). *Electric Power Annual 1994 Volume I*. DOE/EIA-0348(94/1).

U.S. Department of Energy (U.S. DOE). 1995b. Energy Information Administration (EIA). *Electric Power Annual 1994 Volume II*. DOE/EIA-0348(94/1).

U.S. Environmental Protection Agency (U.S. EPA). 2000. Section 316(b) Industry Survey. *Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures* and *Industry Short Technical Questionnaire: Phase II Cooling Water Intake Structures,* January, 2000 (OMB Control Number 2040-0213). *Industry Screener Questionnaire: Phase I Cooling Water Intake Structures*, January, 1999 (OMB Control Number 2040-0203).

U.S. Geological Survey (USGS). 1995. *Estimated Use of Water in the United States in 1995.* At: http://water.usgs.gov/watuse/pdf1995/html/.

Chapter 5: Subcategorization

5.0 Introduction

This section describes EPA's consideration of subcategories for the proposed rule. Section 5.1 discusses the methodology and factors considered when evaluating potential subcategories for the rule. The remainder of the chapter discusses EPA's analysis of each factor.

5.1 Methodology and Factors Considered for Basis of Subcategorization

In the development of other technology-based CWA regulations such as effluent limitations guidelines, EPA is required to consider a number of different factors. Among others, these include the age of the equipment and facilities in the category, manufacturing processes employed, types of treatment technology to reduce effluent discharges, and the cost of effluent reductions (Section 304(b)(2)(b) of the CWA, 33 U.S.C. 1314(b)(2)(B)). The statute also authorizes EPA to take into account other factors that the Administrator deems appropriate.

While the 316(b) language does not specifically require EPA to consider subcategories, EPA concludes it is reasonable to do so because 316(b) requirements are similarly technology-based.

EPA considered a number of factors as a basis of subcategorization in determining best technology available. The major factors EPA considered are:

- the age of facility or unit;
- electricity generation or manufacturing process;
- existing intake type;
- application of various impingement and entrainment reduction technologies;
- geographical location;
- facility size;
- non-water quality environmental impacts (including energy requirements); and
- the cost of achieving impingement and entrainment reductions.

The following sections discuss EPA's consideration of these factors with the exception of the cost of achieving impingement and entrainment reductions. See the Economic Analysis (EA) for those analyses.

5.2 Age of the Equipment and Facilities

As discussed in Chapter 4, many power plants and manufacturers have been in operation for many years. Existing units may operate for decades before being replaced by new or more efficient units or retired altogether. EPA considered the age of equipment as a subcategorization basis. EPA concluded this is not an appropriate basis because power plants and manufacturing facilities tend to be long-lived facilities and have regular maintenance, equipment upgrades, plant expansions, and other activities. Equipment such as intake technologies is generally included in the scheduled maintenance. Factors such as the waterbody type, debris loading, and other site-specific factors will dictate how frequently a facility needs to replace this equipment. EPA did not find that the age of facilities or equipment changed the need of such facilities for cooling water (since gains in efficiency have typically been used to maintain or increase power production or productivity), or the impacts associated with cooling water use. Nor did EPA identify significantly different CWIS technologies based on facility age.

Using information collected through the industry questionnaire, site visits, and conversations with industry representatives, EPA also evaluated age of the existing facility as a possible basis for subcategorization. EPA determined that the age of a facility is not an appropriate measure for subcategorization. Electric generators often add new generating units and may then retire older, less-efficient units. As such, the date at which the facility began operations may not be reflective of a facility's current operations.

However, EPA does recognize that many existing power plants and manufacturing facilities operate older units; as noted in Chapter 4, over 31 percent of coal-fired generating units are more than 50 years old. As a result, it may be undesirable to retrofit some older facilities to closed-cycle cooling, as these facilities may be approaching the end of their useful life.

5.3 Processes Employed

5.3.1 Electric Generators

The major difference between power plants in terms of "process" is the fuel source. As illustrated in Chapter 4 of the TDD, power plants use a variety of fuels to generate electricity.

Exhibit 5-1 shows the typical generating efficiencies for each fuel type.

Exhibit 5-1. Generating Efficiency by Fuel Type

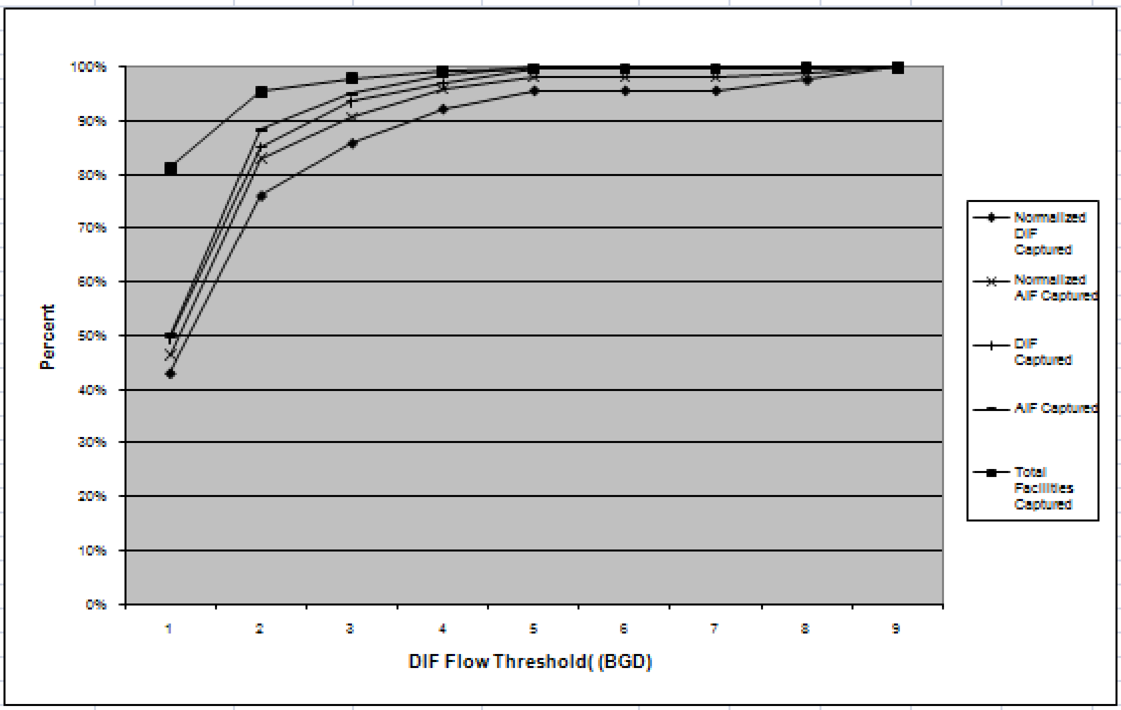
Fuel Type	Typical Plant Efficiency (%)
Coal	32 - 42
Natural Gas	32 - 38
Nuclear	38

In general, the type of fuel used at a facility generally does not affect the design or operation of the facility's CWIS. The type of fuel may affect the volume of water needed, additional design considerations (e.g., emergency backup withdrawal capabilities), or other elements of the facility's operation, but these elements generally do not impact the selection or operation of intake technologies.[1]

EPA also explored the thermal (fuel) efficiency of different fuel types as a basis. While many reviews identify nuclear as far less efficient than coal, these comparisons do not factor in the significant heat losses from the stack of coal-fired units. When this source of heat is accounted for, there is no discernable difference in thermal efficiency by fuel type.

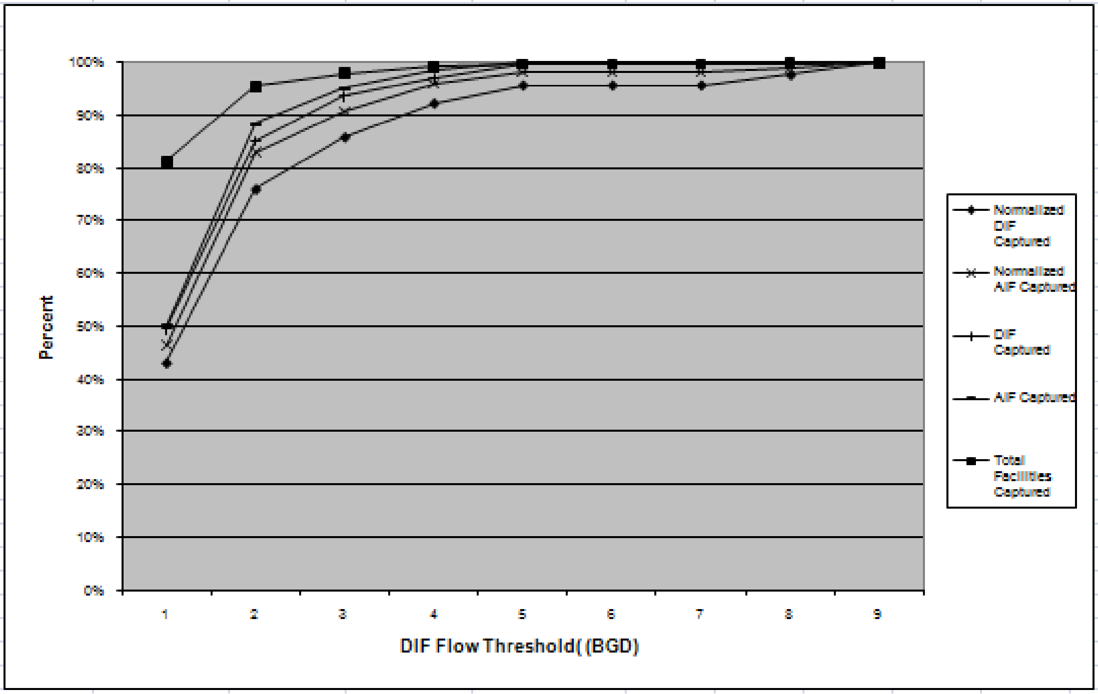
Based on discussions with industry during site visits, one of the main differences related to fuel type is intake flow for nuclear facilities. In order to more fully explore the assertion that nuclear facilities exhibit different trends in the utilization of cooling water, EPA plotted the cumulative intake flow for nuclear and non-nuclear facilities.[2] Exhibits 5-2 and 5-3 below illustrate the flow data by non-nuclear facilities and nuclear facilities, respectively.

Exhibit 5-2. Distribution of Intake Flows for All Non-Nuclear Electric Generators



[1] Note that, where necessary, EPA has incorporated fuel type-based costs in determining the compliance costs for facilities. For example, downtime estimates for nuclear facilities are substantially longer than those for fossil fuel facilities.
[2] See discussion in Section 2.6.1 for information on how EPA created the graphs.

Exhibit 5-3. Distribution of Intake Flows for All Nuclear Electric Generators



These exhibits show that nuclear electric generator facilities on average have a larger flow than non-nuclear electric generators, which affects the size of the cooling system. However, EPA did not identify significant differences in CWIS technologies between nuclear and non-nuclear facilities and, therefore, this was not determined to be an appropriate basis for subcategorization.

EPA data also indicate that the distribution of nuclear facilities versus non-nuclear facilities does not differ significantly by waterbody type (see Exhibit 5-4).

Exhibit 5-4. Distribution of Nuclear and Non-Nuclear Facilities by Waterbody Type

Waterbody Type	Percent of Nuclear Facilities	Percent of Non-Nuclear Facilities
Freshwater River or Stream	39.7	48.7
Tidal River or Estuary	15.5	20.2
Lake or Reservoir	22.4	20.9
Great Lake	13.8	6.8
Ocean	8.6	3.3

EPA data do indicate that a somewhat larger percentage of nuclear facilities use closed-cycle cooling than non-nuclear facilities (see Exhibit 5-5). However, because the percentage of nuclear facilities using closed-cycle cooling remains limited and the majority of applications of closed-cycle cooling are newly built units (i.e., Palisades is the only nuclear facility that has retrofitted to closed-cycle—see DCN 10-6888), this was not determined to be an appropriate basis for subcategorization.

Exhibit 5-5. Distribution of Nuclear and Non-Nuclear Facilities by Cooling System Type

Cooling Water System Type	Percent of Nuclear Facilities	Percent of Non-Nuclear Facilities
Once-through	50.0	78.3
Closed-cycle	37.9	12.0
Combination or Other	12.1	9.7

5.3.2 Manufacturers

In general, manufacturers use cooling water in much the same way as electric generators. While the end product may vary (e.g., paper products versus electricity), the cooling water is often used for similar industrial processes. Where manufacturers differ is in their use of contact cooling water and process water, which are typically also withdrawn from the same intake structure as non-contact cooling water.[3] Contact cooling water is mixed directly with the product, such as quench water for a steel mill. Process water is used to create the end product itself, such as water used in producing beverages. These two categories of water withdrawals are distinct from non-contact withdrawals in that they are much more difficult to reduce or eliminate without having a material effect on the end product. In other words, flow reduction (such as the use of closed-cycle cooling) is not likely to be a viable alternative for contact cooling or process flows, as they would adversely affect the facility's production. As a result, Options 2 and 3 (see Chapter 7 or the preamble) excluded contact and process flows from flow reduction requirements. As discussed in Chapter 8, EPA adjusted its cost methodology for manufacturers to account for this difference; intake flow rates (the basis for cooling tower costs) at manufacturing facilities were adjusted by as much as 47 percent.

Additionally, as shown in Chapter 4, manufacturers use essentially the same intake technologies and cooling system types as electric generators. As a result, there is no data suggesting that manufacturers should be addressed separately on the basis of intake or cooling system technologies.

5.4 Existing Intake Type

As illustrated in Chapter 4, existing facilities use a variety of intake locations, designs, and technologies for withdrawing cooling water. While a facility's site-specific characteristics will have a significant impact on the facility's choice for its intake location (e.g., shoreline, offshore, etc.) and the selection, design, and operation of the facility's intake technology, generally any of the possible intake locations will be able to supply sufficient cooling water to a facility. In addition, the various types of intake configurations (e.g., canal, surface, sub-surface, infiltration, sequenced intakes such as an intake emptying into a forebay) were not, by themselves, found to affect BTA. As such, EPA determined that it could not establish any appropriate subcategories based on the existing intake type.

[3] Electric generators use non-contact cooling water almost exclusively. As a result, no analysis of contact or process water is required for power plants.

In general, the intake type does not affect a facility's ability to retrofit closed-cycle cooling; the existing intake structure will have more than enough capacity to sustain the reduced level of water withdrawals. Therefore, EPA did not consider intake type as a factor in studying entrainment mortality requirements. Intake type may, however, affect impingement mortality requirements. Where appropriate, EPA's compliance costs reflect the existing intake location and the presence of existing intake technologies. As discussed in Chapter 8, facilities with technologies deemed to be compliant with the impingement mortality requirements of the proposed rule are not assigned any compliance costs. Technologies are, in part, assigned based on intake location, in order to facilitate the most cost-effective compliance solution. Other facilities will be required to upgrade, as reflected in the assigned technology costs.

5.5 Application of Impingement and Entrainment Reduction Technologies

The proposed rule and record identifies several impingement and entrainment reduction technologies in various categories, including flow reduction, closed-cycle cooling, screens, diversions, barriers, fish returns, behavioral systems, velocity reduction, physical configurations, and location. However, except for flow reduction, EPA has not identified data that indicate that a specific impingement and entrainment reduction technology is most effective for a particular segment of facilities. Rather, the data indicate that effective technologies can be applied in a variety of settings and that facilities typically use these technologies based on an appropriate configuration for the relevant facility. Thus, the available data does not support subcategorization based on particular impingement and entrainment reduction technologies already in place.

5.6 Geographic Location (including waterbody category)

Existing facilities are located throughout the United States (see Exhibit 4-2 in Chapter 4), operate in a variety of climatic, geologic, and hydrologic regimes, and are located in a range of populated areas from urban to rural. While the local conditions may affect how often a facility operates, its operational requirements, and the maintenance procedures necessary to operate efficiently, facilities are well-accustomed to these site-specific conditions and have incorporated these factors into their daily operations.

Geographic location can affect the physical and biological setting of a CWIS, however, EPA has not identified general trends that would allow the agency to use geographic location as a basis for subcategorization (i.e., EPA has not identified locational factors that affect the efficacy or availability of the primary technologies that may comprise BTA). Rather, the data indicate that effective technologies can be applied in a variety of settings and that facilities typically use these technologies based on an appropriate configuration for the relevant facility. EPA notes that it has included "regional cost factors" that adjusts model facility costs based on the model facility's location to account for local conditions.[4] As discussed in the EA, EPA has also analyzed the impacts of the proposed rule on the reliability of regional power production.

EPA also considered waterbody category as a possible basis for subcategorization. As illustrated in Chapter 4 of the TDD, facilities are located on a variety of waterbody types. In the Phase I rule, certain waterbody types were required to meet design and operational criteria.[5] In the 2004 Phase II rule, EPA established different performance requirements based in part on a facility's location on different waterbody categories.[6] That approach was based on the general characteristics of the waterbody categories and of groups of aquatic organisms. However, in the proposed rule, EPA is not differentiating between waterbody types; all facilities are required to meet the same impingement mortality and entrainment mortality requirements. This approach is based on the study data being used to establish BTA and the fact that these data do not reflect as clear a distinction between waterbody categories as was used in 2004. Specifically, the characterization data show the range of organism densities between waterbody types overlap. (See DCN 10-6711 for more information.)

Further, the density of organisms may not be a key factor in assessing adverse environmental impact. For example, some organisms are broadcast spawners and others are nest-builders.[7] A single egg in a freshwater system may be more important to that ecosystem than a single egg in a marine system.

In the absence of actual data that clearly establishes distinctions among waterbody categories, EPA has determined that it could not establish any appropriate subcategories based on waterbody type and that it is prudent to provide a consistent level of protection to aquatic organisms affected by CWISs.

5.7 Facility Size

EPA evaluated multiple metrics in analyzing facility size for existing facilities: intake flow and electricity output.

5.7.1 Intake Flow

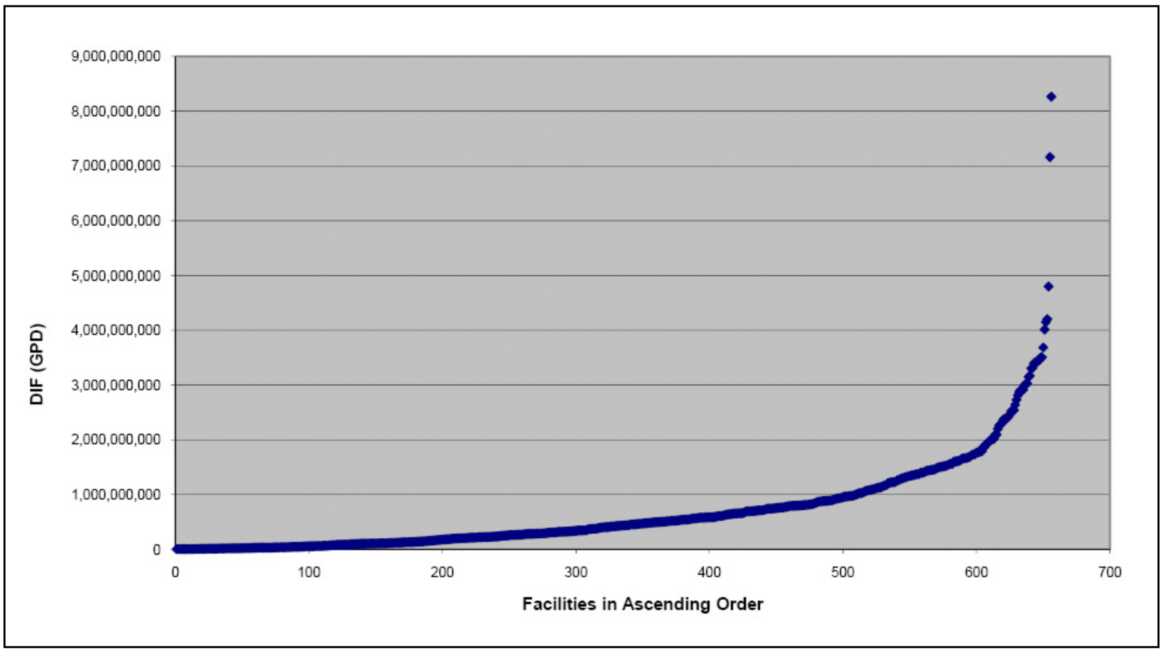
First, EPA examined the universe of electric generators for trends in intake flows. EPA recognizes that intake flow volume is an important element in determining impingement and entrainment and it is, therefore, logical to examine intake flow as a means for subcategorization.

[4] For example, facilities located near the Great Lakes are allotted an increased cost for managing zebra mussels.
[5] For example, facilities are not permitted to withdraw more than 1 percent of the tidal excursion. See 40 CRR 125.84(b)(3)(iii).
[6] Facilities located on estuaries, tidal rivers, Great Lakes, and oceans were subject to more stringent requirements. See 40 CFR 125.94(b)(1) and (2).
[7] Often, marine organisms are broadcast spawners while freshwater organisms are nest-builders or deposit eggs in specific locations.

Industry uses multiple metrics for intake flow: design intake flow (DIF), actual intake flow (AIF), and nameplate capacity. Design intake flow reflects the value assigned during the cooling water intake structure design to the maximum volume of water the cooling water intake system is capable of withdrawing from a source waterbody over a specific period of time. Actual intake flow is the average flow actually used over a specific period of time. Nameplate capacity is the amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station of system is rated by a manufacturer (this capacity is then correlated with required flow). EPA compiled the design intake flow (DIF) information from the industry questionnaires for all electric generators in ascending order and calculated the percent of flow captured by various flow thresholds (see Exhibit 5-6 through 5-10). To allow for the inclusion of closed-cycle facilities in this analysis EPA first needed to normalize the design intake flow (DIF) for each facility with closed-cycle cooling to a comparable DIF that would be utilized by the facility if it employed a once-through cooling system.[8] For facilities that utilize a combination cooling system (i.e., part once-through and part closed-cycle), EPA reviewed the industry surveys to determine the proportion of the DIF that would be converted.[9]

Exhibit 5-6 shows all electric generators plotted in ascending order by normalized DIF.

Exhibit 5-6. Normalized DIF at Phase II and III Electric Generating Facilities



[8] For this analysis, EPA assumed that facilities using cooling towers and located on marine waters experience an 80 percent reduction in flow and facilities on fresh water experience a 95 percent reduction in flow. To approximate the facilities once-through "assumed DIF," its DIF using the closed-cycle system was increased accordingly. Note that EPA has since revised its estimates for the percent reduction in flow, particularly on marine waters.

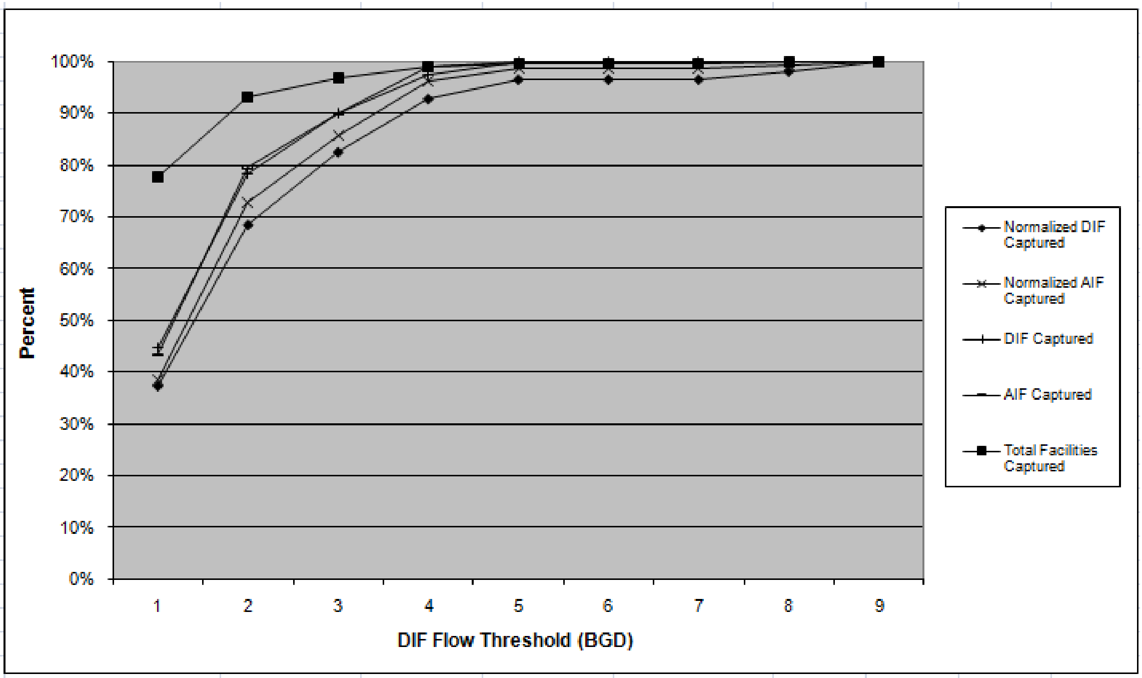
[9] In some cases, facilities use helper cooling towers, cooling lakes, or other configurations that are, for the purposes of this analysis, essentially once-through cooling. EPA did not adjust these flows.

As shown by this plot, approximately 75 percent of these facilities have DIFs less than 1 BGD and approximately 95 percent of facilities have DIFs less than 2BGD.

Exhibits 5-7 through 5-12 present the distribution of DIF and AIF (normalized and non-normalized) flows across several criteria, as well as the distribution of nameplate generating capacity across normalized DIF. Specifically,

- Exhibit 5-7 presents the percent of normalized DIF, normalized AIF, non-normalized DIF, non-normalized AIF and total facilities captured relative to DIF in billion gallons per day;
- Exhibits 5-8 through 5-11 present the percent of normalized and non-normalized DIF and AIF across waterbody categories (FWR – freshwater rivers and streams; TR&E – tidal rivers and estuaries; Oceans; GL – Great Lakes; and all facilities) relative to DIF in billion gallons per day; and,
- Exhibit 5-12 presents the distribution of nameplate generating capacity across normalized DIF.

Exhibit 5-7. Distribution of Intake Flows for All Electric Generators



The exhibit above shows that at thresholds below 3-4 BGD the distribution of flow is such that a higher percentage of facilities are captured relative to overall flow (normalized or non-normalized).

Exhibit 5-8. Distribution of Normalized DIF for All Electric Generators

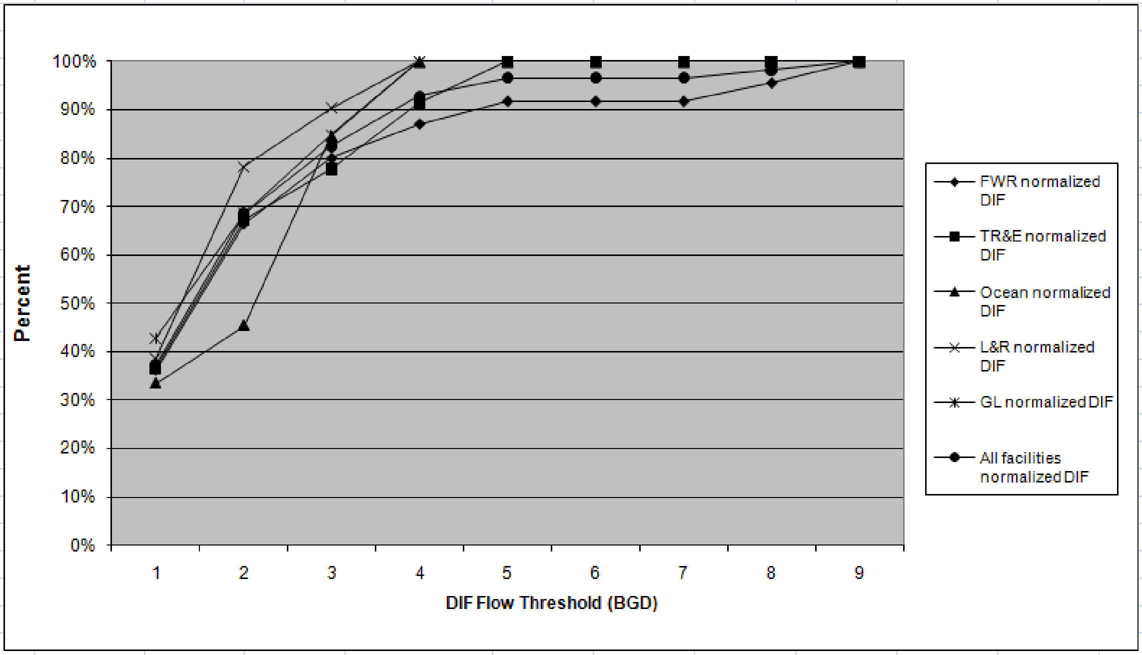
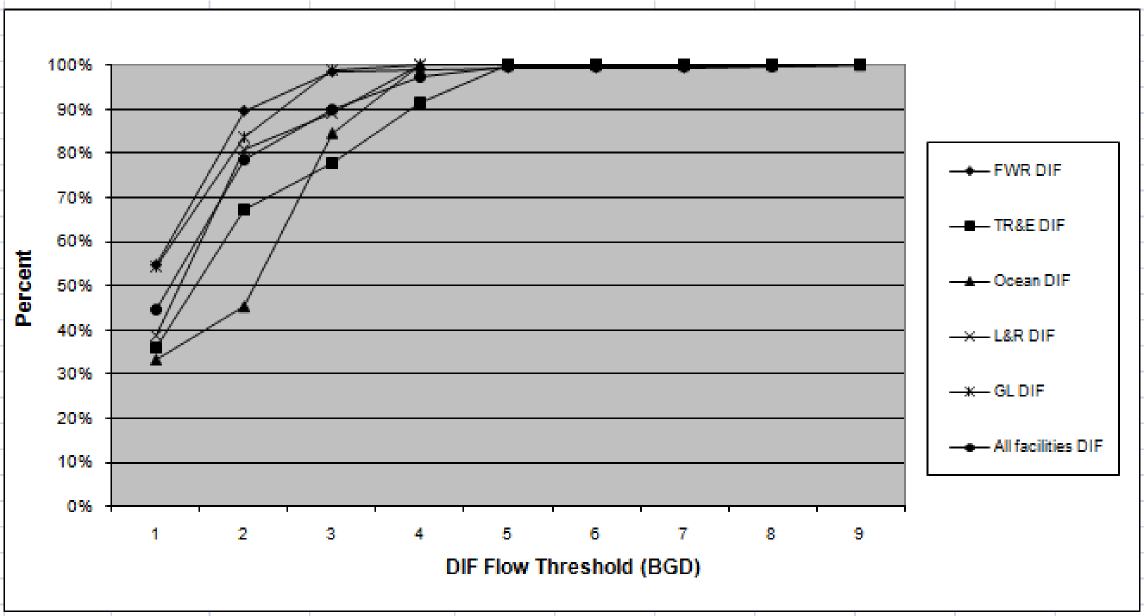


Exhibit 5-9. Distribution of DIF (Non-Normalized) for All Electric Generators



These exhibits show that the distribution of flow and facilities are generally similar across waterbody categories, although ocean facilities appear to use somewhat larger flows. The non-normalized data also reflect greater variation than the normalized data although the general distributions are similar.

Exhibit 5-10. Distribution of Normalized AIF for All Electric Generators

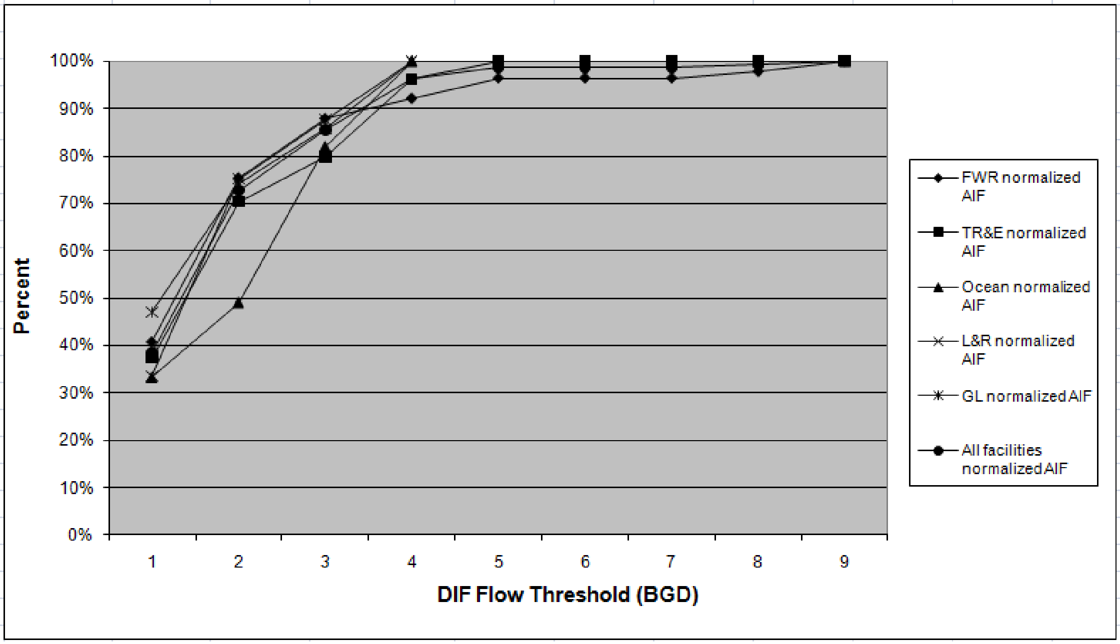
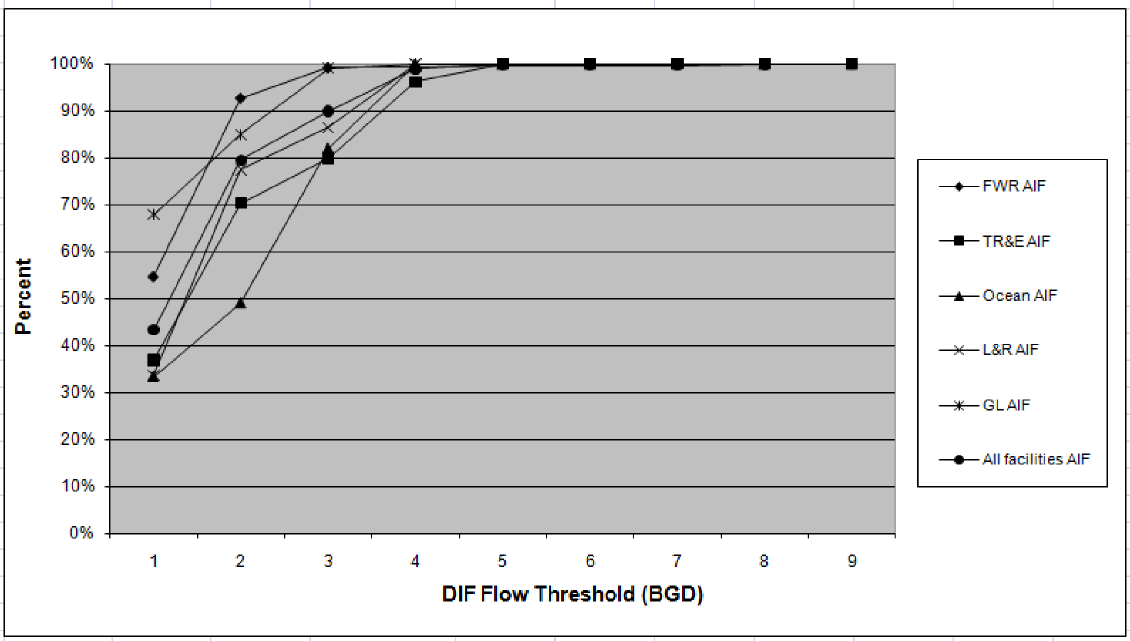


Exhibit 5-11. Distribution of AIF (Non-Normalized) for All Electric Generators



The AIF data do not show dramatic variation when compared with the DIF data for these plots. One difference is that 90 percent or greater of AIF is captured at a lower facility DIF threshold.

Exhibit 5-12. Distribution of Nameplate Generating Capacity

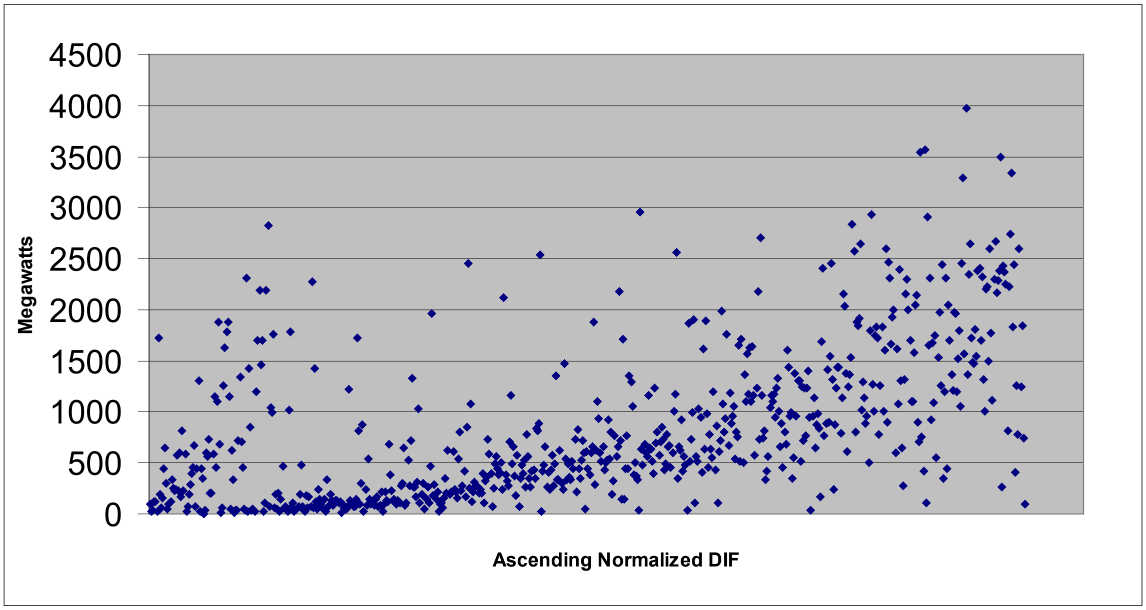


Exhibit 5-12 shows a general and somewhat variable correlation between DIF and electrical power output, and also indicates that some facilities, most likely more efficient operations, are able to produce a range of power at a lower DIF. However, such production is not correlated with CWIS technologies and the proposed rule includes a generally applicable compliance alternative that promotes reductions in cooling water intake flow.

Exhibits 5-13 through 5-15 show the percentage of facilities (electric generator and manufacturer separately, and then all facilities) and the total DIF and AIF that would be addressed by various flow thresholds.

Exhibit 5-13. Electric Generators and Flow Addressed By Various Flow Thresholds

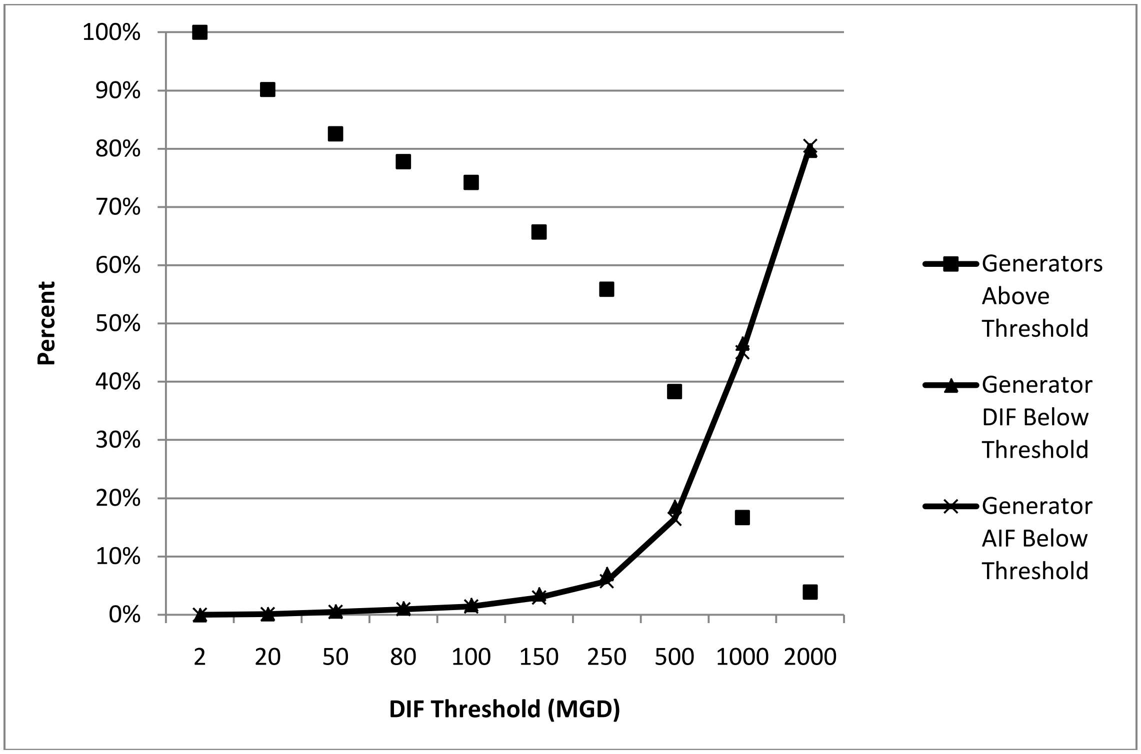


Exhibit 5-14. Manufacturers and Flow Addressed By Various Flow Thresholds

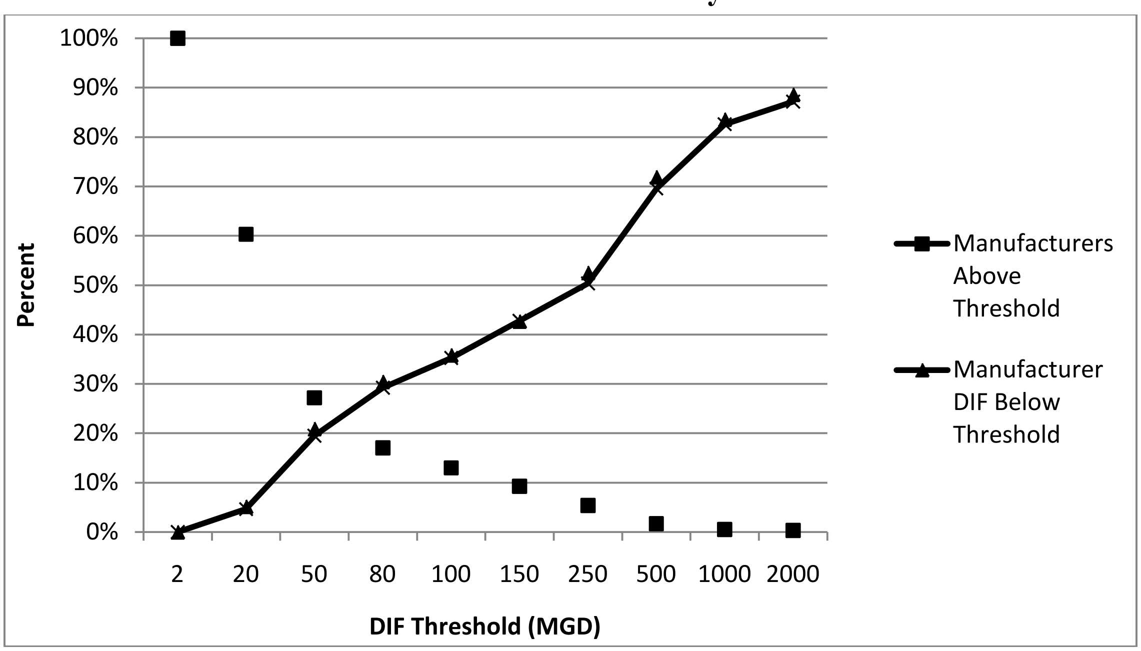
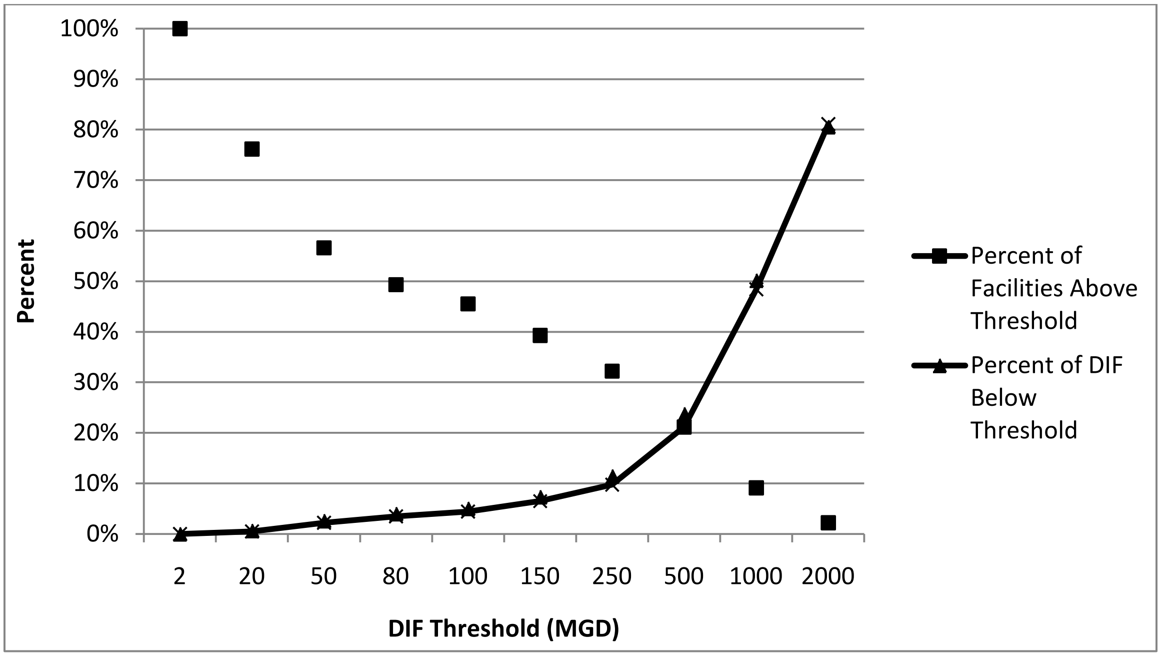


Exhibit 5-15. Facilities and Flow Addressed By Various Flow Thresholds



5.7.2 Generating Capacity

EPA also considered generating capacity as an aspect of facility size. Exhibit 5-12 above presents generating capacity plotted against normalized DIF and Exhibit 5-16 below presents generating capacity plotted against non-normalized DIF.

Exhibit 5-16. Distribution of Nameplate Generating Capacity

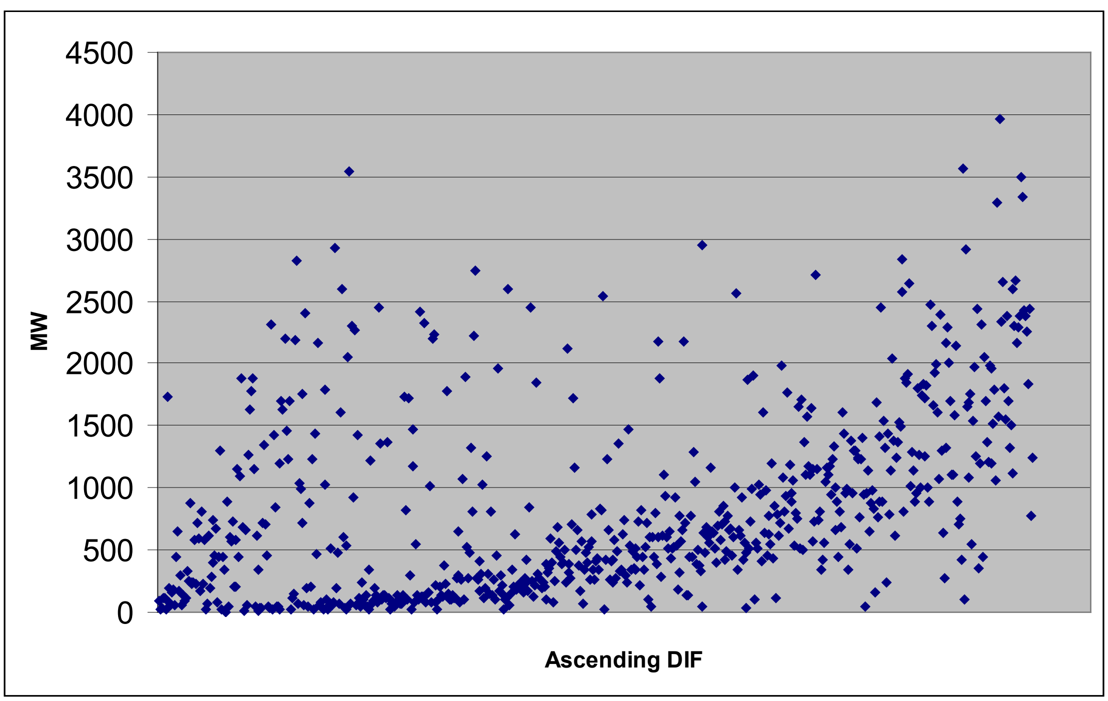


Exhibit 5-11 shows a similar pattern to Exhibit 5-10, with greater scatter of facilities, which suggests that closed-cycle cooling provides a range of flow reduction that is dependent on numerous factors.

As illustrated by the exhibits above, there are no clear trends for electric generating facilities based on intake flow relative to waterbody type or generating capacity. As such, EPA determined that it could not establish any appropriate subcategories based on any of those categories.

5.8 Non-Water Quality Environmental Impacts

New or additional intake technologies will not lead to unusual non-water quality impacts.[10] Many of the technologies discussed in the proposed rule are already in use at many facilities and do not fundamentally change the operation of intake technologies as a whole. EPA recognizes that requiring facilities to retrofit to closed-cycle cooling may incur additional non-water quality impacts that are not insignificant. These impacts are part of the reason that EPA did not propose to use closed-cycle cooling as the basis for BTA for this national rule. EPA did not identify any other significant non-water quality environmental impacts resulting from the engineering aspects of control technologies that provide a basis for establishing appropriate subcategories.

5.9 Other Factors

EPA conducted a series of additional analyses of existing facilities in order to attempt to determine if any additional subcategories were appropriate.

5.9.1 Capacity Utilization

EPA reviewed data on the capacity utilization rate (CUR) for Phase II facilities[11] using information from EPA's E-GRID database.[12] In order to best match the technology data from EPA's industry survey, EPA used the CUR data from the year 2000. Specifically, EPA compared the CUR data against data for fuel type (by individual generating unit and by facility), prime mover, total generating capacity (by individual generating unit and by facility), facility age, and waterbody type. As shown in Exhibits 5-17 to 5-23 below, there are no clear trends in any of these analyses that indicate that BTA should be different based on low usage. As such, EPA determined that it could not establish any appropriate subcategories based on capacity utilization.

[10] See Chapter 10 for a complete discussion of the non-water quality impacts.
[11] The analysis was not repeated to incorporate Phase III facilities, as the distribution of facilities among capacity utilization rate, fuel type, and waterbody type is relatively consistent between the two groups.
[12] CUR was a factor in the 2004 rule and was considered in the proposed rule.

Exhibit 5-17. Cumulative Distribution of Phase II Facility Year 2000 Generating Unit Capacity Factors by Primary Fuel Type

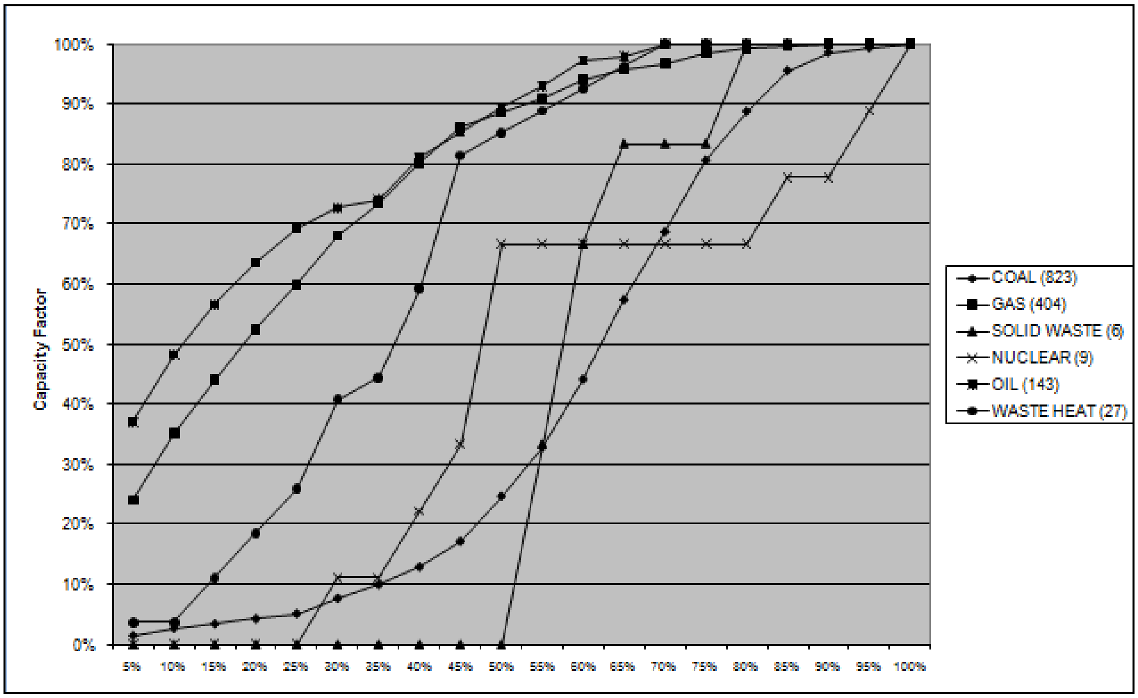


Exhibit 5-18. Distribution of Phase II Facility Year 2000 Generating Unit Capacity Factors by Generating Unit Prime Mover

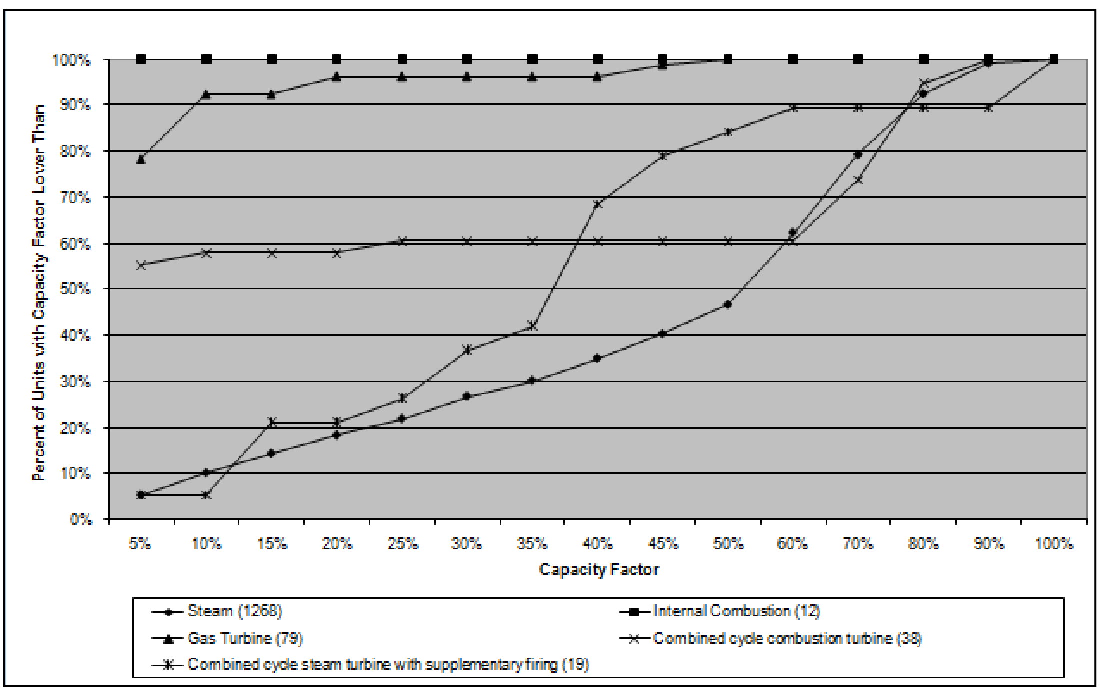


Exhibit 5-19. Phase II Facility Year 2000 Generating Unit Capacity Factors Versus Nameplate Generating Unit Capacity

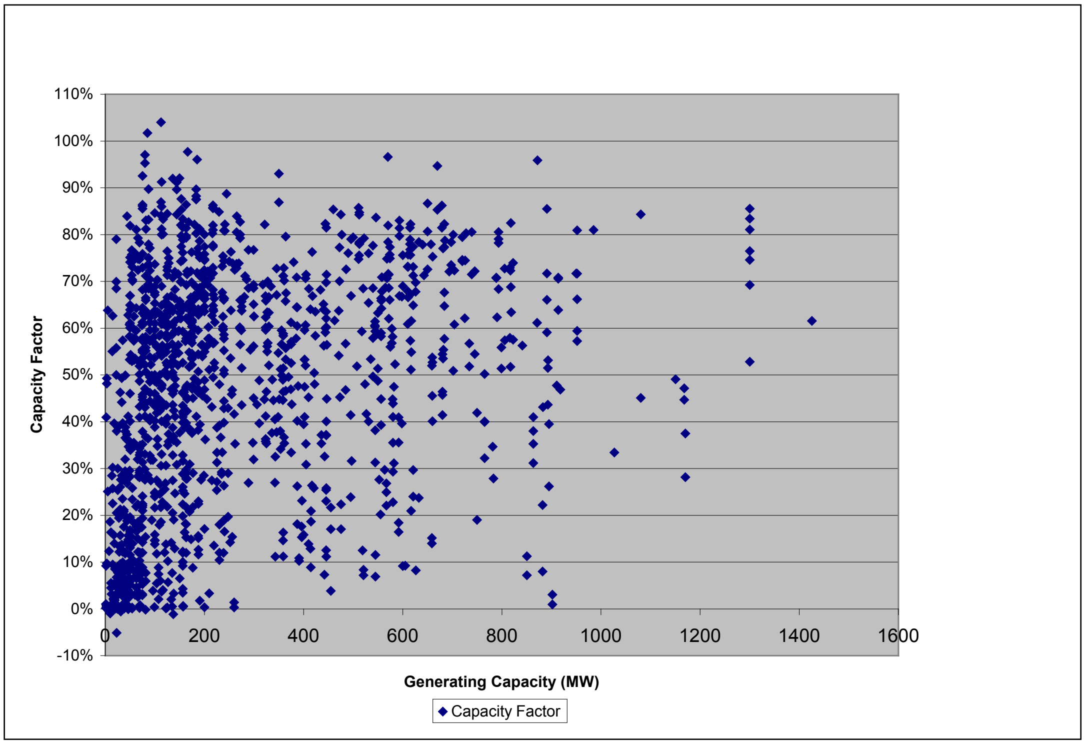


Exhibit 5-20. Phase II Facility Generating Unit Year 2000 Capacity Factor Versus Year Generating Unit Came Online

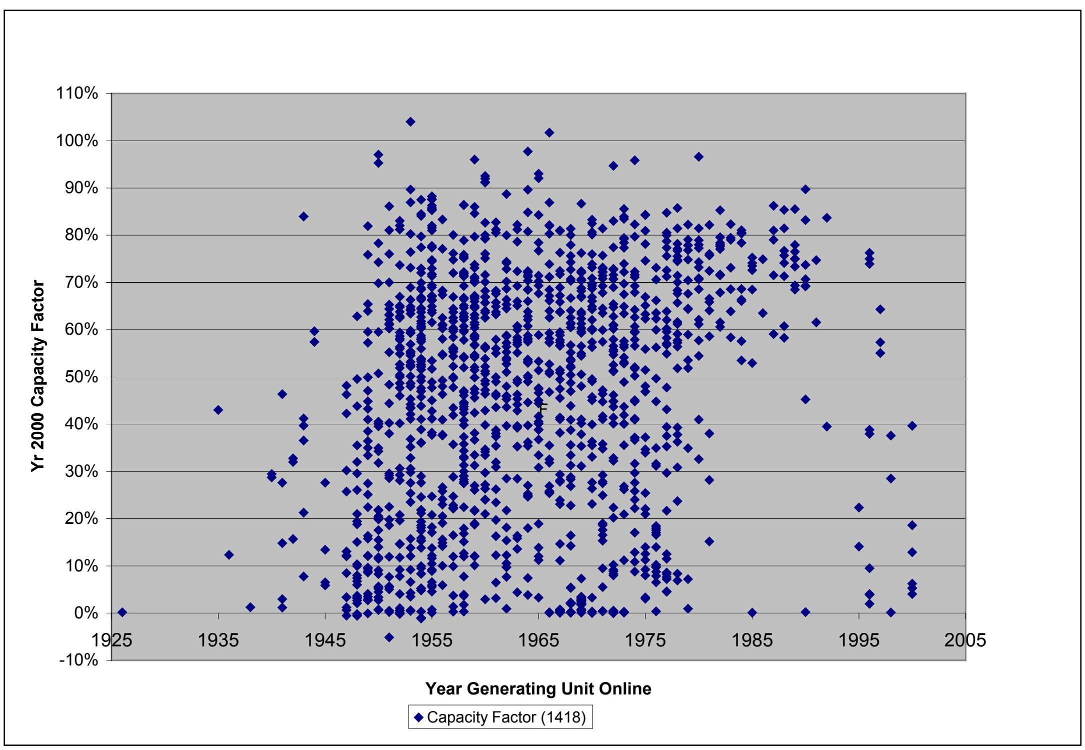


Exhibit 5-21. Distribution of Phase II Facility Year 2000 Total Plant Capacity Factors by Primary Fuel Type

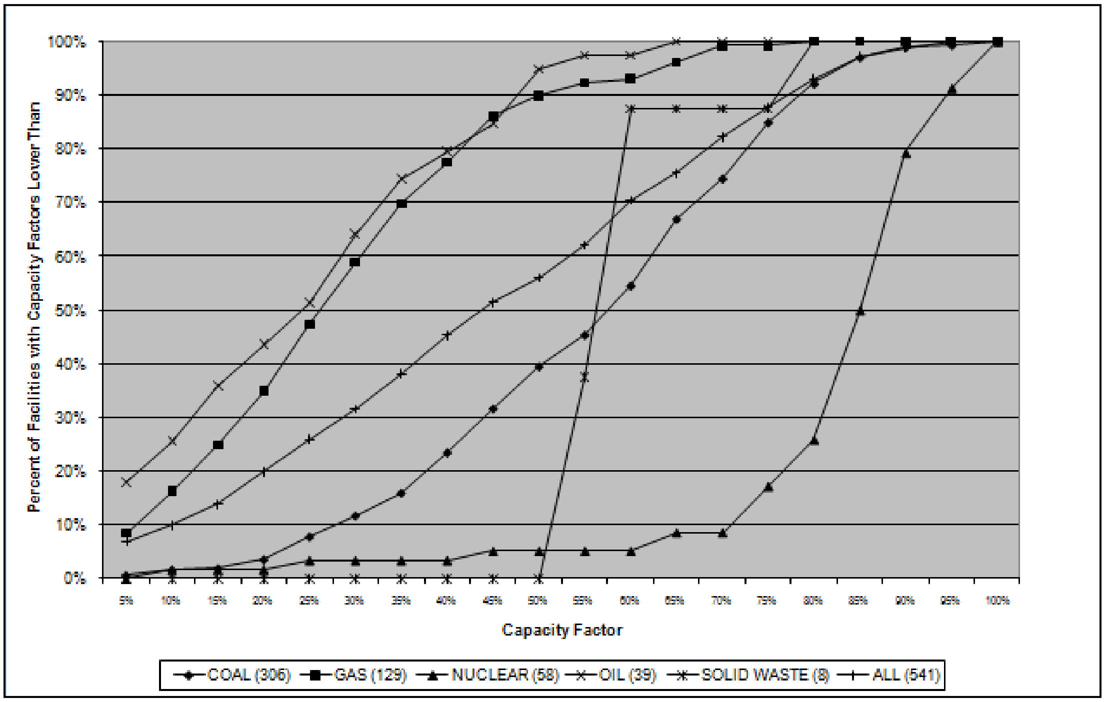


Exhibit 5-22. Distribution of Phase II Facility Year 2000 Total Plant Capacity Factors by Intake Waterbody Type

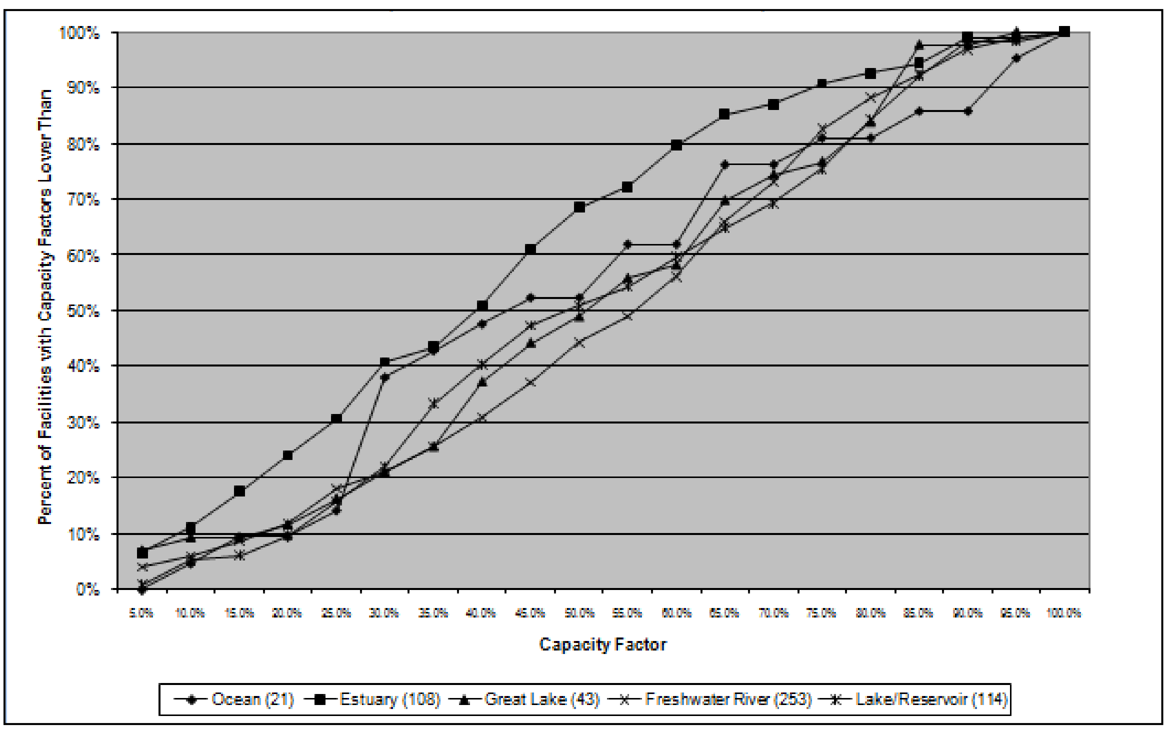
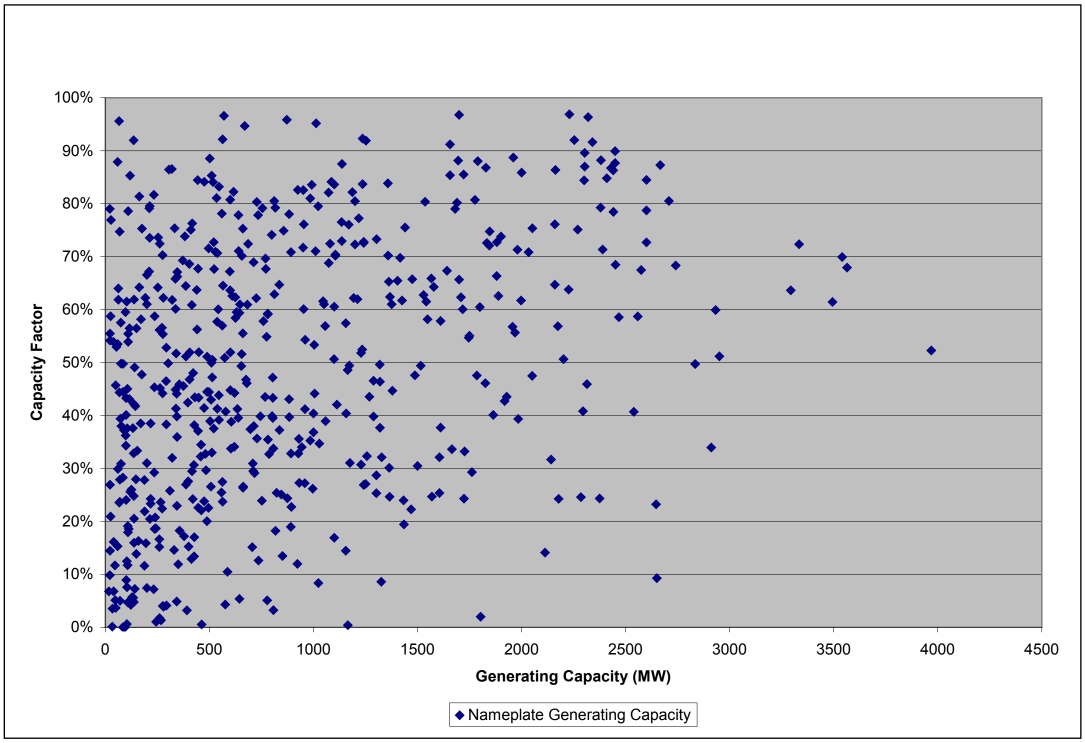


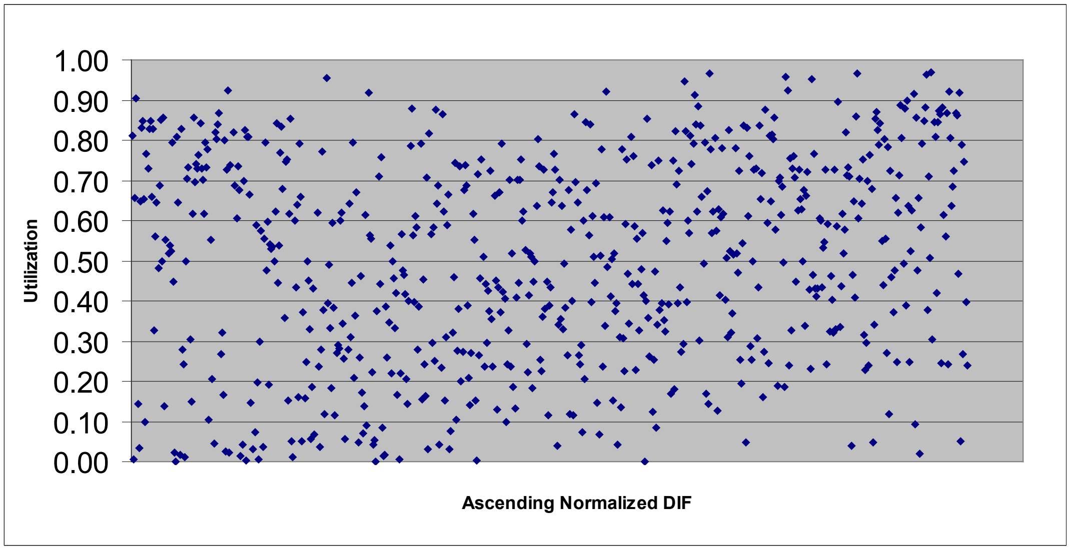
Exhibit 5-23. Phase II Facility Year 2000 Total Plant Capacity Factor Versus Total Generating Capacity



5.9.2 CUR Versus DIF

EPA also examined the relationship between the design intake flow (adjusted for closed-cycle cooling, as described above) and the CUR for Phase II facilities. As shown in Exhibit 5-24 below, there is no clear relationship between a facility's size (i.e., DIF) and it's frequency of operation. As such, EPA determined that it could not establish any appropriate subcategories based on the relationship of CUR and DIF.

Exhibit 5-24. Distribution of Capacity Utilization



5.9.3 Low Capacity Utilization Compared With Spawning Seasonality

In the 2004 Phase II rule, facilities with a CUR below 15 percent were not required to meet entrainment requirements. As discussed in the preamble for the 2002 proposed rule (see 67 FR 17141/1), EPA believed (at that time) that the reduced level of operations at these facilities would provide ample protection for aquatic organisms due to a substantial reduction in intake flows on an annual basis.

However, the proposed rule does not employ the same approach, as all facilities are required to meet impingement mortality and entrainment standards as applicable. EPA has changed its approach because low CUR facilities, while they do offer reduced flows on an annualized basis, typically operate at or near their full design capacity when they are in operation. If these periods of activity coincide with periods of high biological value (such as a spawning period), then these low CUR facilities may be having as much impact on aquatic organisms as a facility that operates more frequently.

EPA reviewed the group of facilities with a CUR below 10 percent (38 facilities[13]) and compared the operational periods of these facilities[14] to key biological periods for fish species in the source waterbodies for these facilities. As expected, low CUR facilities are most active in the summer and winter, when electricity demand is generally highest.

[13] These 38 facilities represent approximately 5.4 percent of the total DIF of Phase II facilities.
[14] Derived from monthly flow data from the industry questionnaire.

Exhibit 5-25. Facilities with CUR Less Than 10 percent

Facility Name	State	Waterbody Region[1]	Waterbody Type[2]
Conners Creek	MI	Great Lakes	Great Lakes
Marysville	MI	Great Lakes	Great Lakes
Oswego	NY	Great Lakes	Great Lakes
Edgewater	OH	Great Lakes	Great Lakes
Honolulu	HI	Hawaii	Ocean
Zuni	CO	Inland	Freshwater River/Stream
Atkinson	GA	Inland	Freshwater River/Stream
Plant Crisp	GA	Inland	Lake/Reservoir
Collins	IL	Inland	Freshwater River/Stream
Peru	IN	Inland	Freshwater River/Stream
Kaw	KS	Inland	Freshwater River/Stream
Monroe	LA	Inland	Freshwater River/Stream
Austin DT	MN	Inland	Lake/Reservoir
Fox Lake	MN	Inland	Lake/Reservoir
M L Hibbard	MN	Inland	Freshwater River/Stream
Hawthorn	MO	Inland	Freshwater River/Stream
Burlington	NJ	Inland	Freshwater River/Stream
Piqua	OH	Inland	Freshwater River/Stream
Delaware	PA	Inland	Freshwater River/Stream
Schuylkill	PA	Inland	Freshwater River/Stream
Lake Pauline	TX	Inland	Lake/Reservoir
North Texas	TX	Inland	Lake/Reservoir
Sam Rayburn	TX	Inland	Freshwater River/Stream
Blackhawk	WI	Inland	Freshwater River/Stream
Menasha	WI	Inland	Lake/Reservoir
Rock River	WI	Inland	Freshwater River/Stream
Riverside	MD	Mid-Atlantic	Estuary/Tidal River
Kearny	NJ	Mid-Atlantic	Estuary/Tidal River
Linden	NJ	Mid-Atlantic	Estuary/Tidal River
Sayreville	NJ	Mid-Atlantic	Estuary/Tidal River
Sewaren	NJ	Mid-Atlantic	Estuary/Tidal River
Indian Point	NY	Mid-Atlantic	Estuary/Tidal River
Hookers Point	FL	Gulf of Mexico	Estuary/Tidal River
Mason Steam	ME	North Atlantic	Estuary/Tidal River
Henry D King	FL	South Atlantic	Estuary/Tidal River
Indian River Plant	FL	South Atlantic	Estuary/Tidal River
McManus	GA	South Atlantic	Estuary/Tidal River
Riverside	GA	South Atlantic	Estuary/Tidal River

1 In this context, “region” is defined as the fisheries region used in the national benefits analysis in the EEBA.
2 Waterbody type is a regulatory classification under the 2004 Phase II rule.

EPA then examined the spawning periods of common fish species in each region of the country. (See DCN 10-6702.) Since the facilities with a low CUR do not show any regional or geographic trends (i.e., no one region has disproportionately more low CUR facilities), it is reasonable to conclude that a broader review of fish species by region will adequately address the correlation between spawning season and CUR. Two conclusions are apparent:

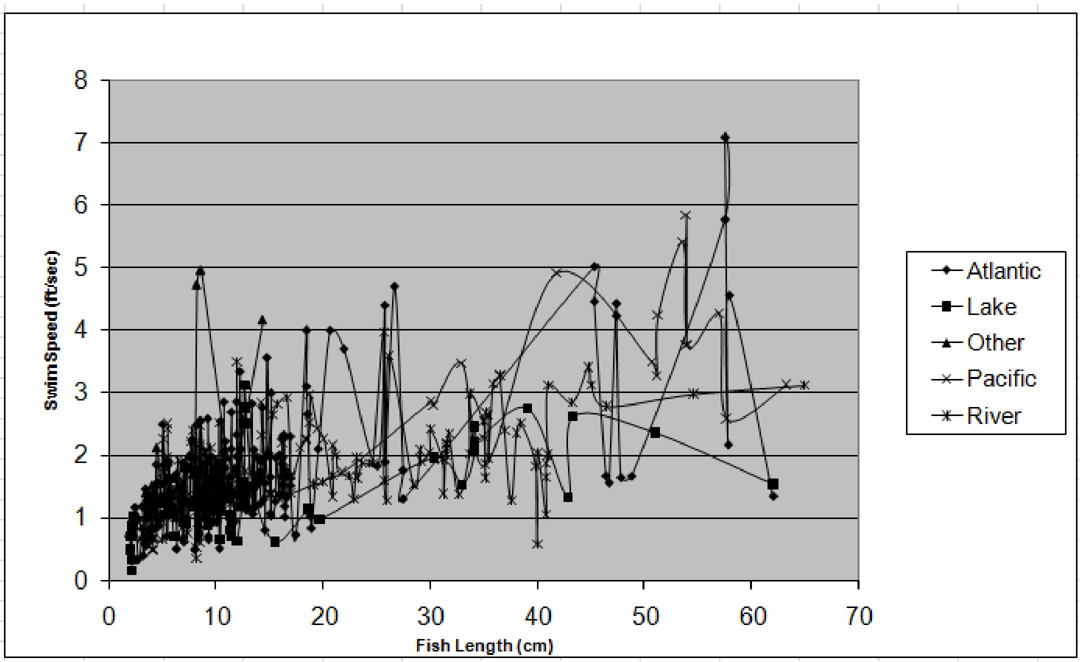
- For many waterbodies, there are few periods in the year when there is an absence of spawning activity, indicating that facility operations at any time of the year could have an impact on aquatic organisms.
- The operational periods of many low CUR facilities coincide with spawning periods of nearby fish species.

As such, EPA determined that low CUR facilities should not necessarily be exempted from entrainment requirements.

5.9.4 Fish Swim Speed

The swimming ability of fish is one key component in reducing impingement (and therefore impingement mortality). EPA reviewed data from an Electric Power Research Institute (EPRI) study on fish swim speeds (see DCN 2-028A) to determine if there was any difference in the swimming abilities of fish in different waterbodies. As shown in Exhibit 5-26, assemblages of fish in the various waterbodies did not demonstrate any clear superiority in swimming ability. As such, EPA determined that it could not establish any appropriate waterbody-based subcategories based on the fish swim speed in those waterbodies.

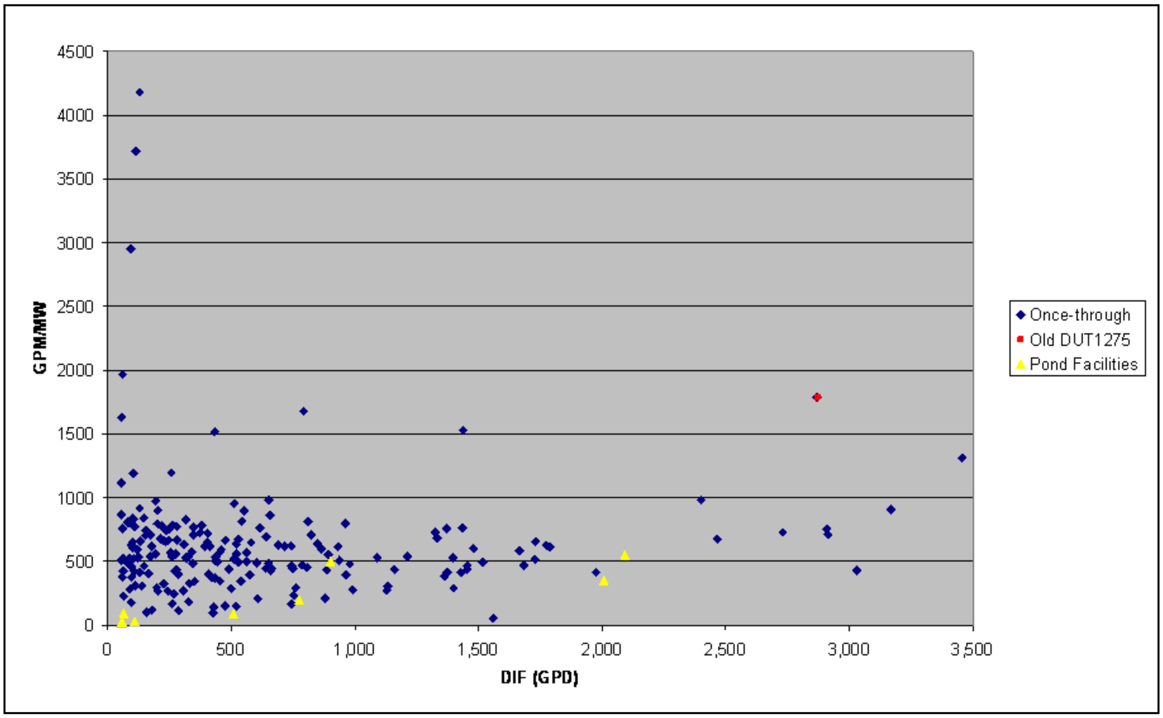
Exhibit 5-26. Swim Speed Versus Fish Length



5.9.5 Water Use Efficiency

EPA also analyzed power generating facilities' cooling water withdrawals and electricity generated as a measure of how efficient a given facility is in its use of cooling water. Initially, EPA examined the design intake flow for facilities above 50 MGD and compared it to their steam generating capacity as a way to identify the least efficient facilities. Exhibit 5-27 shows the results of this analysis, with cooling ponds sites identified separately.

Exhibit 5-27. Design Intake Flow (gpm) / MW Steam Capacity for Once Through Power Plants Over 50 MGD

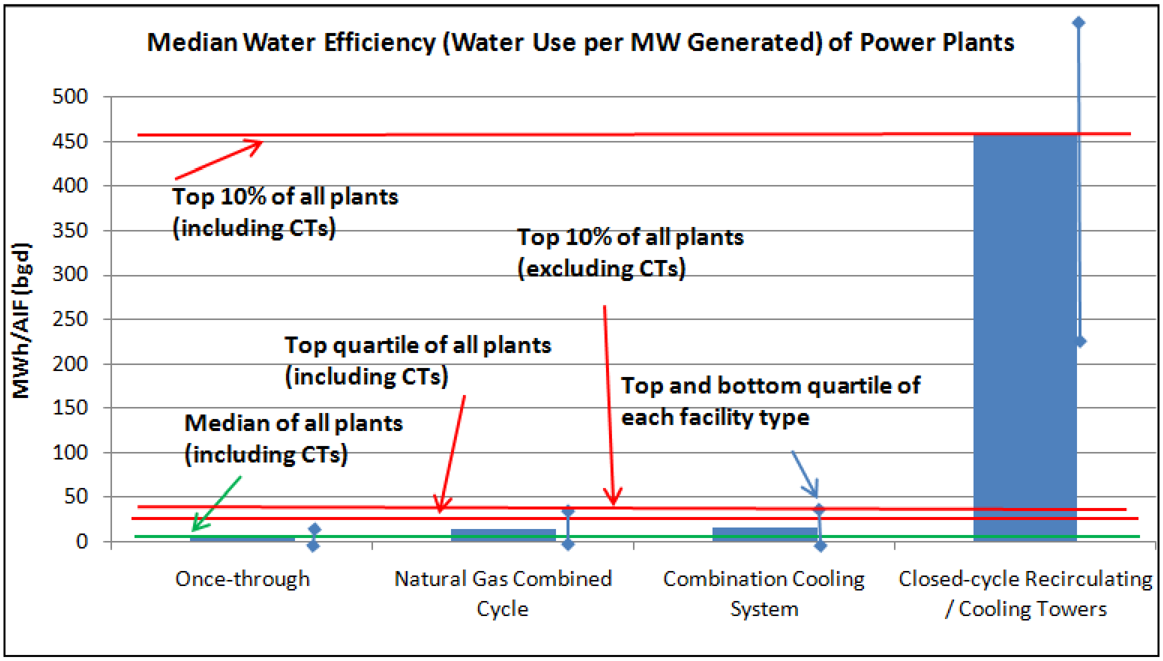


EPA expanded upon this analysis by using data from the industry surveys (actual intake flow) and compared it to the electricity generation from the corresponding period. Facilities were then sorted based on the calculated ratio of water use per megawatt generated. Exhibit 5-28 shows the median ratio for facilities with various cooling system types (once through, closed-cycle, combination, and combined cycle[15]). EPA examined a range of analyses for water use efficiency, including variants that excluded facilities that utilize closed-cycle cooling, as these facilities clearly withdraw less water per megawatt than once through facilities. Exhibit 5-28 shows the median efficiency for each type of facility, with a variety of horizontal lines that represent various thresholds; for example, the top 10 percent most efficient power plants (including closed-cycle)) have approximately the same efficiency as closed-cycle systems, while the same ratio drops

[15] The increased generating efficiencies of combined cycle plants warranted their separation into a different grouping.

significantly when closed-cycle systems are excluded. See Chapter 7 for more discussion of how EPA considered this information.

Exhibit 5-28. Median Water Efficiency (Water Use per MW Generated) of Power Plants (Including CCRS)



5.9.6 Land Availability

While EPA believes that the vast majority of facilities have adequate available land for placement of cooling towers,[16] some facilities may have legitimate feasibility constraints. Based on site visits, EPA has found several facilities have been able to engineer solutions when faced with limited available land. EPA attempted to determine a threshold of land (one option explored a threshold of approximately 160 acres per gigawatt) below which a facility could not feasibly install cooling towers.[17] Based on such an approach, EPA projected an upper bound of 25 percent of facilities that may have insufficient space to retrofit to cooling towers. While EPA estimated that some facilities would not have enough space, EPA found some facilities with a small parcel of land were still able to install closed-cycle cooling by engineering creative solutions.[18] On the other hand, EPA found that some facilities with large acres still could not feasibly install cooling towers due to, for example, protected wetlands. While EPA was able to account for space constraints in its estimated compliance costs (see Chapter 8), there was not enough data to make a site-specific assessment of available land. As a result of the huge uncertainty

[16] In the case of fossil fuel plants, scrubber controls may also be newly required to comply with air rules and standards.
[17] See DCNs 10-6671 and 10-6672.
[18] Facilities could also build cooling towers in elevated locations, such as building roofs but this is more expensive and is not feasible for many facilities.

surrounding EPA's data and analysis of available space, EPA rejected land availability as a potential subcategory.

5.9.7 Other Factors

EPA also explored, in varying degrees of depth, and ultimately rejected a number of other potential approaches to subcategories. These analyses included an evaluation of creating subcategories based on the following:

- Similar groups of fish species (see DCN 10-6704)
- Spawning period (see DCN 10-6702)
- Deep offshore intake location (See Chapter 12)
- Combined cycle (see DCN 10-6631)
- Cogeneration (see DCN 10-6630)
- Dry cooling (see DCN 10-6679)
- 7Q10 of the source waterbody
- Flue gas desulphurization (see DCN 10-6681)

Because these factors were only applicable to a limited number of facilities, EPA found these factors would not improve setting and implementing national performance standards.

5.10 Conclusion

As shown in the analyses above, EPA has examined numerous aspects of existing facilities, including both production-related and CWIS-related characteristics, and has determined that although these facilities exhibit a range of characteristics, these characteristics do not differ to the extent that different technologies are most effective or uniquely available to distinct subcategories of facilities. EPA's analysis demonstrates that several CWIS technologies are effective for existing facilities and that these technologies do not differ significantly across the various subcategory criteria considered. Therefore, EPA is not establishing any subcategories for the proposed rule.

Although no subcategories are being proposed, the rule does reflect the key factors and variability that are relevant to CWIS impacts. The proposed rule would establish basic standards for the reduction of impingement mortality and entrainment. It also provides several compliance alternatives that reflect technologies that can be used to minimize adverse impacts and that are to be implemented on a case-by-case basis in accordance with the characteristics of a specific facility (e.g., location, size, existing technologies, etc.). In this way, the structure of the proposed rule is consistent with the data identified for existing facilities.

Chapter 6: Technologies and Control Measures

6.0 Introduction

In developing the 2004 Phase II rule and 2006 Phase III rule, EPA conducted a comprehensive review of technologies that reduce impingement and entrainment (I&E) at cooling water intake structures.[1] For the proposed Existing Facilities rule, EPA reconsidered existing information on these technologies, identified new technologies, and updated efficacy information based on new study data.[2] This chapter describes the primary technologies and operational measures considered in developing requirements for the proposed rule. Each section provides an overview of the technology, a discussion of performance in reducing impingement and/or entrainment, and examples of facilities and/or laboratory studies that employ the technology.

In general, technologies and control measures can be divided into two major groups: flow reduction and screening or exclusion. Flow reduction is the clearest way to reduce I&E, as lower intake flows will impinge and entrain fewer organisms, generally in proportion to the amount of flow reduction. Screens act to exclude organisms from the intake structure and return them to the source waterbody. Exhibit 6-1 lists the technologies and control measures discussed in this chapter.

In addition to this chapter, the Electric Power Research Institute's (EPRI) 2007 *Fish Protection at Cooling Water Intakes: A Technical Reference Manual* (DCN 10-6813) is a compilation of studies conducted at various sites throughout the country and serves as a comprehensive reference for cooling water intake technology performance. For a discussion of cooling tower technologies and retrofit issues, see Chapter 8 of EPRI (2007) and the California Ocean Protection Council's *California's Coastal Power Plants: Alternate Cooling System Analysis* (DCN 10-6964). EPRI has also released a preliminary document which quantifies environmental and social effects of conversions to closed-cycle for seven facilities, *Net Environmental Effects of Retrofitting Power Plants with Once-Through Cooling to Closed-Cycle Cooling, May 2008* (DCN 10-6926 and 10-6927).

In general, all of the technologies presented in this chapter can be effective and are equally available at both power plants and manufacturers, as well as for existing facilities and new facilities. Cooling water intake structures are a technical apparatus that is designed to supply water; the end use of the water is of little importance when evaluating the CWIS's effectiveness or the feasibility of a given technology. There will certainly be site-specific factors that weigh heavily in evaluating technologies but the type of "downstream" user is generally not relevant. In the case of manufacturers, there are greater opportunities for flow reduction and reuse of cooling water.

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[1] See Chapter 3 of the 2002 Phase II proposed rule (DCN 4-0004), Chapter 4 of the 2004 Phase II final rule TDD (DCN 6-0004), and Chapter 8 of the proposed Phase III rule (DCN 7-0004).
[2] See Chapter 2 of the TDD for a discussion of data collection efforts.

Exhibit 6-1. List of Technologies Considered

Flow Reduction Technologies and Control Measures
- Closed-cycle recirculating systems
- Wet cooling systems
- Dry cooling systems
- Variable speed pumps/variable frequency drives
- Seasonal flow reductions
- Water reuse
- Alternate cooling water sources

Screening Technologies
- Conventional traveling screen
- Modified coarse mesh traveling screen
- Geiger screen
- Hydrolox screen
- Beaudrey W Intake Protection (WIP) screen
- Coarse mesh cylindrical wedgewire screen
- Barrier net
- Velocity cap
- Fine mesh traveling screen
- Fine mesh wedgewire screen
- Aquatic filter barrier

Other Technologies and Operational Measures
- Reduced intake velocity
- Substratum intakes
- Louvers
- Intake location

6.1 Flow Reduction Technologies and Control Measures

This section describes technologies and control measures used to reduce cooling water intake flows. By reducing the intake flow, a facility can reduce its I&E; impingement is related to intake flow (among other variables and entrainment is directly proportional to flow. The largest reductions are usually realized by installing (or retrofitting) a closed-cycle recirculating cooling system but facilities may also employ variable speed pumps, seasonal flow reductions, water reuse, or use of alternate sources of cooling water.

6.2 Closed-Cycle Recirculating Systems

Closed-cycle cooling systems transfer a facility's waste heat to the environment and recycle the cooled water back to the condensers to be used again. These recirculating systems enable a facility to withdraw significantly smaller quantities of (or in some cases no) surface water. Closed-cycle cooling systems include cooling towers and cooling lakes/ponds.[3] Cooling towers are structures that recirculate water within the cooling system, while providing for the exhaust of excess heat. Towers are generally of two designs: mechanical draft, in which heated water is exposed to air currents driven by

[3] Note that the term "cooling pond" is often used or defined broadly, but under the proposed rule, not all cooling ponds are considered to employ closed-cycle cooling. See the preamble to the proposed rule and Chapter 3 of the TDD for additional discussion.

electrical fans, or natural draft, in which heated water is allowed to interact with naturally induced drafts within the tower. In both cases, water within the cooling system is cooled and sent back to the condenser to be used again. Approximately 28 percent of existing power producers and 35 percent of existing manufacturers use recirculating systems (cooling towers).

Due to the evaporative processes involved (and the subsequent buildup of dissolved solids), cooling towers require that a certain portion of the circulating water be discharged (as "blowdown") and replaced (makeup water).[4]

Cooling ponds are surface waterbodies that serve as both a source of cooling water and a heat sink. As with cooling towers, cooling ponds rely on evaporative cooling to dissipate the waste heat. Depending on local hydrology, cooling ponds may also require makeup water from another waterbody (the level of makeup water depends on numerous site-specific factors including size, inflow and outflow, and evaporation; EPA has not identified a source of data that describes cooling pond makeup flows). At many facilities, cooling ponds have evolved into more than part of an industrial waste treatment process, as recreational fishing and other designated uses have been established.

There are two main types of cooling towers, wet cooling and dry cooling. Each of these technologies is described below.

6.2.1 Wet Cooling Systems

In a wet cooling system, waste heat is primarily transferred through evaporation of some of the heated water into the surrounding air.[5] This process enables a facility to re-use the remaining water thereby reducing the quantity of water that must be withdrawn from a water body. While the amount of water withdrawn from the water source is greatly reduced, it is not eliminated completely because make-up water is required to replace water lost through evaporation. There are two main types of wet cooling systems: natural draft and mechanical.

A natural draft cooling tower is tall, up to 500 feet or more, and has a hyperbolic shape which resembles a wide, curved smoke stack (see Exhibit 6-2). The height of these towers creates a temperature differential between the top and bottom of the tower, creating a natural chimney effect. Unlike natural draft towers, mechanical cooling towers rely on motorized fans to draw air through the tower and into contact with the heated water. These towers may be much shorter than natural draft cooling towers, typically ranging from 30 to 75 feet in height (see Exhibit 6-3), but may require more land area and reduce a facility's net generating output due to the electricity required to operate the fans. Both natural draft and mechanical cooling towers can operate in freshwater or saltwater environments. Saltwater applications typically require more make-up water than freshwater applications, making them less efficient in reducing water withdrawals.

[4] The frequency at which blowdown occurs depends on the source waterbody; fresh water requires less frequent blowdown than brackish water.
[5] In addition, a smaller portion of the heat is also removed through direct contact between the warm water and the cooler surroundings.

Exhibit 6-2. Natural draft cooling towers at Chalk Point Generating Station, Aquasco, MD

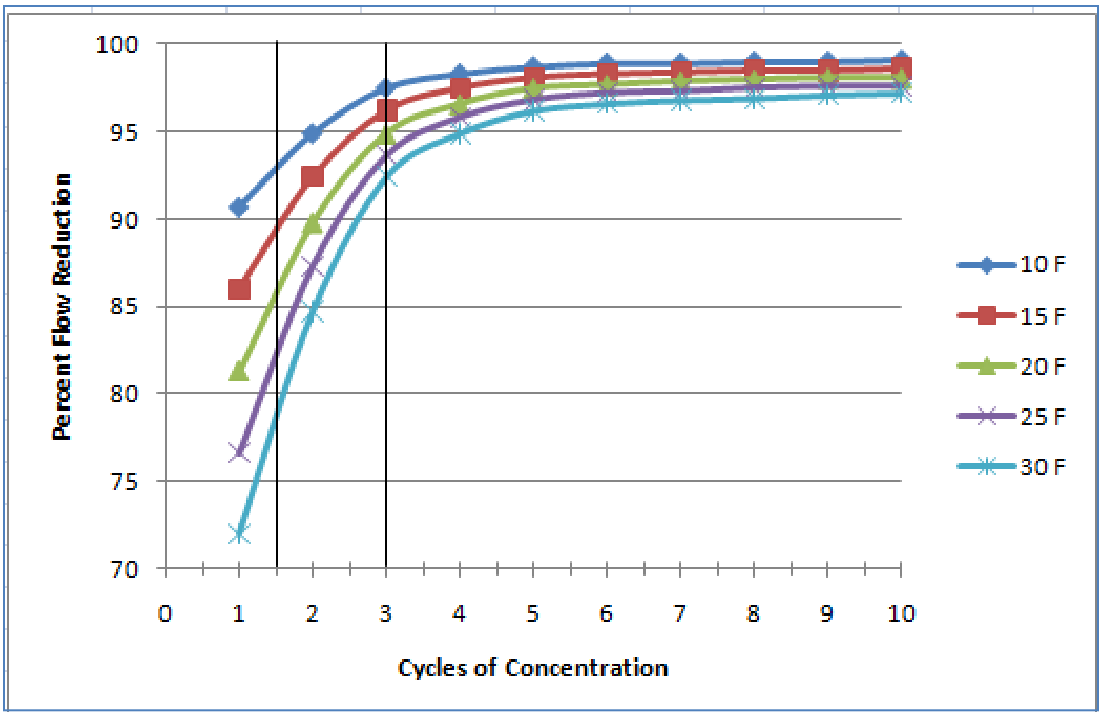
Exhibit 6-3. Mechanical draft cooling towers at Logan Generating Plant, Swedesboro, NJ

Cooling Tower Optimization

The use of cooling towers significantly reduces the withdrawals of cooling water, but some make-up water is still withdrawn in wet cooling tower systems. Facilities can optimize the reduction in flow by also minimizing the make-up flow withdrawals. The most common concept used to describe the level of optimization is cycles of concentration (COC). This represents the ratio of dissolved solids in the recirculated water versus that in the make-up water. Operating at a higher COC usually requires additional O&M, such as an increased use of chemicals.

In its analyses, EPA assumed a minimum COC of 1.5 for salt water towers and 3.0 for freshwater towers. These levels correspond to flow reductions of 94.9 percent and 97.5 percent respectively (at a delta T of 20°F, which is common for power plants and is in the center of the range observed by EPA). Exhibit 6-4 shows the reductions in flow for various waterbody types, cooling system configurations and COCs; the vertical lines represent the two COCs used by EPA in its analyses. See DCNs 10-6673 and 10-6674 for a detailed discussion of cooling tower optimization.

Exhibit 6-4. Percent Reduction in Flow for Various Cooling System Delta Ts



Alternative Configurations

Modular cooling tower units provide an additional cooling tower alternative. Modular cooling towers resemble mechanical cooling towers, but are portable, typically rented for short-term periods and quickly assembled (see Exhibit 6-5). Modular cooling tower units have been used as temporary replacements for existing cooling tower systems that need major repairs, for facilities that are subject to interruptions in the ability to withdraw sufficient quantities of cooling water, and for facilities that require supplemental cooling or flow reduction for only a portion of the year. EPA has determined that the use of modular towers (on a temporary basis) could substantially reduce the effects of downtime from retrofitting intake technologies at some facilities (see DCN 10-6677). Facilities that would be able to install the modular towers may actually face no downtime at all, which would eliminate a significant component of the costs of the proposed rule and replace it with the smaller, temporary cost of modular tower rentals. (See the Environmental and Economic Benefits Analysis for a discussion of the role of downtime costs in EPA's estimation of national economic impacts). Because EPA was not able to estimate how many facilities would be able to employ these modular towers, however, the Agency has not attempted to estimate the overall cost savings of using them. As a result, EPA did not adjust its national cost estimates to include the use of modular cooling towers.

Facilities also often utilize a "combination" cooling system, in which some portion of the cooling system uses closed-cycle cooling.[6] For example, a facility might have one unit operating with a once-through system and a second unit has a cooling tower. For the purposes of costing and consideration of cooling tower retrofits, EPA considered these facilities along with facilities that are fully once-through.

Exhibit 6-5. Modular cooling tower (image from Service Tech)[7]

Facilities that face significant challenges in meeting thermal discharge limits may operate "helper" cooling towers.[8] These are typically mechanical draft towers that are not associated with the cooling system itself; they simply withdraw heated effluent that is

[6] Approximately 8 percent of electric generators and 12 percent of manufacturers use combination systems.
[7] http://servicetechweb.com/photo2.html
[8] See DCN 10-6676 for a detailed discussion of helper towers.

discharged by the facility, evaporate heat, and return the water to the discharge point. These systems do not reduce the overall intake flow. Harllee Branch is an example of such a facility (See DCN 10-6537 for EPA's site visit report to this facility).

6.2.2 Dry Cooling Systems

Dry cooling systems completely eliminate the need for cooling water withdrawals. Unlike wet cooling systems, in dry cooling systems, waste heat is transferred completely through convection and radiation rather than evaporation. Dry cooling systems are in use at a number of facilities in the United States and worldwide (See DCNs 4-4023H, 10-6679 and 10-6943). Since 1990, dry cooling has been installed in at least one facility in every EPA Region, with many being installed in Regions 1 and 2 (states with historically more stringent regulatory regimes) and the west, where water resources (for once-through or wet towers) are more limited. In the 1990s, most of the facilities that installed dry cooling were small (less than 100MW for the dry-cooled unit). But in the past decade, dry cooling has become more prevalent at much larger facilities, with virtually all dry-cooled units being over 100MW and many 250MW and larger. At present, Mystic (MA) and Midlothian (TX) are the largest known dry-cooled units, at 500MW each (out of a pant-wide capacity of 1600MW and 1650 MW, respectively).

There are two main types of dry cooling systems: direct and indirect. Direct systems function similar to a radiator in a car; the turbine exhaust steam passes to a fin tube array where air is drawn across and heat is rejected ultimately producing a condensate that is returned for reuse in the turbine. The system is completely closed to the atmosphere and there is no contact between the outside air and the steam or the resulting condensate (see Exhibit 6-6). Indirect dry cooling requires a cooling tower but a surface condenser is placed between the turbine exhaust and the tower. Heat is transferred to the circulating medium in the condenser and dispersed to the atmosphere through the tower. However, the difference between indirect dry cooling and a wet tower is that the water is not exposed to the outside air.[9]

[9] Indirect dry cooling systems are substantially less efficient in rejecting heat than direct units; however, most facilities that would choose to retrofit dry cooling would select an indirect system, as it would be able to tie into the existing condenser at the facility.

Exhibit 6-6. Dry cooling tower (image from GEM Equipment)[10]

6.2.3 Performance of Cooling Towers

In the 2004 Phase II rule, EPA estimated facilities employing freshwater cooling towers and saltwater cooling towers would achieve flow reductions, and therefore associated entrainment and impingement mortality reductions, of 98 percent and 70-96 percent, respectively.[11] At that time, EPA's record demonstrated saltwater cooling towers typically operated at 1.1-2.0 cycles of concentration. However, more recent information demonstrates that, as a result of advances in design and operation, saltwater cooling towers typically operate at 1.5 cycles of concentration. See DCN 10-6964. This equates to a 94.9 percent reduction in flow over a once-through cooling system. As such, EPA estimates that freshwater cooling towers and saltwater cooling towers reduce impingement mortality and entrainment by 97.5 percent and 94.9 percent, respectively.

[10] http://product-image.tradeindia.com/00208501/b/Dry-Cooling-Tower.jpg
[11] As discussed in the preamble to the proposed rule, impingement mortality and entrainment reductions are proportional to flow reductions.

Retrofit Applications

EPA estimated retrofit costs as described in Chapter 8 of this TDD and in the preamble. Engineering factors affecting the retrofit from once-through systems to cooling towers include the following:

- Availability of space nearby.
- Need to remove or demolish existing structures.
- Whether the tower site elevation is higher than the existing cooling system intake bay so cold water can flow by gravity to the intake bay.
- Whether there are underground interferences in the path of the new circulating water lines or at the location of the hot water sump and new circulating water pumps.
- Whether the tower site has overhead interferences, including transmissions lines.
- Whether the tower design may have to work around excluded areas where activities that may not be moved or blocked occur (e.g., hazardous materials storage, large vehicle turn-around areas, and security areas).
- The degree of construction work needed to convert the existing intake to handle the much lower intake flow volume needed for make-up water.
- How difficult it will be to tie-in the towers to the existing cooling system.
- Whether the site has unfavorable soil or geological conditions.
- Whether the site has contamination that might require remediation.
- Nuclear safety concerns.[12]
- Effects to manufacturing processes.
- Potential for increased water treatment and effects on facility's effluent.
- Land use or zoning conflicts.

Net construction downtimes for retrofitting to cooling towers are estimated to be approximately four weeks for non-nuclear plants and seven months for nuclear plants (68 FR 13526). These estimates assume that the construction tie-in would be scheduled to coincide with the plant's routinely scheduled maintenance (typically a four week outage), thereby reducing the total length of the downtime for tie-in. See Chapter 8 for a detailed discussion of how downtime is calculated and incorporated into the analysis of cost.

The operation of cooling towers also leads to an energy penalty; a parasitic penalty due to operating the cooling fans and a turbine efficiency penalty based on the incremental loss of performance due to a change in the pressure of the steam produced within the generating unit.

[12] While nuclear safety remains a paramount concern, it is less clear that retrofitting a cooling tower would actually have any impact on the safety of the facility. Documentation submitted to the Atomic Energy Commission from Palisades Plant (the lone nuclear facility to undergo a closed-cycle retrofit) indicates that "[t]he existing cooling water system […] has no safety related functions and the modified system will likewise have no safety related functions." See DCN 10-6888B.

As described in Chapter 10 of this TDD, non water-quality impacts may also result from the installation of cooling towers. These impacts may include noise, plume, and salt drift. See Chapter 10 for a discussion of these potential impacts. Cooling tower retrofits may also infringe upon biological resources such as wetlands or manatee habitat.

Dry cooling towers (and the accompanying equipment) will generally occupy the same or greater footprint as wet towers, potentially exacerbating any issues with available space. Additionally, existing facilities might need to upgrade or modify existing turbines, condensers, and/or cooling water conduit systems, which are tasks that are typically not required for wet tower retrofits. As with wet towers, retrofitting a dry cooling tower at an existing facility would require extensive shutdown periods during which the facility would lose both production and revenues, and decrease the thermal efficiency of an electric generating facility. As stated in the preamble to the 2004 Phase II rule,[13] EPA does not believe that dry cooling is a viable alternative for reducing impingement and entrainment at a national scale; dry cooling offers substantial reductions in impingement and entrainment (exceeding the performance of wet cooling in that regard) but with a significantly higher cost and penalty to performance.

Four Factors To Consider In A Closed-Cycle Retrofit

As described in the preamble to the proposed rule, EPA is not proposing to require closed-cycle cooling on a national scale; in part, this is due to the impact of four factors: local energy reliability, air emissions permits, land availability, and remaining useful life of the facility. These factors are discussed in detail in the preamble.

Local Energy Reliability: In its site visits, EPA identified several urban areas where the existing transmission system may not be able to transfer sufficient electricity during periods of extended downtime. This limitation to reliability occurs even when a surplus of electricity can be generated within the same NERC region. For example, EPA identified localized circumstances in Los Angeles and Chicago where an extended outage of one or more generating units could not be readily replaced by excess capacity in nearby areas. Currently available models such as IPM are not able to predict localized impacts and instead are limited to measures of reserve capacity in broader geographic regions. See the EBA for additional discussion about energy reliability.

Air Emissions Permits: Retrofitting to closed-cycle cooling results in an energy penalty, which in turn leads to increased air emissions. Fossil-fueled facilities may need to burn additional fuel (thereby emitting additional CO_2, SO_2, NO_X, and Hg) for two reasons: 1) to compensate for energy required to operate cooling towers, and 2) the slightly lower generating efficiency attributed to higher turbine back pressure. At new units, these impacts are much less, as the design of a new cooling system accounts for these issues. U.S. fleet efficiency will likely increase over the long term, resulting in lower base emissions on a per watt basis, and the turbine back pressure penalty will be further reduced resulting in lower incremental emissions. EPA is also aware that nuclear facilities would also need to compensate for energy required to operate cooling towers and for the turbine back pressure energy penalty. The impact of the increased emissions

[13] See 69 FR 41608.

varies based on the local circumstances. For example, EPA's analysis suggests that increased emissions of $PM_{2.5}$ may result in difficulty in obtaining air permits in those localities designated as non-attainment areas. For PM_{10}, see DCN 10-6954, which states that emissions would be approximately 60 tons per year if all drift is PM_{10}. This document also noted minor drift management issues onsite at facilities using salt water cooling towers and no negative consequences off-site. See Chapter 10 of the TDD for more information.

Land Availability: While EPA believes that the majority of facilities have adequate available land for placement of cooling towers, some facilities may have legitimate feasibility constraints due to small sites, existing equipment, buildings, transmission yards, or rail lines, challenging topography or other factors. Based on site visits, EPA has found several facilities have been able to engineer solutions when faced with limited available land. On the other hand, EPA found that some facilities with large sites that still could not feasibly install cooling towers due to, for example, protected wetlands. As described in Chapter 5, EPA attempted to numerically analyze land availability but lacks adequate data to better analyze how land constraints can be accommodated at existing facilities.

Remaining Useful Life of the Facility: As described in Section V of the preamble, many existing facilities have been operating for 30 to 50 years or longer. Making major structural and operational changes (such as retrofitting to closed-cycle cooling) may not be an appropriate response for a facility or unit that will not be operating in the near future. The remaining useful life of many of these units is uncertain, as this relationship is not based solely on plant age, because plant age alone does not discern those facilities that have completed an uprate, recently repowered, or completed other major facility modifications to individual units.

6.2.4 Examples of Cooling Towers

An estimated 374 existing facilities currently employ either a fully or partially recirculating cooling system using wet cooling towers. EPA has identified a number of power plants that have converted to closed-cycle recirculating wet cooling tower systems. Many of these facilities (including Palisades Nuclear Plant in Michigan, Jefferies Generating Station and Canadys Station in South Carolina, McDonough and Yates in Georgia) converted from once-through to closed-cycle wet cooling tower systems after significant periods of operation utilizing the once-through system. Another facility, Pittsburg Unit 7, converted from a recirculating spray-canal system to a closed-cycle wet cooling tower system. In this case, the conversion occurred after approximately four years of operation utilizing the original design. Detailed case studies of these retrofit efforts are found in Chapter 4 of the TDD for the 2002 proposed Phase II rule (DCN 4-0004) and in the site visit reports available in the docket for the proposed rule.

Additionally, Brayton Point Generating Station in Somerset MA is currently constructing two natural draft cooling towers as part of its retrofit from once-through cooling to closed-cycle cooling.[14]

As discussed in DCN 3-3029-R6 from the Phase I docket, the data from the industry survey indicates that newer facilities and units are trending towards the use of closed-cycle cooling.

6.3 Variable speed pumps/variable frequency drives

At their design maximum, a facility with variable speed pumps (VSPs) or variable frequency drives (VFDs) can withdraw the same volume of water as a conventional circulating water pump. However, unlike a conventional (i.e., single speed) circulating water pump, VSPs and VFDs allow a facility to reduce the volume of water being withdrawn for certain time periods. The pump speed can be adjusted to tailor water withdrawals to suit the cooling water needs for a specific time.[15] See DCN 10-6602 for more information.

A reduced flow volume will result in reduced O&M costs as a result of the reduction in pump energy requirements. Depending on site-specific conditions, this reduction may allow the facility to recover the initial capital investment sooner and produce savings thereafter. In fact, VSPs are often employed in industrial systems solely for their economic benefit. In the case of power plant intakes, the reduction in flow volume has the added benefit of reducing impingement and entrainment impacts.

VSPs can be used to reduce flow volume even during periods of peak power generation, but there are operational limitations and consequences associated with this flow reduction technology. These limitations include:

- Inherent limits of the technology that, based on system characteristics, may restrict pump operation to a specified flow range to prevent damage to the pump. The system hydraulic characteristics will also affect the amount of savings in pump energy cost;
- Limits in flow reduction associated with NPDES permit thermal discharge limits, since a decrease in flow will result in an increase in the temperature of the effluent;
- Economic consequences of reduced plant generation output resulting from reduced turbine efficiency associated with higher condenser temperatures.

[14] See http://www.epa.gov/ne/braytonpoint/index.html for details.
[15] Cooling systems are designed to enable the facility to meet its cooling needs at maximum operations under adverse environmental conditions (such as a warm source waterbody). The amount of heat the facility needs to reject is a known value; depending on several factors, the facility actually may not need to operate its pumps at full speed; there may be an intermediate flow rate that is sufficient to remove the heat being generated. Facilities with multiple pumps could also choose to operate fewer than normal pumps, perhaps reducing the value of VSPs.

The latter two limitations are more of a concern during periods when the source water is warmer, and will also tend to limit flow reduction during periods when the system is operating at peak capacity.

Retrofit Applications

A VSP retrofit involves replacing fixed speed intake pumps with variable speed pumps. At a minimum, this involves the installation of a variable frequency drive (VFD) and replacement of the pump motor, switches, and controller. In many cases, this may be all that is needed. A variable frequency drive is an electronic device that varies the pump motor speed by varying the electrical frequency of the AC power delivered to the pump motor. In some cases, the existing motor may not be designed to handle the added harmonic electric currents associated with this type of system. In such cases, the pump motor may need to be derated (the maximum power output and flow rate is reduced) or the motor will need to be replaced. Additionally, the pump itself may require replacement if the existing pump hydraulic characteristics place too many limitations on the amount of flow reduction that can be obtained. If multiple pumps are operated simultaneously and in parallel, it is best to retrofit all of the pumps.

The use of VFDs allows the flow through the pumps to be controlled over a range of flow volumes, thus allowing the flow volume to be tailored to the plant operating conditions. With proper control, the effect on turbine efficiency can be minimized and the effluent temperature can be maintained within the NPDES permit temperature limits. This allows the facility full flexibility to effect both small and moderate flow volume reductions when conditions allow.

During the winter months, use of flow reduction can actually result in an increase in turbine efficiency by eliminating subcooling in the condensers. Subcooling occurs when the steam condensate in the condenser is cooled excessively, resulting in the system's consumption of additional heat to bring the condensate back up to the boiling temperature when it is recycled back to the boilers. Excessive subcooling can also result in the formation of condensed water droplets within the last stage of the turbine, which can damage the turbine blades. Measures to control excessive subcooling include the flow reduction methods described above for fixed speed pumps, as well as piping configurations that can bypass a portion of the flow around the condensers and piping configurations that can recirculate condenser outflow back to the pump inlet. In the latter case, some flow reduction is already occurring but pumping energy requirements are not reduced. The control of subcooling, especially slight to moderate subcooling that might otherwise be tolerated, provides another economic benefit for VSP retrofits through increased plant power output.

<u>Millstone Nuclear Plant</u>

The Millstone Nuclear Plant on Long Island Sound in Connecticut is installing VFDs on its circulating pumps. The goal is to reduce impingement and entrainment of winter flounder which are present in greatest abundance in April and May (their spawning season). The plant has agreed to reduce their 2.2 BGD flow by 40 percent during this period. Flow reduction will be required from April 4 to June 5 or until the source water reaches 52°F (whichever happens first). To facilitate this, the facility's NPDES permit[16] allows for increase in discharge ΔT for this period (see Exhibit 6-6 below) while retaining the limit of 4°F increase outside mixing zone.

This example is noteworthy for several reasons: first, the facility is a nuclear plant and second, it is a baseload facility. As discussed in the preamble, nuclear facilities may have additional safety considerations when assessing technologies to minimize impingement and entrainment, but VSPs appear to not trigger any concern. Second, baseload plants are arguably the least able to reduce flow using VFD technology, as they are typically operating continuously and have relatively constant demands for heat rejection. However, Millstone appears to be able to capitalize on the cooler source water temperatures in these months and balance the needs of heat rejection and impingement and entrainment.

Exhibit 6-7 shows the revisions in permit's ΔT limits. Calculated reductions were supplemented with data from PCS (the reported actual monthly max ΔT during Apr-May period was in the low-mid 20s). Using a ΔT value of 24 compared to 41 results in a 41 percent reduction, assuming the facility is able to tailor their intake flow to operate close to the seasonal temperature limit.

Exhibit 6-7. Flow Reduction at Millstone

Millstone Nuclear	Normal ΔT Limit	Seasonal VFD ΔT Limit	Calculated Reduction in Intake Flow
	Deg F	Deg F	
Unit 2 Condenser	32	46	30%
Unit 3 Condenser	28	38	26%
Combined Discharge	32	41	22%
Typical Seasonal Max from PCS	24	41	41%

Operational Limitations

There are technical limitations to the amount of volume reduction that can be achieved with VSPs. For any pump, as the speed is reduced, there is a point reached where the pump's output head is equal to the system's static head, resulting in zero flow. Continuous operation at such a condition must be avoided because the impeller will continue to spin and the water will recirculate within the pump casing, resulting in damage to the pump. The flow volume response to varying speed is unique for every combination of pump and system hydraulics, and thus the minimum safe speed must be calculated for each application to avoid operation at or even near the shutoff head. System controls are set such that the minimum pump speed will be well above that which produces zero flow conditions. Two power plants in California (Pittsburg and Contra

[16] See http://www.ct.gov/dep/lib/dep/public_notice_attachments/draft_permits/071210_millstone_revised_fact_sheet.pdf.

Cost) have installed VSPs and documentation indicated that as much as a 50 percent reduction in flow was attainable. However, this level of flow reduction is usually high and typical flow reduction rates are from 8-15 percent, with some variability depending on whether the facility is baseload or load following.

One important system characteristic that affects the performance of VSPs is whether the total pumping head is predominantly the result of losses from friction or to static head. Where the pumping head is predominantly from friction losses, the flow reduction capability of VSPs is greater and overall system efficiency at reduced flows will be greater. An example of a system where friction losses are a large component of the pumping head would be a system that uses an inverted siphon configuration. Inverted siphon configurations are often used in once-through systems where the condenser elevation is close to the water surface, because they are well worth the savings in pump energy requirements associated with the siphon configuration. Such systems require vacuum pumps to remove the gases that collect in the high points. To prevent water vapor from forming under the vacuum conditions that form within the siphon, the height of the inverted siphon is limited. If the condenser elevation is above the maximum siphon height, then the siphon height is shortened by exposing the downstream end to the air at an elevation above that of the source water in a structure called a seal pit. Facilities where the condensers are located well above the water surface will have higher static components of the pumping head even when inverted siphons are used. Thus, the condenser elevation and piping configuration will affect the performance of VSPs.

In systems where the pumping head is predominantly static head, as the pump speed is reduced a point is soon reached where small changes in speed can result in large changes in flow rate, especially as the pumping head approaches the system static head as described above. Thus, the available range of flow reduction is much lower than in systems where the pumping head is mostly friction losses. Also, in systems where the pumping head is predominantly static head, the pump efficiency drops substantially with reduced speed. Such systems will experience much less power usage savings. Thus, use of VSPs in such systems is less advantageous. In these high static head systems, the pump and system hydraulic characteristics must be carefully evaluated before deciding whether the available benefits outweigh the costs.

When the turbine system is operating at a given generation rate (i.e., a constant steam load), a reduction of the cooling water flow volume will result in a proportional increase in the condenser temperatures. This will result in an increase in the difference in cooling water temperature between the condenser inlet and the condenser outlet (ΔT). Many plants have NPDES permit conditions that set a maximum limit for the ΔT value. This effectively places a practical limit on the amount of flow reduction that can be achieved. During warmer months, the increase in condenser temperature will also result in a higher turbine exhaust pressure, resulting in a reduction in turbine efficiency. Thus, there is a competing economic incentive to maintain higher flow levels.

Many plants have NPDES permit conditions that set a maximum effluent temperature, which may put additional limitations on the availability of flow reduction through variable speed pumping, especially during summer months, regardless of the economic considerations. In fact, under extreme summer conditions, some plants may be required to maintain the cooling water flow at full capacity while having to reduce power output (derate) in order to meet temperature limits.

VSPs can reduce the facility's intake flow, which is one of the most effective ways to reduce impingement and entrainment. However, as described above, the amount of flow reduction that can be achieved has both operational and seasonal limitations. In general, opportunities for flow reduction are greater during cooler months and thus the benefits of I&E reductions may be enhanced or reduced depending on the timing of the seasonal variations in the presence and behavior of the various life stages of the affected aquatic organisms.

Applicability

Flow reduction through the use of VSPs alone may not be sufficient to result in sufficient I&E reductions. Because of the economic benefit associated with reduced pumping energy requirements, VSPs may be useful even when the other technologies are fully capable of meeting the I&E requirements alone and when the presence of sensitive organisms coincides with the period when the source water is warmest.

The capital costs of VSP retrofit will be dependent on which components of the pumps need to be replaced; it should be assumed, at a minimum, that a retrofit will include replacement of the pump motors. Given the savings in pump energy costs associated with VSPs, the net operating costs should be negative in most applications (i.e., savings in pump energy costs will exceed any maintenance costs). Actual savings will be highly variable depending on the system hydraulic conditions, the plant operating schedule, and the degree of flow reduction attained. If conditions are favorable, the net operating savings will offset capital costs (i.e., the technology will pay for itself). However, if flow volume reduction is aggressively sought, then pump energy savings will be offset by reduced plant output associated with a reduction in turbine efficiency.

VSPs will be most effective when:

- Facility capacity utilization rates are not very high.
- Cooling pump head is predominantly from friction losses and not static head.
- They are combined with other I&E reduction technologies.

Technologies that could benefit from being paired with VSPs may include:

- Traveling screens
- Fish barrier net
- Velocity cap

Since reduced flow volume will result in a reduction in the approach and through-screen velocities, VSPs will likely result in improved performance of velocity caps and traveling screens, particularly those with high approach velocities.

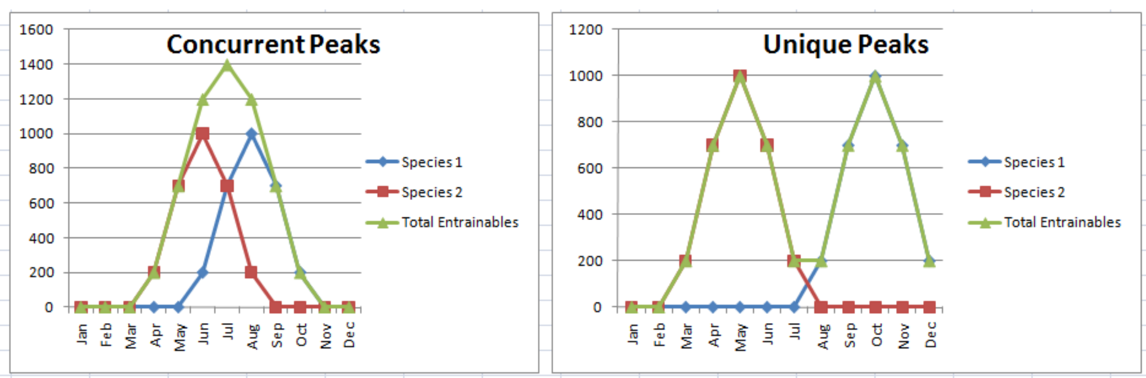
6.4 Seasonal Flow Reductions

Seasonal flow reduction refers to the reduction or elimination of a quantity of water being withdrawn during certain biologically important time periods. Most facilities that practice seasonal flow reductions do so in order to reduce entrainment because entrainment often peaks during specific times of the year (i.e., during spawning season). Typically, this means that a facility produces less energy or no energy for some portion of the year thereby reducing or eliminating the volume of cooling water it requires. This may be accomplished through a variable speed drive or pump or shutting down some portion or all of the pumping system (and unit).

See DCN 10-6702 for specific examples of spawning periods at existing facilities. In these examples, there are often organisms that have some degree of spawning at all times of the year but peak spawning periods can be identified. If only species of concern are examined, the spawning period analysis may appear very different than a broader analysis of all species present.

Additionally, the specific timing and abundance of organisms present may affect how seasonal flow reductions are achieved. As an example, Exhibit 6-8 below presents two possible scenarios that might be addressed differently under a seasonal flow reduction approach.

Exhibit 6-8. Examples of Seasonal Flow Reductions



Because of the difficulty in projecting, on a national scale, which facilities might employ seasonal flow reductions (due to the species present, seasonal utilization rates, percentage of flow reduced and other factors), EPA did not include seasonal flow reductions in any formal analysis of compliance costs.

6.5 Water Reuse

EPA encourages any reduction in water withdrawals or water usage in general. Throughout the 316(b) rulemaking process, EPA has included provisions for water reuse whereby a facility that uses water withdrawn for another purpose (e.g., contact cooling or process water) as cooling water, then said volume would not be considered in determining whether a facility is subject to the regulation.[17]

For power plants, water reuse is typically not an available option, as there is very little water that is used for purposes other than non-contact cooling; the "credit" would be extremely small.

Manufacturers, on the other hand, may realize substantial benefits from water reuse. As discussed above, a facility may avoid national 316(b) requirements if it reuses a significant portion of its cooling water and does not meet the 25 percent threshold. Additionally, the proposed rule provides that entrainment requirements at new units at an existing facility do not apply to cooling water that is reused for another purpose. See the preamble for the proposed rule for more information on how EPA considered water reuse in the regulatory framework.[18]

6.6 Alternate Cooling Water Sources

Cooling water need not be withdrawn from a surface waterbody. Groundwater, grey water (i.e., POTW effluent) or other sources of water may be used for once-through cooling or as make-up water for a closed-cycle system. Unfortunately, many facilities have cooling needs that substantially outpace the volume of water available to them from alternate sources, especially for once-through cooling systems. In the *California's Coastal Power Plants: Alternate Cooling System Analysis*, OPC analyzed alternate sources as cooling tower makeup water but concluded that even for power plants located in densely populated areas of southern California (where infrastructure to facilitate alternate sources such as grey water), alternate sources of cooling water were not a viable option. Similarly, EPA did not consider any regulatory analyses or alternatives that relied on alternative cooling water sources.

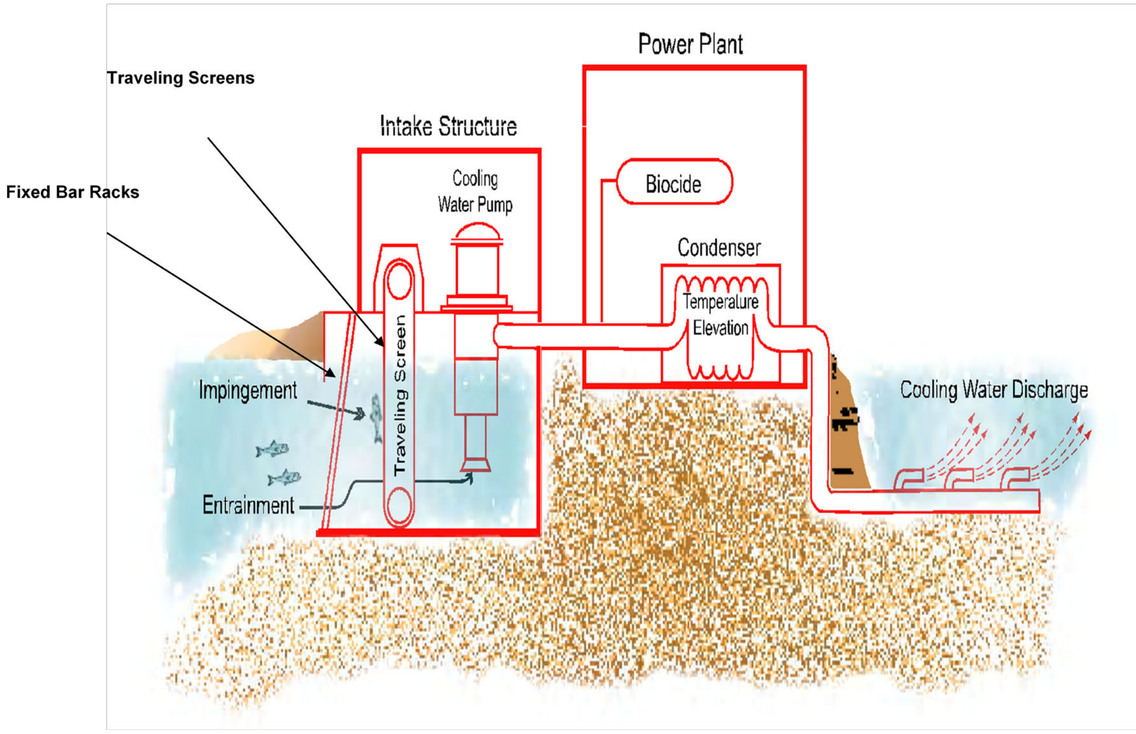
6.7 Screening Technologies

Screening technologies have been used on cooling water intake structures for more than 75 years to prevent debris and aquatic organisms from entering the condensers. These technologies include both traveling screens and passive screens. Over 93 percent of power plants and 73 percent of manufacturers use some sort of screening technology (see Chapter 4 of this TDD).

Exhibit 6-9 provides a generic diagram of a cooling water intake structure that employs traveling screens, with the power plant operations and cooling water discharge also shown.

[17] See, e.g., 40 CFR 125.83 (definition of cooling water).
[18] Also see Chapter 8 of the TDD for information on how EPA considered the relationship between non-contact cooling water, contact cooling water, and process water flows in developing compliance costs.

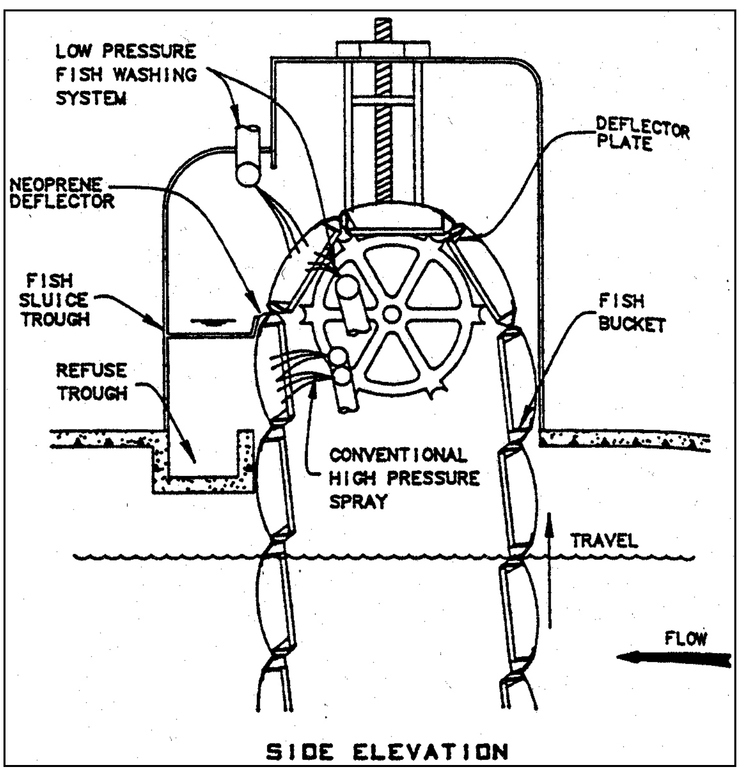
Exhibit 6-9. Generic CWIS With Traveling Screens



Traveling screens (see Exhibits 6-10 and 6-11) are used at most cooling water intake structures. These screens were originally designed for debris control, but also serve to prevent some fish and shellfish from entering the cooling system. Traveling screens have been installed in numerous environmental conditions: salt water, brackish water, fresh water, and icy water. There are many types of traveling screens (e.g., through-flow, dual-flow, center-flow). The most common design in the US is the through-flow system. The screens are typically installed behind bar racks (trash racks) but in front of the water circulation pumps. The screens rotate up and out of the water where debris (including impinged organisms) is removed from the screen surface by a high pressure spray wash. Screenwash cycles are triggered manually, on a timer, or by a certain level of head loss across the screen (indicating clogging). By design, this technology works by collecting or "impinging" fish and shellfish on the screen.

Exhibit 6-10. Traveling screen at Eddystone Generating Station, Eddystone, PA

Exhibit 6-11. Traveling screen diagram



Passive screens are non-moving fixed screens that use physical exclusion to minimize debris and fish from entering the condensers and hydrodynamics to prevent the buildup of debris and screen loading leading to head loss. Passive screens include wedgewire screens, perforated pipes, and porous dikes/leaky dam systems. Wedgewire screens are the most common type of passive screen and the most effective passive screen at minimizing impingement and entrainment (see Exhibit 6-12). Wedgewire screens are discussed in more detail later in this chapter.

Exhibit 6-12. Cylindrical wedgewire screen

Traveling screens and passive screens are further defined by screen mesh size as coarse mesh or fine mesh. Coarse mesh screens have mesh sizes of 3/8" (about 9.5 mm) and fine mesh screens have mesh sizes typically ranging from about 0.5 mm to 3 mm depending on the organisms to be protected. Coarse mesh screens are generally not protective of smaller organisms (such as eggs and larvae) that may become entrained by passing through the screen openings and into the cooling system. Coarse mesh systems may also cause mortality of impinged fish due to impact, stress, descaling, and suffocation against the screen. Fine mesh screens may prevent entrainment, but may also lead to increased mortality of impinged organisms (specifically eggs and larvae that would otherwise have been entrained).

The sections below discuss each screen type in greater detail.

6.8 Conventional Traveling Screens

Conventional traveling screens, also called coarse mesh traveling screens, are a common component of virtually all cooling water intake structures and provide essential debris and fouling control for pumps and condensers; over 83 percent of all existing facilities already employ this type of screen.[19] The screens are mounted on fixed-loop chains or belts that rotate through the water column and remove debris from the intake stream, preventing the entrainment of debris through the intake system where they can damage sensitive pumps and condensers. Objects collected on the screen are typically removed with a high-pressure spray (> 60 pounds per square inch [psi]) and deposited in a dumpster or debris return trough for disposal. Screens are rotated and washed periodically based on a set time interval or when the pressure differential between the upstream and downstream faces exceeds a set value. Intermittent rotation minimizes operational wear and tear and keeps maintenance costs relatively low. In the U.S., facilities employ multiple traveling screen types, including dual-, center-, and through-flow designs. The through-flow type—the most common at U.S. facilities—removes debris and screenings from the water on the upstream (ascending) side. Dual and center-flow designs screen water through the ascending and descending screen faces, which prevents debris carryover to the downstream side.

Conventional traveling screens were not designed with the intention of protecting fish and aquatic organisms that become entrapped against them. Marine life may become impinged against the screens from high intake velocities that prevent their escape. Insufficiently strong species or life stages may suffocate after prolonged contact with the screens. Exposure to high pressure sprays and other screening debris may cause significant injuries that result in latent mortality, or increase the susceptibility to predation or reimpingement. Organisms that do survive initial impingement and removal are not typically provided with a specifically-designed mechanism to return them to the water body and are handled in the same fashion as other screening debris. These screens do not address organism entrainment, as eggs and larvae are typically swept through the screen and into the condensers.

6.8.1 Technology Performance

Conventional screens are not used to mitigate the impacts of impingement and/or entrainment.

6.8.2 Facility Examples

Conventional screens are used at a large number of existing facilities.

6.9 Modified Coarse Mesh Traveling Screens

Following the 1972 Clean Water Act's requirement to use technology-based solutions to minimize adverse environmental impacts, some conventional coarse mesh traveling screen systems were modified to reduce impingement mortality by removing fish trapped

[19] The percentage is based on responses to the industry questionnaire. Upon further review of facilities that did not identify a traveling screen, EPA found that most of these facilities did in fact have traveling screens. As a result, EPA assumes that virtually all existing facilities have a traveling screen at some point in their cooling water intake system. The screen may be located in the forebay instead of at the cooling water intake structure, but some form of screening is almost always necessary.

against the screen and returning them to the receiving water with as few injuries as possible. The modified screens, also known as "Ristroph" screens, feature capture and release modifications that include a fish collection bucket or trough, a low pressure spray, and a fish return system. In the simplest sense, these screens are fitted with troughs (also referred to as buckets) containing water that catch the organisms as they are sprayed off of the screen. The return component consists of a gentle mechanism to remove impinged fish from the collection buckets, such as a low-pressure spray. The buckets empty into a collection trough that returns fish to a suitable area in the source waterbody. These modified "Ristroph" screens have shown significant improvements in reducing impingement mortality compared with unmodified screen systems. Of the 766 existing facility intakes that were reported in the detailed questionnaires, 9 intakes specifically reported "Ristroph" traveling screens, 16 additional intakes may qualify as having "Ristroph-type" traveling screens, 50 intakes reported having "Fish Buckets, Baskets, or Trays," and 130 intakes reported an inlet or through-screen screen velocity of $\leq$ 0.5 fps.

The first Ristroph screens, named for the lead engineer who developed the initial prototype, were installed at Dominion Power's Surry Station in Virginia in 1977. The existing screen panels were fitted with water-retaining collection buckets at the base of each panel that lifted impinged fish out of the main stream flow as the screens rotated. At the top of the screen assembly, buckets emptied into a collection trough that returned fish to a suitable area in the source water body. The initial survival rate for the modified screen at Surry Station, averaged across all species, was 93.3 percent (EPRI 1999). Bay anchovy had the lowest initial survival at 83 percent (White and Brehmer 1977, Pagano and Smith 1977). Notably, these survival rates did not account for latent mortality that may have resulted from injuries sustained during the collection and removal process.

Data from early applications of the "Ristroph" screen design showed that while initial survival rates might be high at some installations, latent mortality rates were higher than anticipated, indicating significant injuries could be sustained during the impingement and return process that were not immediately fatal. Many of these flaws were identified in an analysis of a modified screen design proposed for the Indian Point facility in New York by Fletcher (1990; see DCN 5-4387). This analysis identified points in the collection/removal process where latent injuries might be sustained, including poor debris removal, which became entangled with impinged fish and prevented their safe return; rough or corroded screen basket materials that increased descaling; and fish reimpingement occurring when fish escaped the ascending buckets by jumping over the outer bucket lip just prior to the bucket breaking the surface.

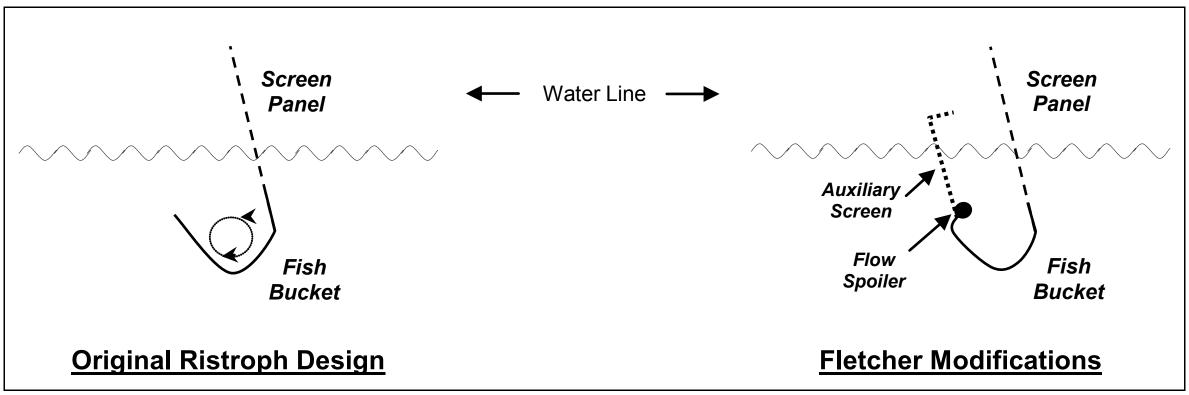
Most significantly, Fletcher identified a principal cause for many of the injuries sustained by impinged fish. Screen panels retrofitted with water-retaining buckets induced a secondary flow pattern in the bucket while it remained below the water line, creating turbulent conditions in the bucket that repeatedly buffeted any fish against the screen and bucket materials. Fletcher observed that fish caught in this flow pattern suffered far more significant injuries than those which only came in contact with the screen mesh.

Several critical modifications were proposed following this analysis, many of which have been adopted by other facilities, including:

- Redesign of collection buckets to address hydraulic buffeting with a new shape and inclusion of a flow spoiler on the outer bucket edge. These modifications minimize turbulence within the bucket and prevent significant injuries during capture and retention.
- Addition of a fish guard rail/barrier to prevent fish from escaping the collection bucket and increasing their total impingement time. The fish guard rails extend above the water surface before the main bucket as the screens are rotated.
- Reordered fish and debris removal. At Indian Point, filamentous debris collecting on the screen panels was originally removed after impinged fish. This debris blocked the screen panels, however, and prevented the fish removal spray system from functioning properly. The modified design included a high pressure spray to remove debris on the ascending side prior to removing impinged fish.
- Replaced screen panel materials with smooth woven mesh. Significant descaling was observed with more abrasive screen designs such as crimped or welded wire.

A schematic comparison of each basket design type is shown in Exhibit 6-13.

Exhibit 6-13. Ristroph and Fletcher Basket Designs



The Fletcher study also evaluated impingement durations up to 30 minutes. Impingement durations of 10 minutes or less did not significantly affect survival, with mortality rates increasing with longer impingement times. Likewise, sufficient water retention in the buckets was shown to be essential. Exposure to the air and temperature extremes, even for a short duration, could negatively impact fish survival. These findings support the general assumption that modified Ristroph screens must be continually rotated instead of the periodic rotation schedule common with conventional screen systems.

6.9.1 Screen Design Elements

The collection portion of a modified Ristroph system comprises all CWIS elements geared towards fish protection up to the point where fish are removed from the screens/buckets. The collection system's key function is to capture entrapped fish that cannot escape the intake screens and remove them from the intake flow for safe return to the source water body. This must be accomplished by sustaining all captured fish with sufficient water and minimizing potential injuries from screen interactions and turbulence. While the cooling water intake structure location and orientation may play a significant role in determining how many fish and shellfish are susceptible to impingement before coming in contact with the screens, this subsection focuses on the screens and fish return systems. EPA notes that a comprehensive design approach that carefully considers the cooling water intake location and orientation prior to installing a modified traveling screen system may yield significant benefits. At existing facilities, however, many of these modifications are more problematic due to space constraints and interference with existing systems, and may not be practical options given their cost and complexity.

Screen Type/Design

The screen itself is the first point at which any fish will come in contact with a physical element. When a conventional traveling screen is modified to include Ristroph and Fletcher modifications, many of the system's existing elements may need to be upgraded to incorporate newer, more fish-friendly materials, or with more robust mechanical components that are better suited to the new operating conditions. New components like fish buckets or rails also require careful consideration to maximize the desired level of protection. All of these factors must be evaluated against the specific demands at a particular site such as water quality, intake velocity, and species composition and abundance. In some cases, it may be more economical, and ultimately more efficient, to replace the entire screen assembly rather than retrofit existing components. A comprehensive retrofit may mitigate other effects and better enable all components to work more efficiently with one another.[20]

Screen Mesh Material

The primary design focus for existing conventional traveling screen systems is the removal of smaller debris (i.e., debris not screened by a trash rack) that may clog or damage sensitive intake equipment like pumps and condensers. The screen panel material is selected to serve this function while remaining durable and functional with the lowest possible maintenance costs. Screen materials must be able to resist corrosion and degradation while being alternately immersed in water and exposed to air. They must also withstand potentially high debris loads that might compromise weaker materials and damage the intake system. Stainless steel is among the most common screen material used for traveling screen, although copper alloys are also used where screen fouling from colonial organisms is a concern. Likewise, advances in engineered polymer coatings have proven effective in resisting corrosion and degradation.

[20] EPA's cost methodology for the proposed Existing Facilities rule included full replacement costs for all screen components.

For a modified traveling screen system, materials and configurations that are smooth by design and can maintain a near-design condition will assist in minimizing any contact injuries sustained by impinged fish. Smoother configurations and materials, such as woven wire mesh (as opposed to punched or welded mesh) and SmoothTex flat wire, will also aid fish removal and limit descaling during transfer to the return system.

Through-screen Area and Mesh Size

As noted above, many existing conventional screening systems were initially designed to remove debris from the intake stream to prevent damage to other equipment. The optimal mesh size prevents entrainment of any debris large enough to clog the condenser tubes while maximizing the through-screen area, and allows the facility to optimize its intake velocity-to-screen area ratio and install a properly sized system. Because many condenser tubes used in power plants are 3/4 or 7/8 inches in diameter, a 3/8-inch mesh size (i.e., coarse mesh) is found at a majority of facilities employing traveling screens.

Screen intake velocity may be categorized into two types: approach and through-screen. The approach velocity is generally defined as the localized velocity component perpendicular to the screen face measured at a distance from the screen (often three inches). Through-screen velocity, as the term implies, is the velocity of water passing through the screen mesh openings. This is difficult to measure in the field, but a reasonable through-screen estimate can be calculated by dividing the intake structure's flow rate by the total open area submerged in the water column. Changes to either the water depth (tidal cycles or seasonal flooding) or screen open area (from fouling or clogging) affects both velocity values if the same intake flow is maintained. Likewise, sedimentation in front of the screens or intake structure constricts the flow channel and increases the approach velocity.

The mesh opening and the total screen size are key factors in determining the CWIS's intake velocity, which, in turn, influences the impingement mortality rate. This relationship is well-established, with higher intake velocities generally corresponding to increased impingement rates and higher mortalities due to injury. Several different swim speed studies have shown that velocities at or below 0.5 feet per second (fps) would be expected to cause *de minimis* impingement. For the Phase I rule, EPA compiled data from three studies on fish swim speeds and found that a velocity of 0.5 fps would protect 96 percent of fish tested.[21] Maintaining an intake velocity as low as possible is critical to reducing overall impingement probability. For some species, a velocity less than 0.5 fps is necessary, e.g., the State of Alaska requires a velocity limit of 0.1 fps to protect salmonids.[22] EPA has long recognized the benefits of maintaining a low through-screen velocity (of 0.5 fps or less) by including it as an impingement mortality compliance option in the previous 316(b) rulemakings.

Retrofitting existing traveling screens to operate with a fish collection system may decrease the total through-screen area by blocking a portion of the screen face with fish bucket or rail. Any impact on intake velocities, however, will depend on the original

[21] 66 FR 65274
[22] See DCN 1-5015-PR in the Phase I docket.

screen design and the modifications made to incorporate new equipment. Advances in screen design, materials, and fabrication methods enable newer screen systems that have been designed with the fish protection measures to achieve comparable, and sometimes greater, through-screen areas than older equipment that is retrofitted. In some cases, it may be more advantageous to replace the entire screen assembly rather than retrofit the existing traveling screen (Gathright 2008).

Collection Buckets

One of the more critical elements, collection buckets incorporate several design elements to maximize safe capture of impinged fish. Buckets should extend across the screen panel's full length to prevent gaps where fish may fall through and be deep enough to hold sufficient water for the expected number and size of species impinged. Depending on screen's size and rotation interval, captured fish may held in these buckets for several minutes, often with other fish. Close proximity with other fish in a confined space, particularly with those of another species, may create stress and behaviors that result in additional injury. The selected bucket size and depth should reflect the target species and allow for sufficient space and water coverage to sustain them during transfer to the return system.

The design of pre-Fletcher collection buckets were found to cause significant turbulence within the buckets, leading to high mortality rates as fish were buffeted against the screen elements. The modifications described by Fletcher to minimize flow-induced turbulence in the collection bucket have become common practice for this system type. The bucket's shape was redesigned to include an additional lip or flow spoiler attached to the bucket's leading edge. Further, modifications to prevent fish from escaping the rising bucket as it nears the surface may also be necessary. A rail or guard that extends above the water surface before the rest of the bucket keeps capture fish in the bucket and prevents their re-impingement (Exhibit 6-12).

6.9.2 Removal and Return System Design Elements

The removal and return portion of the modified system comprises all elements that aid in the removal of fish from the screens and buckets and returns them to a safe location in the source water body.

Debris and Fish Removal

Traveling screen systems without specific measures to reduce impacts to aquatic organisms will collect impinged fish and debris without making a distinction between the two. One of the major advances associated with the Ristroph design is the inclusion of a separate fish removal system and return trough that sought to segregate aquatic species from other debris. Unavoidably, some debris will end up with fish return trough and, vice versa; the key is designing the system to separate the two as much as possible. Separate spray removal systems—a low pressure spray for removing fish and a high pressure spray for debris—are typically included as part of a two-stage removal process that sorts most fish and debris to their own dedicated troughs.

Using a low pressure spray (less than 20 pounds per square inch) is based on the assumption that fish will not become attached or entangled with the screen panels and thus require only a "gentle removal" from the screens and buckets. Removal in this manner is also aided by smooth materials and structural components that eliminate protrusions, sharp angles and rough surfaces that prevent fish release. Depending on the spray head's position relative to the screen panel, it may be advantageous to remove debris before fish. Heavy debris loads might clog screen panels and block the low-pressure spray from functioning properly if the spray head is located behind the screen, as described in the Indian Point analysis (Fletcher 1990). In this instance, a high pressure spray (60 to 80 psi) placed ahead of the low pressure spray forcibly removes debris that has become attached to the screen panels and may increase fish removal efficiency. When low pressure spray heads are placed lateral to the screen instead of behind, it may be more effective to remove debris after any impinged fish. As noted above, deciding the order of low and high pressure spray must be carefully considered to optimize fish protection.

Fish Return

Mortality-inducing injuries are more likely to occur during the collection and removal portion of a modified traveling screen system. The return system, however, plays an important role in the overall effectiveness and has many critical design elements that must be considered to ensure safe return of healthy fish. Most criteria are universally applicable to any modified traveling screen system, and include:

- *Construction materials.* Structural components should be constructed using materials that minimize rough surfaces and protrusions that may cause abrasions, contusions, descaling, or more serious physical injury during the return process. Fiberglass-reinforced plastic, PVC, and stainless steel share this characteristic while also being resistant to biofouling. Joints between pipe sections should also be as smooth as possible.
- *Size and capacity.* As with the collection buckets themselves, the return trough should be able to accommodate the largest species in the maximum estimated number without overcrowding.
- *Transport velocity.* The water velocity in the return trough must be strong enough to overcome the swimming capacity of the strongest species and ensure their return to the water. A gravity return system will require a sufficient slope and water volume to induce the necessary flushing action. Pump-aided returns can adjust the return pressure accordingly.
- *Flow disruptions.* Where possible, the return should avoid sharp angles and short bend radius turns to reduce flow disruption and redirection. At all points, care should be taken to ensure a smooth, consistent return flow free from hydraulic jumps and flow separation areas.
- *Exposure.* Fish confined in a return trough have limited avenues of escape and, depending on the length of the return, may have long transit times back to the source water body. Because an open trough may unnecessarily expose these fish to predation from birds or other animals, the preference in most cases is to enclose

the system entirely until fish are returned to the water. This has the added benefit of reducing exposure to air temperature extremes. In cold weather climates, even brief exposure to sub-freezing temperatures can increase mortality.

- *Flushing cycle.* Adequate flow must be maintained in the trough to clear all transported fish from the return trough and drain completely following the cycle's completion to prevent backflow and biofouling/deoxygenation. A consistent flow may also be maintained in lieu of draining the trough.[23]
- *Return Location*. The final return point in the water body must be located outside of the intake's radius of influence to prevent reimpingement. The final transition to the water body should be smooth and free of any significant hydraulic jump. Water quality and temperature should be comparable to conditions at the intake to prevent any contact shock upon return. Preferably, organism re returned to the water quickly (i.e., to a nearby location) as longer exposure to the return system may cause descaling or other injuries. An ideal location will also avoid areas where predators congregate or attract increased predation.

6.9.3 Operation and Maintenance

Routine maintenance and operating protocols enacted for each modified traveling screen installation also play a key role in determining the system's overall effectiveness. While some parameters are widely applicable (e.g., rotation interval) others are tailored to meet the specific needs at a particular location and may vary significantly from one facility to another. These parameters include:

- *Rotation interval.* Evaluations at many different facilities over the last 30 years have generally shown that impingement mortality rates are lowest when traveling screens are rotated continuously at a fixed speed instead of the intermittent rotation schedule more common with conventional traveling screens. Continuous rotation ensures that any impinged fish will be caught on the screens for a minimum time period, but in some cases may not be necessary, at least for all seasons. Periodic full rotation cycles may be sufficient (i.e., some number of complete rotations per hour) when impingement is dramatically lower or non-existent during certain times of the year (e.g., seasonal migrations may limit the critical time period to a few weeks or months of the year). Additionally, new designs use composite materials to frame the traveling screens which weigh less and reduce wear on chains and drives.
- *Rotation speed.* The longer a fish is impinged against a screen, the higher its probability for suffering significant injury. Continuously rotated screens should travel fast enough to minimize the impingement durations but be slow enough to prevent higher maintenance costs associated with a faster screen rotation. The

[23] Facilities usually withdraw screenwash water from within the intake structure (i.e., after it has passed through the intake screens) or from a separate pump in the area of the intake structure. In either case, EPA envisions that any increase in flow to accommodate improved flushing of the return system would be small compared to the cooling water flow but nonetheless should generally not be included in calculating a facility's cooling water withdrawals (for calculating DIF or the percent of water withdrawn for cooling purposes).

rotation speed should also minimize the amount of time the fish are out of the water.

- *Preventative maintenance.* Modified screens that are rotated continuously will incur higher operating and maintenance costs than a conventional traveling screen cycled intermittently. Mechanical equipment may require more robust components to accommodate the increased rotation frequency and higher rotation speeds necessary to minimize the impingement duration. Likewise, the screen panels may require more intensive maintenance that minimizes corrosion and biofouling, which may increase mortality rates by creating a rougher or more unforgiving contact surface.

Retrofit/Downtime issues

Modified traveling screens with fish handling systems are among the oldest technologies developed specifically to address impingement and these screens have been widely deployed and studied throughout the United States. Because so many existing facilities already use conventional traveling screens, modified traveling screens are broadly applicable and may not require significant changes to the CWIS to achieve high levels of performance. A successful installation is generally independent of factors such as waterbody type, climate zone, age, fuel type or intake flow. In other words, a facility that has previously used a conventional traveling screen (nearly all facilities, operating under a wide variety of conditions) should also be able to employ a modified traveling screen.

Compared with other impingement design and construction technologies used as retrofit options, modified traveling screens are relatively easy to install and operate. Changes to the screens themselves are relatively straightforward and, in all but the most unique instances, do not require substantial modification or expansion of the screen houses and can be completed during normal maintenance outages without affecting the facility's generating schedule. Likewise, because this technology does not alter the cooling water flow *per se,* the facility's generating output is unaffected; no energy penalty is incurred save for the small increase in electrical usage due to continual or more frequent screen rotation.

6.9.4 Technology Performance

Conventional traveling screens that have been modified to include a fish collection and return system based on Ristroph and Fletcher designs have an extensive record of performance at numerous facilities. Data shows impingement survival values greater than 90 percent for many species. However, the actual performance of conventional traveling screens is typically less than 90 percent when holding times are considered; in most cases, the longer an organism is held, the less likely it is to survive. Additionally, larval impingement on fine mesh screens must also be addressed when reviewing technology performance. See Chapter 11 of the TDD and the preamble to the proposed rule for more information about how EPA assessed these data.

EPA also found that in many cases, only a few species comprise over 90 percent of the impinged organisms. For example, at the Arthur Kill Station, Atlantic herring, blueback herring and bay anchovy composed over 90 percent of the impinged species during the course of the study as described below. In addition, some of the impinged species may not be typically considered "species of concern," i.e., highly valued commercial or recreational species or listed species. Gizzard shad and bay anchovy are commonly impinged organisms reflected in study data, but may not be considered as species of concern.

6.9.5 Facility Examples

Salem Generating Station

Salem Generating Station, on the Delaware Bay estuary in New Jersey, converted 6 of its 12 conventional traveling screen assemblies to a modified design that incorporated improved fish buckets constructed of a lighter composite material (which improved screen rotation efficiency), smooth-woven mesh material, an improved spray wash system (both low and high pressure), and flap seals to improve the delivery of impinged fish from the fish buckets to the fish return trough (EPRI 2007). The initial study period consisted of 19 separate collection events during mid-summer 1996. The configuration of the facility at the time of the study (half of the screens had been modified) allowed for a direct comparison of the effectiveness of the modified and unmodified screens on impingement mortality rates. The limited sampling timeframe enabled the analysis of only the species present in numbers sufficient to support any statistical conclusions. 1,082 juvenile weakfish were collected from the unmodified screens while 1,559 were collected from the modified structure. Analysts held each sample group separately for 48 hours to assess overall mortality due to impingement on the screens. Results showed that use of the modified screens had increased overall survival by as much as 20 percent over the use of the unmodified screens. Approximately 58 percent of the weakfish impinged on the unmodified screens survived, whereas the new screens had a survival rate approaching 80 percent. Both rates were based on 48-hour survival and not adjusted for the mortality of control samples.

Water temperature and fish length are two independent factors cited in the study as affecting overall survival. Researchers noted that survival rates decreased somewhat as the water temperature increased, possibly as a result of lower levels of dissolved oxygen. Survival rates decreased to a low of 56 percent for the modified screens when the water temperature reached its maximum of 80°F. At the same temperature, the survival rate on the unmodified screens were 35 percent. Differences in survival rates were also attributable to the size of the fish impinged. In general, small fish (< 50 mm) fared better on both the modified and unmodified screens than large fish (> 50 mm). The survival rates of the two size categories did not differ significantly for the modified screens (85 percent survival for small, 82 percent for large), although a more pronounced difference was evident on the unmodified screens (74 percent survival for small, 58 percent for large).

Salem Generating Station conducted a second series of impingement sampling from 1997 to 1998. By that time, all screen assemblies had been modified to include Ristroph/post-Fletcher fish buckets and a fish return system. Additional modifications to the system sought to enhance the chances of survival of fish impinged against the screens. One modification altered the fish return slide to reduce the stress on fish being delivered to the collection pool. Flap seals were improved to better seal gaps between the fish return and debris trough, thus preventing debris from affecting returning fish. Researchers used a smaller mesh screen in the collection pools during the 1997-1998 sampling events than had been used during the 1995 studies. The study notes that the larger mesh used in 1995 might have enabled smaller fish to escape the collection pool. Since smaller fish typically have a higher mortality rate due to physical stress than larger fish, the actual mortality rates may have been greater than those found in the 1995 study. The second impingement survival study analyzed samples collected from October through December 1997 and April through September 1998. Samples were collected twice per week and analyzed for survival at 24- and 48-hour intervals. Six principal species were identified as constituting the majority of the impinged fish during the sampling periods: weakfish, white perch, bay anchovy, Atlantic croaker, spot, and *Alosa* spp. Fish were sorted by species and size, classified by their condition, and placed in holding tanks. For most species, survival rates varied noticeably depending on the season. For white perch, survival was above 90 percent throughout the sample period (as high as 98 percent in December). Survival rates for weakfish varied from a low of 18 percent in July to a high of 88 percent in September. Although the number of weakfish collected in September was approximately one-fifth of the number collected in July, a possible explanation for the variation in survival rates is the modifications to the collection system described above, which were implemented during the study period. Similarly, bay anchovy fared worst during the warmer months, dropping to a 20 percent survival rate in July while achieving a 72 percent rate during November. Rates for Atlantic croaker varied from 58 percent in April to 98 percent in November. Spot were collected in only one month (November) and had a survival rate of 93 percent. The survival rate for the *Alosa* spp. (alewife, blueback herring, and American shad) remained relatively consistent, ranging from 82 percent in April to 78 percent in November. For all species in the study, with the exception of weakfish, survival rates improved markedly with the use of the modified screen system when compared to data from 1978-1982, when the unmodified system was still in use.

EPA conducted a site visit to Salem in January 2008. See DCN 10-6513.

Arthur Kill Station

The Arthur Kill Station is located on the Arthur Kill estuary in New York. To fulfill the terms of a consent order, Consolidated Edison modified two of the station's dual-flow intake screens to include smooth mesh panels, fish-retention buckets, flap seals to prevent fish from falling between screen panels, a low-pressure spray wash system (10 psi), and a separate fish return sluiceway (EPRI 2007). One of the modified screens had mesh of 1/8-inch by 1/2-inch while the other had 1/4-inch by 1/2-inch while the six unmodified screens all had 1/8-inch by 1/8-inch mesh. Screens were continuously rotated at 20 ft/min during the sampling events. The sampling period lasted from September 1991 to September 1992. Weekly samples were collected simultaneously from all screens, with the exception of 2 weeks when the facility was shut down. Each screen sample was held separately in a collection tank where initial mortality was observed. A 24-hour survival rate was calculated based on the percentage of fish alive after 24 hours versus the total number collected. Because a control study was not performed, final survival rates have not been adjusted for any water quality or collection factors. The study did not evaluate latent survival beyond the 24-hour period. Atlantic herring, blueback herring and bay anchovy typically composed the majority (> 90 percent) of impinged species during the course of the study period. Bay anchovy alone accounted for more than 72 percent of the sample population. Overall performance numbers for the modified screens are greatly influenced by the survival rates for these three species. In general, the unmodified screens demonstrated a substantially lower impingement survival rate when compared to the modified screens. The average 24-hour survival for fish impinged on the unmodified screens was 15 percent. Fish impinged on the larger mesh (1/4") and smaller mesh (1/8") modified screens had survival average 24-hour survival rates of 92 percent and 79 percent, respectively.[24] Most species with low survival rates on the unmodified screens showed a marked improvement on the modified screens. Bay anchovy showed a 24-hour survival rate increase from 1 percent on the unmodified screens to 50 percent on the modified screens. The study period at the Arthur Kill station offered a unique opportunity to conduct a side-by-side evaluation of modified and unmodified intake structures. The results for 24-hour post-impingement survival clearly show a marked improvement for all species that had fared poorly on the conventional screens. The study notes that lower survival rates for fragile species such as Atlantic herring might have been adversely affected by the collection tanks and protocols. Larger holding tanks appeared to improve the survival of these species, suggesting that the reported survival rates may under-represent the rate that would be achieved under normal (unobserved) conditions, though by how much is unclear.

Dunkirk Steam Station

Dunkirk Steam Station is located on the southern shore of Lake Erie in New York. In 1998 a modified dual-flow traveling screen system was installed on Unit 1 for an impingement mortality reduction study (EPRI 2007). The new system incorporated an improved fish bucket design to minimize turbulence caused by flow through the screen face, as well as a nose cone on the upstream wall of the screen assembly. The nose cone was installed to reduce the flow and velocity variations that had been observed across the screen face. Samples were collected during the winter months of 1998/1999 and evaluated for 24-hour survival. Four species (emerald shiner, juvenile gizzard shad, rainbow smelt, and spottail shiner) compose nearly 95 percent of the sample population during this period. All species exhibited high 24-hour survival rates; rainbow smelt fared worst at 83 percent. The other three species had survival rates of better than 94 percent. Other species were collected during the sampling period but were not present in numbers significant enough to warrant a statistical analysis. The results presented above represent one season of impingement sampling. Species not in abundance during cooler months might be affected differently by the intake structure. Sampling continued beyond the winter months, but data has not yet been reviewed by EPA.

[24] Note that these values may not directly compare with the impingement mortality performance requirements, which are based on the use of 3/8 inch mesh.

Huntley Steam Station

Huntley Steam Station is located on the Niagara River in New York. The facility replaced four older conventional traveling screens with modified Ristroph screens on Units 67 and 68 (EPRI 2007). The modified screens are fitted with smoothly woven coarse mesh panels on a rotating belt. A fish collection basket is attached to the screen face of each screen panel. Bucket contents are removed by low-pressure spray nozzles into a fish return trough. High-pressure sprays remove remaining fish and debris into a separate debris trough. The study does not contain the rotation interval of the screen or the screen speed at the time of the study. Samples were collected over five nights in January 1999 from the modified-screen fish return troughs. All collected fish were sorted according to initial mortality. Four targeted species (rainbow smelt, emerald shiner, gizzard shad, and alewife) were sorted according to species and size and held to evaluate 24-hour survival rates. Together, the target species accounted for less than 50 percent of all fish impinged on the screens. (An additional 6,364 fish were not held for latent survival evaluation.) Of the target species, rainbow smelt and emerald shiners composed the greatest percentage with 57 and 37 percent, respectively. Overall, the 24-hour survival rate for rainbow smelt was 84 percent; some variation was evident for juveniles (74 percent) and adults (94 percent). Emerald shiner were present in the same general life stage and had a 24-hour survival rate of 98 percent. Gizzard shad, both juvenile and adult, fared poorly, with an overall survival of 5 percent for juveniles and 0 percent for adults. Alewife were not present in large numbers ($n = 30$) and had an overall survival rate of 0 percent. The study notes the low survival rates for alewife and gizzard shad and posits the low water temperature as the principal factor. At the Huntley facility, both species are near the northern extreme of their natural ranges and are more susceptible to stresses associated with extremes in water conditions. The water temperatures at the time of collection were among the coldest of the year. Laboratory evaluations conducted on these species at the same temperatures showed high degrees of impairment that would likely adversely affect post-impingement survival. A control evaluation was performed to determine whether mortality rates from the screens would need to be adjusted for waterbody or collection and handling factors. No discrepancies were observed, and therefore no corrections were made to the final results. Also of note in the study is the inclusion of a spray wash collection efficiency evaluation. The spray wash and fish return system were evaluated to determine the proportion of impinged fish that were removed from the buckets and deposited in the fish trough instead of the debris trough. All species had suitable removal efficiencies.

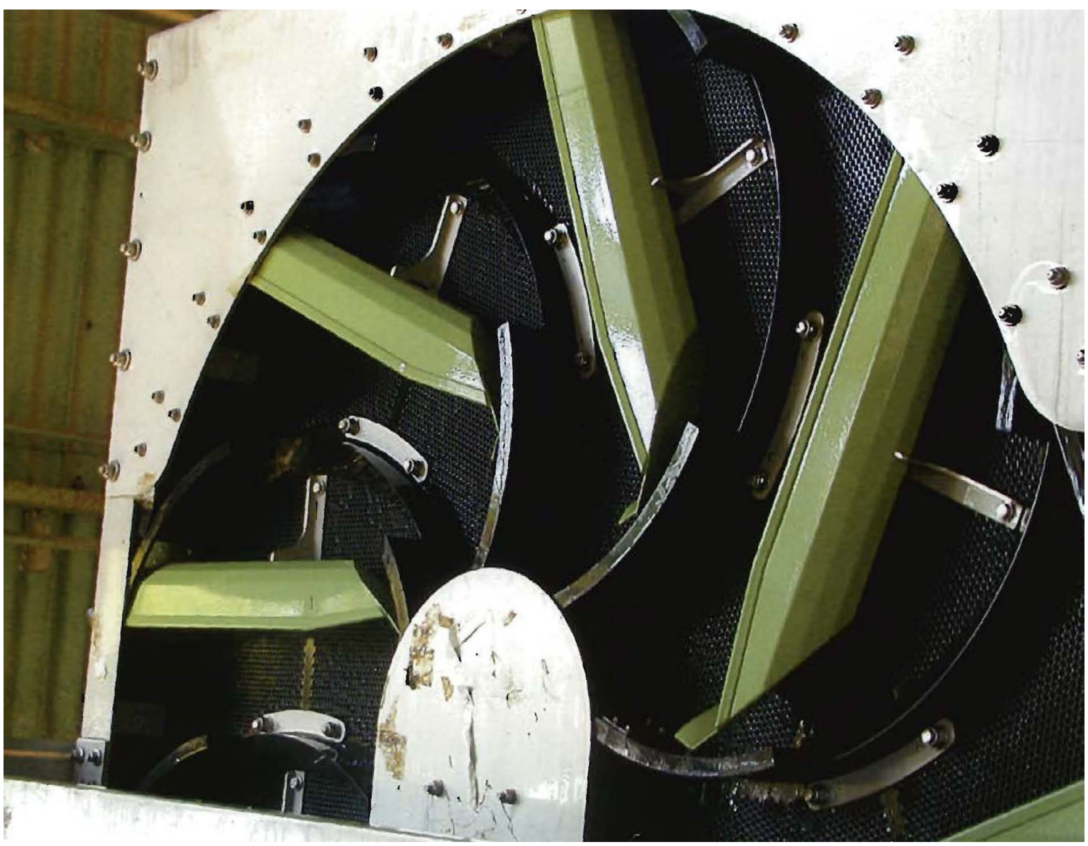
6.10 Geiger screens

Geiger screens are a relatively new type of traveling screen made up of a series of curved screen panels that rotate along the face of the intake screen along an oval path, much like a luggage carousel at an airport (see Exhibit 6-14). This configuration serves to virtually eliminate debris carryover. Geiger screens may be coarse mesh or fine mesh. The standard design is to use stainless steel for the construction, using different grades for freshwater and saltwater. As a result, capital costs for multi-disc screens may be higher for freshwater systems than conventional screens but comparable for saltwater systems. Standard screens have two drive chains and difficulty in maintaining equal tensioning on both often results in sprocket failure. O&M costs should be lower for multi-disc screens, as they only have one drive chain. Elimination of debris carryover can save on condenser cleaning O&M. In addition, because water passes through the screens only once, head loss across the screen is lower as compared to other types of screens.

The sickle-shaped screen panels can be fitted with different types of screen materials such as drilled plastic, nylon or metal screen mesh. One manufacturer has designed a fine mesh screen material that provides added strength for fine mesh by weaving in larger wire stands – about one every inch – among the finer strands to give strength while helping maintain a lower percent open area that using finer strands provides. Other manufacturers use screen backings instead.

EPA is aware of at least one facility in the U.S. that has installed Geiger screens (on a test basis), but has found that the use of Geiger screens is much more widespread in Europe. European Geiger screens often use screen mesh sizes in the 1 mm to 3 mm range, with some as low as 0.5 mm and very few exceeding 4 mm. Many are installed on large industrial rivers like the Rhine, which should have similar sediment and debris characteristics as large U.S. rivers. European intake designs, however, are somewhat different from U.S. designs in that they often use center-flow type screens and may have a three step screening process.

Exhibit 6-14. Geiger screen (image from EPRI 2007)



6.10.1 Technology Performance

Due to the relatively recent deployment of this technology, little performance data is available. Preliminary results from the Mirant Potomac Generating Station have shown impingement survival ranging from 0-100 percent depending on species. The most numerous species included bluegill, channel catfish, spottail shiner, and white perch. Representatives from EPRI and Mirant noted during the site visit at Potomac Generating Station that testing of a fine mesh Geiger screen was underway.

6.10.2 Facility/Laboratory Examples

Mirant Potomac Generating Station

Mirant Potomac is located on the Potomac River in Virginia. The facility previously used single-entry, single-exit traveling screens and installed Geiger screens on each of its cooling water intake structures in 2004 to reduce the debris carryover experienced by some of the vertical traveling screens. The new screens (mesh size of 3/8”) have virtually eliminated debris clogging in the condenser. However, due to high suspended sediment loads in the source water, the facility still regularly shuts down to remove sediment buildup in the condenser tubes. The Geiger screen for Unit 1 is also equipped with fish buckets, a low pressure spray wash, and the ability to add a fish return trough. Data generated in 2005 and 2006 showed mixed results. Bluegill impingement survival ranged from 95-100 percent; channel catfish ranged from 50-94 percent; spottail shiner ranged from 54-95 percent; and white perch ranged from 30-56 percent. The facility noted that major runoff events may have compromised some of the sampling and that additional data would need to be collected. (See DCN 10-6814.)

EPA conducted a site visit to Potomac in December 2007. See DCN 10-6512.

Donald C. Cook Nuclear Power Plant

Donald C. Cook Nuclear Power Plant is located in Michigan on Lake Michigan. From October 1, 2003 through the first week of January 2004, the facility conducted a pilot test of the Geiger Multidisc screens, using a drilled polyethylene disk, to minimize debris carryover. (See DCN 10-6811.)The plant tested the screens in two of 14 screens. The screens functioned well and were able to be maintained at the deck level as opposed to being transported off-site. Installation required about one week per screen and the retrofit could be completed without downtime. No fish protection data was available.

6.11 Hydrolox screens

The Hydrolox screen is a hinged vertical traveling screen made of an engineered polymer and consists of interconnected modules assembled in a bricklayed pattern for strength. The Hydrolox screen has a smooth polymer surface and minimizes impingement mortality through the use of “fish scoops,” similar to fish buckets used in Ristroph screens. Debris carryover is reduced by using “flights” which may be interchanged with the fish scoops. Screen slot sizes are about ¼” or 6-7 mm. The Hydrolox screen fits into existing areas made for traditional vertical traveling screens. The modular components allow maintenance to be performed on-site without having to replace the entire screen. The engineered polymer is light, non-corrosive, and minimizes biofouling. This is a relatively new technology that underwent laboratory testing by Alden Laboratories in December of 2006.

6.11.1 Technology Performance

Results of laboratory testing conducted in 2006 show over 90 percent impingement survival of golden shiner, common carp, bluegill, and channel catfish (See DCN 10-6807.)

6.11.2 Facility Examples

Alden Laboratories Flume Testing

Alden Laboratories conducted impingement tests using a Hydrolox screen from July-August 2006. Flume tests were conducted using a 4 ft wide by 12 ft high Hydrolox screen installed perpendicular to the flow. The screening material was made of molded plastic with slot openings of 0.25 in. by 0.30 in. Five freshwater species were used in the experiment including the following: golden shiner, common carp, bluegill, striped bass, and channel catfish. The screen was rotated at either 5 ft/min or 10 ft/min with water flow velocities of 1 fps or 2 fps. Mortality rates were less than 10 percent for four of five species (golden shiner, common carp, bluegill, and channel catfish), and injury and scale loss were under 5 percent. Striped bass results seemed to be impacted by handling issues as mortality rates for both the test group and the control group were higher but did not seem to be caused by the Hydrolox screen (Alden 2006).

6.12 Beaudrey W Intake Protection (WIP) Screen

The Beaudrey W Intake Protection (WIP) screen is a screen wheel that faces the incoming flow, screening both debris and organisms into a backwash pump that transports debris and organisms back to the source water. The WIP screen is installed in front of the recirculating water pumps and is easily retrofitted into existing traveling screen openings and guides. All components are mounted either on the deck plate or the WIP module itself. The WIP module can easily be raised for maintenance or inspection without disassembling the screen (see DCN 10-6810 and 10-6606). This reduces costs and no downtime is necessary.

Beaudrey's Fish Protection System (FPS) works as part of the WIP and includes a Hidrostal® fish pump and backwash screens. The FPS also works with fine mesh screens and can be installed at the same time as the screens or added/retrofitted later. Fish are impinged for a maximum of two minutes, as the FPS operates at two revolutions per minute. With the FPS/WIP screen combination (rotating screening wheel with no chains or sprocket teeth), there is no carry-over of debris or fish. The system works well for high, low, and mid-range water levels. Only two facilities in France currently use the

FPS; however, there are also systems installed at facilities in Belgium and Portugal. The FPS/WIP screen is being tested at one site in the US, but is not in widespread use.

6.12.1 Technology Performance

System operational tests of the Beaudrey FPS_{TM} have shown strong capabilities to reduce impingement mortality; tests have demonstrated mean survival rates in excess of 90 percent across a range of fish species (see DCN 10-6810 and 10-6606). Preliminary impingement survival sampling results from May 2008, for bluegill, fathead minnow, and channel catfish ranged from 79.3 percent to 99.0 percent. A holding time of 48 hours was used for the study.

6.12.2 Facility/Laboratory Examples

Omaha Public Power District – North Omaha Power Station, Nebraska

The North Omaha Power Station is located in North Omaha, Nebraska. The facility completed a two-year pilot study (in coordination with EPRI) of the WIP/FPS screen in 2008 to study impingement mortality. Initial efforts were abandoned as researchers discovered that the number of fish normally impinged at the facility was too low to provide meaningful data. The study then shifted to introduce fish directly in front of the screen and study the subsequent impingement event. Hatchery fish representative of the species found in the Missouri River were used, as well as "wild" fish caught in a seine net near the facility. The study results showed impingement survival rates of 79 percent to over 90 percent, with no statistically significant difference between fish exposed to the screen versus the control group that was not exposed to any screens.

EPA conducted a site visit to North Omaha in March 2009. See DCN 10-6521.

6.13 Coarse Mesh Cylindrical Wedgewire

Cylindrical wedgewire screens, also called "V" screens or profile screens, unlike traveling screens, are a passive intake system. Their performance is largely dictated by conditions that are independent of the source water body's biological composition. The typical design consists of wedge-shaped wires or bars welded to an internal cylindrical frame that is mounted on a central intake pipe, with the entire structure submerged in the source water body. When appropriate conditions are met, these screens exploit physical and hydraulic exclusion mechanisms to achieve consistently high reductions in impingement (and as a result, impingement mortality). Significant entrainment reductions may also be observed when the screen slot size is small enough to exclude egg and larval life stages (see below for a discussion of fine mesh wedgewire screens). Of the 766 existing facility intakes that were reported in the detailed questionnaires, 60 intakes used wedgewire screens.

Slot sizes for conventional traveling screens typically refer to a square opening (3/8" x 3/8") that is punched or woven into the screen face.[25] Wedgewire screens are constructed differently, however, with the slot size referring to the maximum distance between longitudinally adjacent wires. These screens are designed to have a low, uniform through-slot velocity (less than 0.5 feet per second) and typically have smaller slot sizes than a coarse mesh traveling screen. The intake velocity quickly dissipates away from the screen due to the cylindrical shape, thus creating a relatively small flow field in the water body. This small flow field, together with optimal screen orientation, results in a small system profile and minimizes the potential for contact between the screen and any susceptible organisms that may come under the intake's hydraulic influence. In addition, the ambient current crossflow (i.e., to maximize the sweeping velocity provided by the waterbody) carries most free-floating organisms and debris past the screen, removing organisms that are temporarily in contact with or pinned against the screen.[26] As such, screen orientation is also an important component of this technology's overall performance. The low through-slot velocity in combination with the screen orientation and cross current flow carries organisms away from the screen allowing them to avoid or escape the intake current. Wedgewire screens may also employ cleaning and de-icing systems, such as air-burst sparging or may be constructed with nickel or copper alloys to discourage biofouling.

EPA believes that cylindrical wedgewire screens can be successfully employed by large intake facilities under certain circumstances. Although many of the current installations of this technology have been at smaller-capacity facilities, large water withdrawals can be accommodated by multiple screen assemblies in the source waterbody. The limiting factor for a larger facility may be the availability of sufficient accessible space near the facility itself because additional screen assemblies consume more space on the waterbody floor and might interfere with navigation or other uses of the waterbody. Consideration of the impacts in terms of space and placement must be evaluated before selecting wedgewire screens for deployment.

As with any intake structure, the presence of large debris poses a risk of damage to the structure if not properly managed. Cylindrical wedgewire screens, because of their need to be submerged in the water current away from shore, might be more susceptible to debris interaction than other onshore technologies. Vendor engineers indicated that large debris has been a concern at several of their existing installations, but the risk associated with it has been effectively minimized by selecting the optimal site and constructing debris diversion structures. Significant damage to a wedgewire screen is most likely to occur from fast-moving submerged debris. Because wedgewire screens do not need to be sited in the area with the fastest current, a less damage-prone area closer to shore or in a cove or constructed embayment can be selected, provided it maintains a minimum ambient current around the screen assembly. If placement in the main channel is unavoidable, deflecting structures can be employed to prevent free-floating debris from contacting the screen assembly. Typical installations of cylindrical wedgewire place them roughly parallel to the direction of the current, exposing only the upstream nose to

[25] See DCN 10-6604 for additional discussion on wedgewire slot sizes.
[26] In fact, some hydrodynamic studies suggest that at a through-slot velocity of 0.5 fps, the sweeping flow is dominant over the intake flow and can even reduce the number of organisms entrained.

direct impacts with debris traveling downstream. EPA has noted several installations where debris-deflecting nose cones have been installed to effectively eliminate the damage risk associated with most debris. Apart from the damage that large debris can cause, smaller debris, such as household trash or organic matter, can build up on the screen surface, altering the through-slot velocity of the screen face and increasing the risk of entrainment and/or impingement of target organisms. Again, selection of the optimal location in the waterbody might be able to reduce the collection of debris on the structure. Ideally, cylindrical wedgewire is located away from areas with high levels of submerged aquatic vegetation (SAV) and out of known debris channels. Proper placement alone may achieve the desired effect, although technological solutions also exist to physically remove small debris and silt. Automated air-burst systems can be built into the screen assembly and set to deliver a short burst of air from inside and below the structure. Debris is removed from the screen face by the air burst and carried downstream and away from the influence of the intake structure. Improvements to the air burst system have eliminated the timed cleaning cycle and replaced it with one tied to a pressure differential monitoring system.

Wedgewire screens are more likely to be placed closer to navigation channels than other onshore technologies, thereby increasing the possibility of damage to the structure itself or to a passing commercial ship or recreational boat. Because cylindrical wedgewire screens need to be submerged at all times during operation, they are typically installed closer to the waterbody floor than the surface. In a waterbody of sufficient depth, direct contact with recreational or commercial vessels is unlikely. EPA notes that other submerged structures (e.g., pipes, transmission lines) operate in many different waterbodies and are properly delineated with acceptable navigational markers to prevent accidents associated with trawling, dropping anchor, and similar activities. Such precautions would likely be taken for a submerged wedgewire screen as well.

6.13.1 Technology Performance

Cylindrical wedgewire screens have not been used extensively as an impingement control technology at a large number of facilities with large intake flows, but data describing their performance at several installations, as well as laboratory evaluations, suggest a strong potential to reduce impingement impacts when certain design and construction criteria are satisfied. Data from limited studies have shown reductions in impingement of near 100 percent.[27]

Other factors also influence this technology's overall performance and must be considered during the system's design phase. Some data suggest that orienting the screens perpendicular to the ambient flow can minimize contact injuries by reducing screen-organism contact times, but at the expense of increasing the screen's profile. A parallel orientation offers the smallest possible profile but may raise screen-organism contact times as the organism has to travel the full length of the screen before returning to

[27] In the 2004 Phase II rule, use of a wedgewire screen (under certain parameters) was deemed to be a pre-approved technology for impingement requirements. This designation is no longer specifically included under the proposed Existing Facilities rule, as installation of a wedgewire screen presumably already meets the intake velocity criteria.

the waterbody. The optimal orientation may be further influenced by the sensitivity and abundance of the target species, as well as the probability for high debris loads in the water body or the potential for frazil/sheet ice buildup.

6.13.2 Facility/Laboratory Examples

JH Campbell

JH Campbell is located on Lake Michigan in Michigan, with the intake for Unit 3 located approximately 1,000 meters from shore at a depth of 10.7 meters. The cylindrical intake structure has 9.5 mm mesh wedgewire screens and withdraws approximately 400 MGD. Raw impingement data are not available, and EPA is not aware of a comprehensive study evaluating the impingement reduction associated with the wedgewire screen system. Comparative analyses using the impingement rates at the two other intake structures (onshore intakes with conventional traveling screens) have shown that impingement of emerald shiner, gizzard shad, smelt, yellow perch, and alewife associated with the wedgewire screen intake has been effectively reduced to insignificant levels. Maintenance issues have not been shown to be problematic at JH Campbell because of the far offshore location in deep water and the periodic manual cleaning using water jets to reduce biofouling.

Eddystone Generating Station

Eddystone Generating Station is located on the tidal portion of the Delaware River in Pennsylvania. Units 1 and 2 were retrofitted to include wide-mesh wedgewire screens and currently withdraw approximately 500 MGD from the Delaware River. Pre-deployment data showed that over 3 million fish were impinged on the unmodified intake structures during a single 20-month period. An automatic air burst system has been installed to prevent biofouling and debris clogging from affecting the performance of the screens. EPA has not been able to obtain biological data for the Eddystone wedgewire screens but EPRI (2007) indicates that fish impingement has been eliminated.

EPA conducted a site visit to Eddystone in January 2008. See DCN 10-6507.

6.14 Barrier nets

Barrier nets are nets that encircle the point of water withdrawal from the bottom of the water column to the surface that prevent fish and shellfish from coming in contact with the intake structure and screens. Of the 766 existing facility intakes that were reported in the detailed questionnaires, at least eight intakes employ a barrier net. Barrier net mesh sizes vary depending on the intake configuration, level of debris loading, species to be protected, and other factors such as the waterbody, velocity and tides, and typically range from 4 mm to 32 mm (EPRI 1999). Relatively low through-technology velocities are usually maintained through the nets because the area through which the water can flow is usually large. Most barrier nets are designed to prevent impingement and do not prevent entrainment due to the larger mesh size. Barrier nets are especially helpful in controlling impingement during seasonal migrations of fish and other organisms and to prevent impingement of shellfish on the intake traveling screen. Shellfish pose a unique challenge to the operation of traveling screens because they affix themselves to the screen; spray wash pressure is not able to remove them from the screen. Barrier nets are often removed from the water in winter to prevent damage from ice and to make any necessary repairs. In some cases, the use of barrier nets might be further limited by the physical constraints and other uses of the waterbody, such as navigation.

6.14.1 Technology Performance

Barrier nets have clearly proven performance for controlling impingement (i.e., more than 80 percent reductions over conventional screens without nets) in areas with limited debris flows. High debris flows can cause significant damage to net systems. Biofouling can also be a concern but may be addressed through adequate maintenance.

6.14.2 Facility Examples

JP Pulliam Station

The JP Pulliam Station is located on the Fox River in Wisconsin. Two separate nets with 6 mm mesh are deployed on opposite sides of a steel grid supporting structure. The operation of a dual net system facilitates the cleaning and maintenance of the nets without affecting the overall performance of the system. Under normal operations, nets are rotated at least two times per week to facilitate cleaning and repair. The nets are typically deployed when the ambient temperature of the intake canal exceeds 37°F. This usually occurs between April 1 and December 1.

Studies undertaken during the first 2 years after deployment showed an overall net deterrence rate of 36 percent for targeted species (noted only as commercially or recreationally important, or forage species). Improvements to the system in subsequent years consisted of a new bulkhead to ensure a better seal along the vertical edge of the net and additional riprap along the base of the net to maintain the integrity of the seal along the bottom of the net. The improvements resulted in a deterrence rate of 98 percent for some species; no species performed at less than 85 percent. The overall effectiveness for game species was better than 90 percent while forage species were deterred at a rate of 97 percent or better.

JR Whiting Plant

The JR Whiting Plant is located on Maumee Bay of Lake Erie in Michigan. A 3/8-inch mesh barrier net was deployed in 1980 as part of a best technology available determination by the Michigan Water Resources Commission. Estimates of impingement reductions were based on counts of fish impinged on the traveling screens inside the barrier net. Counts in years after the deployment were compared to data from the year immediately prior to the installation of the net when over 17 million fish were impinged. Four years after deployment, annual impingement totals had fallen by 98 percent.

Bowline Point

Bowline Point is located on the Hudson River in New York. A 150-foot long, 0.95-cm mesh net has been deployed in a V-shaped configuration around the intake pump house. The area of the river in which the intake is located has currents that are relatively stagnant, thus limiting the stresses to which the net might be subjected. Relatively low through-net velocities (0.5 ft/s) have been maintained across a large portion of the net because of low debris loadings. Debris loads directly affecting the net were reduced by including a debris boom outside the main net. An air bubbler was also added to the system to reduce the buildup of ice during cold months. The facility has attempted to evaluate the reduction in the rate of impingement by conducting various studies of the fish populations inside and outside the barrier net. Initial data were used to compare impingement rates from before and after deployment of the net and showed a deterrence of 91 percent for targeted species (white perch, striped bass, rainbow smelt, alewife, blueback herring, and American shad). In 1982 a population estimate determined that approximately 230,000 striped bass were present in the embayment outside the net area. A temporary mesh net was deployed across the embayment to prevent fish from leaving the area. A 9-day study found that only 1.6 percent of the estimated 230,000 fish were ultimately impinged on the traveling screens. A mark-recapture study that released individual fish inside and outside the barrier net showed similar results, with more than 99 percent of fish inside the net impinged and less than 3 percent of fish outside the net impinged. Gill net capture studies sought to estimate the relative population densities of fish species inside and outside the net. The results agreed with those of previous studies, showing that the net was maintaining a relatively low density of fish inside the net as compared to the outside.

Chalk Point

Chalk Point is located on the Patuxent River in Aquasco, Maryland. The facility began using barrier nets in 1982 to address problems with blue crab impingement. Initially, a single net was used, but a second net was later added to improve performance. Currently, the outer net has a 1.25 inch square mesh and the inner net has a 0.75 inch square mesh. Facility studies estimate a reduction in impingement of over 82 percent.

EPA conducted a site visit to Chalk Point in December 2007. See DCN 10-6504.

Dallman

Dallman is located on Lake Springfield in Springfield, Illinois. Since 1981, the facility has used a barrier net at the mouth of its intake canal to reduce impingement at the traveling screens. A study has shown a 90 percent reduction in impingement mortality.

6.15 Velocity Cap

Many offshore intakes are fitted with a velocity cap, a physical structure rising vertically from the sea bottom and placed over the top of the intake pipe. Intake water is withdrawn horizontally through openings in the velocity cap, converting the flow from a vertical direction to a horizontal one at the entrance to the intake (see Exhibits 6-15 and 6-16). The horizontal flow provides a physiological trigger in fish to induce an avoidance response thereby reducing impingement mortality. Velocity caps are also configured with supports and bar spacing designed to prevent larger aquatic organisms from entering the intake pipe and swimming to the forebay. Of the 766 existing facility intakes that were reported in the detailed questionnaires, velocity caps are used by at least 13 intakes. Velocity caps are sometimes used in combination with other technologies to optimize performance; often, the offshore intake will send water to a forebay at the shoreline, where a second CWIS with traditional traveling screens will further screen the cooling water. Because velocity caps operate under the principle that the organisms can escape the current, velocity caps alone do not offer a reduction in entrainment.

A far offshore technology, velocity caps may work to minimize impingement and entrainment by virtue of their location. In some waterbodies, shoreline locations are thought to have the potential for greater environmental impact because the water is withdrawn from the most biologically productive areas. As such, some facilities elect to employ an offshore intake to withdraw from less productive areas and further minimize impingement and entrainment. Depth of the offshore intake is also a consideration as deeper waters are often less biologically productive. Distance offshore and depth are very site specific variables and must be carefully evaluated prior to siting the offshore intake. The section on Intake Location later in this chapter discusses these factors. When compared with a shoreline intake, an offshore location may reduce overall impingement and entrainment rates but may also alter the impingement and entrainment species profile.

Exhibit 6-15. Velocity cap diagram

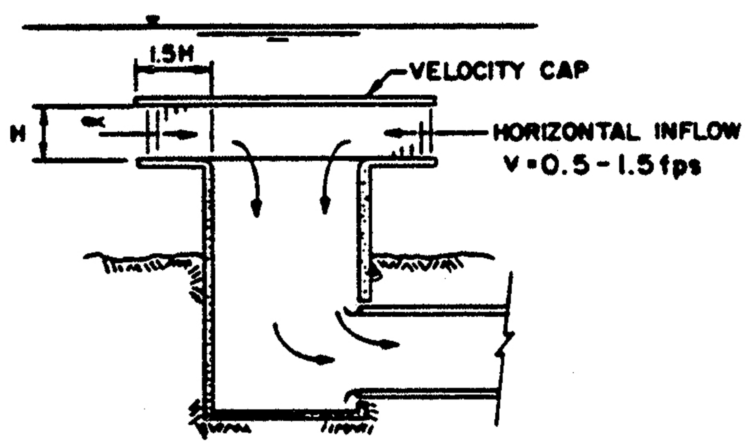


Exhibit 6-16. Velocity caps prior to installation at Seabrook Generating Station (Seabrook, NH)

6.15.1 Technology Performance

Velocity caps reduce the number of fish drawn into intakes based on the concept that fish tend to avoid rapid changes in horizontal flow. This technology does not reduce entrainment of free-floating eggs and larvae, which are unable to distinguish flow characteristics or have sufficient swimming ability to avoid them. Velocity caps are often used in conjunction with other fish protection devices, so data is somewhat limited on their performance when used alone.

At Huntington Beach and El Segundo in California, velocity caps have been found to provide 80 to 90 percent reductions in fish entrapment.[28] (See DCN 10-6603 for more information.) At Seabrook Station in New Hampshire, the velocity cap on the offshore intake has minimized the number of pelagic fish entrapped except for pollock. Two facilities in England each have velocity caps on one of two intakes. At the Sizewell Power Station, intake B has a velocity cap, which reduces impingement about 50 percent compared to intake A. Similarly, at the Dungeness Power Station, intake B has a velocity cap, which reduces impingement about by 62 percent compared to intake A.

[28] Entrapment refers to the number of impingeable fish drawn into the velocity cap. Under most circumstances, these organisms will eventually be impinged on the traveling screens at the facility.

Impingement reductions observed at velocity cap facilities along the southern California Bight have been generally been significant, with overall reductions ranging from 65 to 95 percent. These reduction values must be qualified, however, based on the methods used to collect and analyze the samples as well as the species on which the reduction is calculated. Earlier studies, such as the 1985 El Segundo report, tended to focus on commercially and recreationally important species only, leaving aside forage species that were presumed to be of little value at the time.

Velocity cap performance may vary significantly based on temporal or local factors. Significant diurnal fluctuations in impingement rates have been observed with nighttime performance often well below daytime values. At Huntington Beach Generating Station, for example, observed impingement rates were 12 to 37 percent higher during nighttime collection.

In addition, there are several factors that may influence velocity cap effectiveness and may be unique to southern California's facilities:

- It is worth nothing that coastal waters along the southern California Bight are subject to short and long-term periodic shifts in ocean temperatures that can affect the number and composition of species potentially affected by the intake. Two major climatic factors, the Pacific Decadal Oscillation (PDO) and the El Niño Southern Oscillation (ENSO), can significantly raise or lower water temperatures compared with long-term averages. During the El Niño phase of the ENSO, warmer waters from the south generally replace the cooler water of the California Current along the bight. During the La Niña phase, the pattern may shift and result in colder than normal temperatures.

  Each shift has the potential to alter the species mix in the vicinity of the intake, with El Niño cycles driving cold water species further from shore and into areas where they may be affected by the intakes. Effects of El Niño/La Niña events may be magnified or moderated depending on the concurring phase of the PDO, which may take 20-30 years to complete a full cycle. Temperatures may fluctuate by 2.5° F or more during the event peaks. Comparisons between historical and current information do show differences in species abundance, although a direct correlation is difficult.
- Benefits of offshore intakes with respect to entrainment have not been studied in as much detail as impingement, although recent sampling efforts by several facilities offer a substantial data set from which entrainment reductions may be calculated.
- Several of southern California's coastal facilities with offshore intakes are located in areas with rocky substrates that support giant kelp forests. These kelp forests support larger nursery and spawning areas offshore than are generally found off the Atlantic coast.

6.15.2 Facilities/Laboratory Examples

Huntington Beach Generating Station

Huntington Beach has one intake (equipped with a velocity cap) located 1,500 feet from shore in Pacific Ocean. The intake is approximately 18 feet below Mean Lower Low Water (MLLW) and 5 feet above intake riser. The initial study was conducted by the University of Washington from 1978 through 1979. Velocity cap performance was calculated by comparing the relative impingement rates of a capped versus uncapped intake. This was done by reversing the intake and discharge locations, both of which are located offshore in the same general area. Results from the comparative tests showed the velocity cap was effective in reducing impingement by as much as 99 percent during the day but as low as 53 percent at night. Overall effectiveness averaged 82 percent for all sampling events regardless of time. As part of its NPDES permit requirements, the facility has continued impingement monitoring during all heat treatments and representative operating periods.

Entrainment analyses were not conducted at Huntington Beach in the late 1970s. Rather, data collected at two other SCE facilities (Ormond Beach and SONGS) were used to extrapolate Huntington Beach entrainment rates based on local conditions. Entrainment performance was not calculated because source water references were not developed on which any reduction could be based.

Huntington Beach conducted additional I&E sampling in 2003 and 2004 as part of its relicensing agreement with the state. These samples included source water abundance monitoring for both I&E at several reference monitoring stations located near the intake and along the shoreline. Because these data were considered representative of current conditions, Huntington Beach did not collect additional data in order to comply with requirements for the Comprehensive Demonstration Study (CDS) under the 2004 Phase II rule.

Various models were used to estimate entrainment impacts relative to the source water. Depending on the target species, adult equivalent loss (AEL) model, fecundity hindcasting (FH), and empirical transport model (ETM), methods were used to estimate the percent mortality, which, in turn, provided the basis for acres of production foregone (APF) estimates. Huntington Beach proposed to use this method to determine the calculation baseline and any existing design credits under the 2004 Phase II rule.

Huntington Beach concluded that I&E impacts were not significant, although raw data supporting this determination were not provided for review. Presumably, data collected in 2003 and 2004 would be able to show entrainment rates relative to the source water body abundance. Huntington Beach also conducted an entrainment survival study (through condenser), but results are not yet available.

Scattergood Generating Station

Scattergood has on velocity cap located 1,600 feet from shore in Santa Monica Bay, approximately 17 feet below MLLW. Site-specific evaluations of the velocity cap's impingement performance were first conducted in the early 1970s when a storm damaged the original velocity cap. The cap was removed and, at the request of California Department of Fish and Game, left off so as to allow a comparison of impingement rates between the capped and uncapped intake. The facility estimated the velocity cap's impingement reduction effectiveness at 83 percent compared with the uncapped intake. As part of its NPDES permit requirements, the facility has continued impingement monitoring during all heat treatments and representative operating periods. A 2006 study again compared the performance of a capped versus uncapped intake by reversing the operating flows; effectiveness was calculated at 95 percent using a biomass metric and more than 97 percent based on abundance.

Entrainment analyses at Scattergood were first conducted in 1978 but only focused on commercially and recreationally important species. As part of its 2004 Phase II CDS compliance requirement, Scattergood conducted additional entrainment monitoring in 2006. Samples were collected from the intake structure as well as several reference stations along the shoreline and in the vicinity of the intake structure. In contrast to the 1978 efforts, all taxa were identified as accurately as possible.

Various models were used to estimate entrainment impacts relative to the source water. Depending on the target species, AEL, FH, and ETM methods were used to estimate the percent mortality, which, in turn, provided the basis for APF estimates. Scattergood proposed to use this method to determine the calculation baseline and any existing design credits under the 2004 Phase II rule. An aggregate "percent reduction" value is not explicitly presented in the final report, although raw data are available from both the intake and reference stations that would enable such a determination.

Scattergood bases its discussion of entrainment impacts on guidelines set forth in EPA's 1977 guidance document, which categorizes AEI as significant or insignificant relative to the known source populations. Scattergood concludes that the current intake's impacts are insignificant.

EPA conducted a site visit to Scattergood in August 2009. See DCN 10-6545.

El Segundo Generating Station

El Segundo has two intakes with velocity caps, located 2,600 feet from shore in Santa Monica Bay, but only one is currently operational. The velocity caps are approximately 15 feet below MLLW.

The original velocity cap effectiveness study at El Segundo was conducted in 1958 and consisted of a full year of impingement monitoring before and after the velocity cap was installed, showing an impingement reduction of 95 percent.

Entrainment analyses were not conducted at El Segundo in the late 1970s. Rather, data collected at Ormond Beach were used to extrapolate El Segundo's entrainment rates based on local conditions. These data are not considered reliable for El Segundo because of the distance separating the two facilities (60 miles) and the sample collection and analysis methods used that the time. Entrainment performance was not calculated because source water references were not developed on which a reduction could be based.

El Segundo did conduct additional entrainment monitoring as part of its 2004 Phase II CDS. Samples were collected in the intake forebay[29] as well as at several reference monitoring stations along the shoreline and in the vicinity of the intake. Total entrainment values were estimated based on actual and design flows.

Various models were used to estimate entrainment impacts relative to the source water. Depending on the target species, AEL, FH, and ETM methods were used to estimate the percent mortality, which, in turn, provided the basis for APF estimates. El Segundo proposed to use this method to determine the calculation baseline and any existing design credits under the 2004 Phase II rule.

El Segundo bases its discussion of entrainment impacts on guidelines set forth in EPA's 1977 guidance document, which categorizes AEI as significant or insignificant relative to the known source populations. El Segundo concludes that the current intake's impacts are insignificant.

EPA conducted a site visit to El Segundo in September 2009. See DCN 10-6552.

6.16 Fine Mesh Screens

Both traveling screens and wedgewire screens can be designed to incorporate a fine screen mesh to reduce entrainment.

6.16.1 Fine Mesh Traveling Screens

Fine mesh screens (mesh size of 5 mm or less[30]) are typically mounted on conventional traveling screen systems and are used to exclude eggs, larvae, and juvenile forms of fish from intakes.[31] Successful use of fine mesh screens is contingent on the application of satisfactory handling and return systems to allow the safe return of impinged organisms to the aquatic environment. Of the 766 existing facility intakes that were reported in the detailed questionnaires, 43 intakes reported using fine mesh screens with a mesh size of 5 mm or less.

A retrofit with fine mesh screens is more complicated than one with coarse mesh because the total through screen area will be decreased as a result of smaller screen slot sizes (assuming the same intake structure size). Because the intake volume remains unchanged, through-screen velocity will increase, perhaps significantly, unless the total intake structure area is also increased. The former is generally undesirable, as intake velocity is an important criterion in reducing impingement. The latter could result in a

[29] The velocity cap transports water from offshore to a forebay, which is an area of water storage from which conventional intake technologies (such as traveling screens and circulating water pumps) withdraw cooling water for use in the facility.
[30] There is no widely accepted definition of "fine mesh." EPA's industrial surveys in 2000 used 5mm as the threshold.
[31] Fine mesh screen overlays can also be used to attach to a coarse mesh screen.

longer downtime period than for retrofitting to modified coarse mesh traveling screens. For example, replacing coarse mesh screens with a 68 percent open area with fine mesh screens of the same size with a 44 percent open area will increase the through-screen velocity by a factor of 1.55. If the retrofit analysis estimated a total screen area required that is greater than what is available at the existing intake (i.e., the compliance screen area factor is greater than 1.0), a new intake with a larger screen area would be needed. EPA assumed the new larger intake would have a through-screen velocity of 1.0 fps when estimating the screen area factor and technology costs for a new larger intake.[32] The size and cost of this new screen technology are directly related to the required screen surface area.[33] Velocity increases beyond a certain range would be unacceptable because they might increase impingement of other organisms and would increase the mortality of eggs and larvae captured on the fine mesh screen panels.

Fouling and clogging concerns may be more pronounced with fine mesh screens as well. With a smaller screen open area, the effects of fouling on through-screen velocity (and flow volume provided for cooling) may be affected.

As the desired mesh size decreases (i.e., as the screen compliance factor increases), the potential for problems associated with the availability of space to construct a larger intake increases. This is especially true for shore-based intake technologies, since water depth is generally relatively shallow, thereby requiring any screen expansion to cover a proportionally longer length of shoreline. The availability of additional shore space at many existing intakes may be limited due to existing structures and other considerations.[34] See DCN 10-6601 for further information on fine mesh screen feasibility, particularly with respect to debris handling and screen expansion.

EPA analyzed several options for fine mesh screens (see Chapter 7 and the preamble) but ultimately did not adopt them as the technology basis. In its analysis, EPA found that many model facilities would be required to significantly expand their intake structures to accommodate the fine mesh screens and maintain a 0.5 fps through-screen velocity; in some cases, as many as 68% of facilities would need to expand the size of their intake by more than five times, leading EPA to believe that fine mesh screens would not be an available technology at those sites.

6.16.1.1 Technology Performance

Fine mesh traveling screens designed to reduce entrainment impacts have been used at a few large intake facilities, but data describing their performance is limited. Data demonstrates that entrainment typically decreases as mesh size decreases, particularly for eggs. In an August 2008 presentation to EPA, EPRI stated that field deployment of fine mesh traveling screens with favorable screen operating performance (i.e., can properly

[32] The design through-screen velocity of 1.0 fps for new expanded intakes is not a regulatory requirement; it simply reflects a best professional judgment (BPJ) design standard for a new intake structure. In part, EPA assumed that a new facility would be designed using a more conservative through-screen velocity to avoid operational problems involving debris accumulation

[33] See Chapter 8 of the TDD, which describes the costing model used for the proposed rule. Module 3 contains the costs for expanding an existing intake structure.

[34] Examples might include limited ownership of shoreline property or conflicting uses of the shoreline.

handle debris loading) included eight power plant sites in the US (Dixon 2008).[35] These plants represent various waterbody types, flows, fuel types, configurations, and locations throughout the country. The wide variety of operating conditions at facilities with fine mesh traveling screens suggests that with proper design and operation, these screens are technically feasible at most facilities.[36]

For the 2004 Phase II rule, EPA assumed that the mortality of entrained organisms would be 100 percent. However, as mesh sizes are reduced to prevent entrainment,[37] more and more entrainables become impinged on the screens (i.e., "converted" from entrainable to impingeable) and subjected to spray washes and return along with larger impinged organisms as well as debris from the screens. Under the 2004 Phase II rule, these "converts" would be classified as a reduction in entrainment, since the entrainment performance standard simply required a reduction in the number (or mass) of entrained organisms entering the cooling system. However, for some facilities the low survival rate of converts resulted in the facility have difficulty complying with the impingement mortality limitations. By comparison, the performance standard for impingement was measured as impingement mortality. Organisms that were impinged (i.e., excluded) from the cooling water intake structure were typically washed into a return system and sent back to the source water. In this case, impingement mortality is an appropriate measure of the biological performance of the technology.

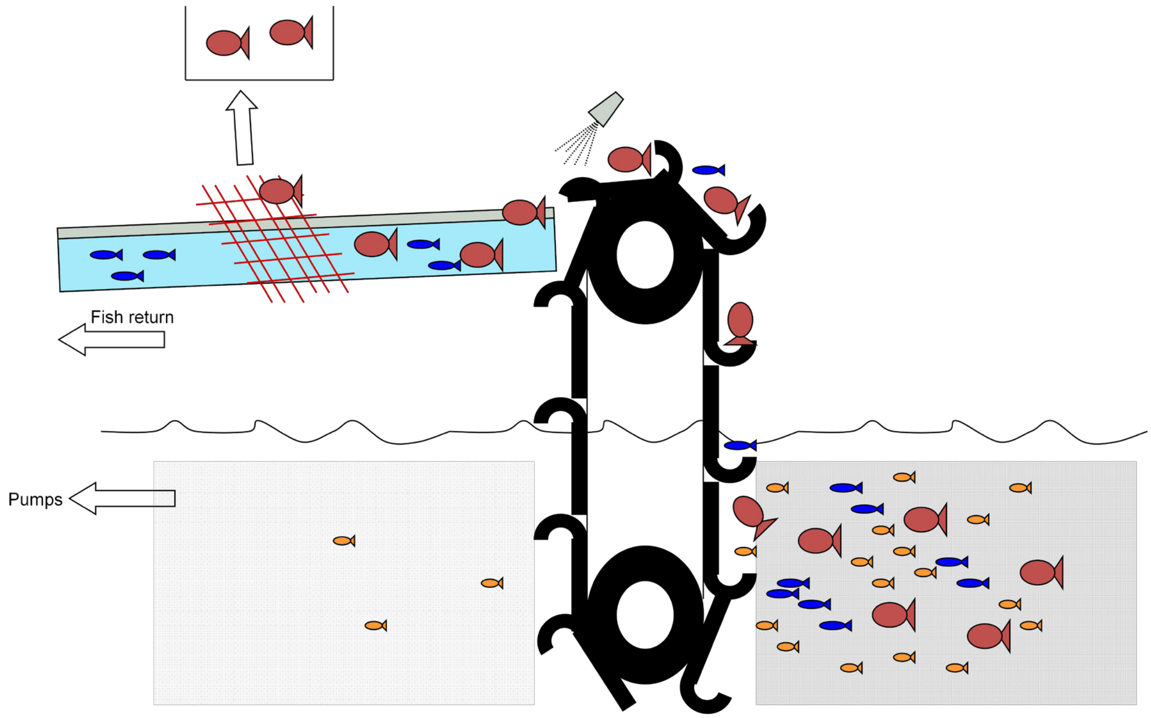
Through EPA's review of control technologies, the Agency found that the survival of "converts" on fine mesh screens was very poor, and in some extreme cases comparable to the extremely low survival of entrained organisms that are allowed to pass entirely through the facility.[38] More specifically, EPA found that nearly 100 percent of eggs were entrained unless the mesh slot size was less than 2 mm, and mortality of eggs "converted" to impingement ranged from 20 to 30 percent.[39] More telling, the mortality of larvae collected from a fine mesh screen was usually greater than 80 percent. As a result, a facility with entrainment exclusion technologies such as fine mesh screens could approach 90 percent performance, but the subsequent survival of these organisms ranged from 0 to 52 percent (mean value of 12 percent survival) depending on life stage and species, and the facility's impingement mortality rates increased.

Exhibit 6-17 illustrates this concept. Organisms of all sizes are exposed to the screen face. Larger organisms (i.e., those that would be impinged by any mesh size) are impinged and sent to the fish return. "Converts" (i.e., those that would pass through a

[35] The facilities listed were Hanford Generating Project, Barney Davis, Indian Point, Big Bend, Brunswick, Somerset, Dunkirk, and Prairie Island.
[36] Further, the technology vendors stated that the distribution of fine mesh traveling screens has been limited due to the fact that few facilities have been *required* to install fine mesh screens. EPRI also concluded that the potential for future use of fine mesh screens is favorable, as handling procedures and screen designs have continued to improve (Dixon 2008).
[37] Fine mesh screens were considered to be one technology that could be used to meet the entrainment performance standards under the 2004 Phase II rule. EPA also reviewed performance data for screens with mesh sizes as small as 0.5 mm, as described in Chapter 11 of this TDD.
[38] Through-plant entrainment survival has been studied extensively, with EPRI's Review of Entrainment Survival Studies being amongst the most comprehensive. See DCN 2-017A-R7 from the Phase I docket.
[39] See Chapter 11 of this TDD for details on these analyses.

coarse mesh screen) are also impinged and sent to the fish return.[40] Small organisms and eggs that would not be impinged by any mesh size pass through the screen and are entrained.

Exhibit 6-17. Illustration of Fine Mesh Screen Operation and "Converts"



So, a facility that simply excluded entrainable organisms (with no attention being paid to whether they survive or not) could be deemed to have met its entrainment requirements under the 2004 Phase II rule, when in fact it may be causing the same level of mortality as a facility with no entrainment controls at all. EPA's current review of entrainment and entrainment mortality shows the same trends identified in the research reviews by EPRI (see DCNs 10-6802 and 6-5004B), namely that entrainment decreases with increasing larval length, increased sweeping flow, decreasing slot (intake) velocity, and decreasing slot width.[41]

A representative for Eimco (a traveling screen vendor) stated that 0.5 mm fine mesh requires low screen velocities (i.e., approximately 0.5 fps) and that retrofitting a high velocity traveling screen with 0.5 mm mesh would be very difficult on large rivers such as the Mississippi and Missouri Rivers (Gathright 2008). The Missouri River is known for having high levels of suspended sediment, which can create problems in "blinding" of the intake screens. Blinding of the screens occurs when the sediment and debris

[40] Exhibit 6-15 also shows a screen applied to the fish return. Consistent with EPA's definition of impingement in the proposed rule, this symbolizes that impingement standards would be applied to those fish that would have been impinged by a 3/8" screen.
[41] See Chapter 11 of this TDD for additional details.

accumulate on the screens at a rapid rate. If increased screen rotation and backwashing is not sufficient to remove the sediment, then the desired cooling pumping rate may not be sustained, which would force the facility to reduce the pumping rate or cease withdrawals, leading to a reduction (or cessation) of power generation. Typically, the problem of screen blinding in rivers with high sediment loading diminishes as the screen mesh size approaches 1.0 mm and does not present a problem if 2.0 mm screens are used (Gathright 2008).

The primary reason for the difference in performance of screens with different mesh sizes is due to the typical distribution of sand particle size in the river water. In a study of sand grain size distribution from the Fraser River Port in British Columbia, 90 percent of the sand particles were < 0.5 mm in size, with the percent content increasing rapidly below 0.5 mm (see DCN 10-6601). The particle size distribution graph shows that 0.5 mm was somewhat of an inflection point where grain size content diminished more gradually as the size increased, approaching 0 percent at 2 mm. Thus, a screen with a mesh size of 0.5 mm would capture a significant portion of the suspended material, while a screen with a mesh size near 2.0 mm would capture very little of it.

Problems with larger, less-dense debris particles such as leaves will not be affected as much by mesh size, since such debris particles will be captured on the screen regardless of mesh size and, therefore, no changes in operation would be expected with finer mesh.

EPA recognizes that high sediment waterbodies pose a challenge for fine mesh screens. However, a mesh size of 2.0 mm has been shown to be effective in handling the high sediment loads. EPA also acknowledges that facilities located on high sediment rivers face constant challenges related to sediment, as existing intake screens may become clogged or suffer premature failure or condenser tubes may require more frequent cleaning.

6.16.1.2 Facility Examples

<u>Big Bend</u>

The most significant example of long-term use of fine-mesh screens has been at the Big Bend Power Plant in the Tampa Bay area. The facility has an intake canal with 0.5 mm mesh Ristroph screens that are used seasonally on the intakes for Units 3 and 4. During the mid-1980s when the screens were initially installed, their efficiency in reducing I&E mortality was highly variable (EPRI 2007). The operator, Florida Power & Light (FPL) evaluated different approach velocities and screen rotational speeds. In addition, FPL recognized that frequent maintenance (manual cleaning) was necessary to avoid biofouling. By 1988, system performance had improved greatly. The system's efficiency in screening fish eggs (primary species are drum and bay anchovy) exceeded 95 percent,[42] with 80 percent latent survival for drum and 93 percent for bay anchovy. For larvae (primary species are drum, bay anchovy, blennies, and gobies), screening

[42] The 95 percent value reflects the exclusion rate, the percentage of organisms prevented from entering the cooling water system and does not address entrainment mortality. The same is true for the following sentence which cites a screening efficiency of 85 percent, again an exclusion rate.

efficiency was 86 percent, with 65 percent latent survival for drum and 66 percent for bay anchovy. Note that latent survival in control samples was also approximately 60 percent. Although more recent data are generally not available, the screens continue to operate successfully at Big Bend in an estuarine environment with proper maintenance.

EPA conducted a site visit to Big Bend in March 2008. See DCN 10-6502.

Other Facilities

Although egg and larvae entrainment performance data are not available, fine mesh (0.5 mm) Passavant screens (single entry/double exit) have been used successfully in a marine environment at the Barney Davis Station in Corpus Christi, Texas. Impingement data for this facility show an overall 86 percent initial survival rate for bay anchovy, menhaden, Atlantic croaker, killfish, spot, silverside, and shrimp. EPA conducted a site visit to Barney Davis in March 2008. See DCN 10-6500.

Additional full-scale performance data for fine-mesh screens at large power stations are generally not available. However, some data are available from limited use or study at several sites and from laboratory and pilot-scale tests. Seasonal use of fine mesh on two of four screens at the Brunswick Power Plant in North Carolina has shown 84 percent reduction in entrainment compared to the conventional screen systems. Similar results were obtained during pilot testing of 1 mm screens at the Chalk Point Generating Station in Maryland.[43] At the Kintigh Generating Station in New Jersey, pilot testing indicated that 1 mm screens provided 2 to 35 times the reduction in entrainment over conventional 9.5 mm screens. Finally, Tennessee Valley Authority (TVA) pilot-scale studies performed in the 1970s showed reductions in striped bass larvae entrainment of up to 99 percent for a 0.5 mm screen and 75 and 70 percent for 0.97 mm and 1.3 mm screens, respectively. A full-scale test by TVA at the John Sevier Plant showed less than half as many larvae entrained with a 0.5 mm screen than with 1- and 2 mm screens combined.

6.16.2 Fine Mesh Wedgewire Screens

Fine mesh wedgewire functions in the same way as coarse mesh wedgewire, but due to the reduced slot size also acts to exclude smaller organisms (including larvae and eggs), reducing entrainment. Physical exclusion is accomplished by designing the screens with a slot size that will prevent the entrainment of the smallest target taxa or life stage. In general, a smaller slot size will translate into larger or more numerous screen assemblies in order to maintain the desired through-slot velocity. Furthermore, small slots increase the debris clogging potential and associated maintenance needs.

6.16.2.1 Technology Performance

Fine-mesh applications (those designed to target eggs and larvae) have shown high potential to reduce entrainment if intake velocities are maintained. Reductions in

[43] EPA conducted site visits to Brunswick and Chalk Point in January 2008 and December 2007, respectively. See DCN 10-6504.

entrainment exclusion of approximately 90 percent have been demonstrated. Due to difficulty in collecting entrainables from a fine mesh wedgewire screen, entrainment survival is not known.

6.16.2.2 Facility Examples

Laboratory Evaluation

EPRI published (May 2003; see DCN 6-5004B) the results of a laboratory evaluation of wedgewire screens under controlled conditions in the Alden Research Laboratory Fish Testing Facility. A principal aim of the study was to identify the important factors that influence the relative rates of impingement and entrainment associated with wedgewire screens. The study evaluated characteristics such as slot size, through-slot velocity, and the velocity of ambient currents that could best carry organisms and debris past the screen. When each of the characteristics was optimized, wedgewire screen use became increasingly effective as an impingement reduction technology; in certain circumstances it could be used to reduce the entrainment of eggs and larvae. EPRI notes that large reductions in impingement and entrainment might occur even when all characteristics are not optimized. Localized conditions unique to a particular facility, which were not represented in laboratory testing, might also enable successful deployment. The study cautions that the available data are not sufficient to determine the biological and engineering factors that would need to be optimized, and in what manner, for future applications of wedgewire screens.

Slot sizes of 0.5, 1.0, and 2.0 mm were each evaluated at two different through-slot velocities (0.15 and 0.30 m/s) and three different channel velocities (0.08, 0.15, and 0.30 m/s, corresponding to 0.25, 0.5, and 1.0 ft/sec) to determine the impingement and entrainment rates of fish eggs and larvae. Screen open area increased from 24.7 percent for the 0.5 mm screens to 56.8 percent for 2.0 mm screens. The study evaluated eight species (striped bass, winter flounder, yellow perch, rainbow smelt, common carp, white sucker, alewife, and bluegill) because of their presence in a variety of waterbody types and their history of entrainment and impingement at many facilities. Larvae were studied for all species except alewife, while eggs were studied for striped bass, white sucker, and alewife. (Surrogate, or artificial, eggs of a similar size and buoyancy substituted for live striped bass eggs.) Individual tests followed a rigorous protocol to count and label all fish eggs and larvae prior to their introduction into the testing facility. Approach and through-screen velocities in the flume were verified, and the collection nets used to recapture organisms that bypassed the structure or were entrained were cleaned and secured. Fish and eggs were released at a point upstream of the wedgewire screen selected to deliver the organisms at the centerline of the screens, which maximized the exposure of the eggs and larvae to the influence of the screen. The number of entrained organisms was estimated by counting all eggs and larvae captured on the entrainment collection net. Impinged organisms were counted by way of a plexiglass window and video camera setup.

In addition to the evaluations conducted with biological samples, Alden Laboratories developed a Computational Fluid Dynamics (CFD) model to evaluate the hydrodynamic characteristics associated with wedgewire screens. The CFD model analyzed the effects of approach velocity and through-screen velocities on the velocity distributions around the screen assemblies. Using the data gathered from the CFD evaluation, engineers were able to approximate the "zone of influence" around the wedgewire screen assembly under different flow conditions and estimate any influence on flow patterns exerted by multiple screen assemblies located in close proximity to each other.

The results of both the biological evaluation and the CFD model evaluation support many of the conclusions reached by other wedgewire screen studies, as well as in situ anecdotal evidence. In general, the lower impingement rates were achieved with larger slot sizes (1.0 to 2.0 mm), lower through-screen velocities, and higher channel velocities. Similarly, the lowest entrainment rates were seen with low through-screen velocities and higher channel velocities, although the lowest entrainment rates were achieved with smaller slot sizes (0.5 mm). Overall impingement reductions reached as high as 100 percent under optimal conditions, and entrainment reductions approached 90 percent. It should be noted that the highest reductions for impingement and entrainment were not achieved under the same conditions. Results from the biological evaluation generally agree with the predictions from the CFD model: the higher channel velocities, when coupled with lower through-screen velocities, would result in the highest rate of protection for the target organisms.

Other Facilities

Other plants with lower intake flows have also installed wedgewire screens, but there are limited biological performance data for these facilities. Unit 1 at the Cope Generating Station in South Carolina is a closed-cycle unit that withdraws about 6 MGD through a 2 mm wedgewire screen; however, no biological data are available. Westchester RESCO (design flow of 55 MGD) uses a wedgewire screen with 0.5mm slot size; however, no studies relating to reductions in impingement and entrainment have been conducted. The Logan Generating Station in New Jersey withdraws 19 MGD from the Delaware River through a 1 mm wedgewire screen. Entrainment data show 90 percent less entrainment of larvae and eggs than conventional screens. No impingement data are available.[44]

Wedgewire screens have been considered or tested for several other large facilities. In situ testing of 1 and 2mm wedgewire screens was performed in the St. John River for the Seminole Generating Station Units 1 and 2 in Florida in the late 1970s. This testing showed virtually no impingement and 99 and 62 percent reductions in larvae entrainment for the 1 mm and 2 mm screens, respectively, over conventional screen (9.5 mm) systems. In 1982 and 1983 the State of Maryland conducted testing using 1, 2, and 3 mm wedgewire screens at the Chalk Point Generating Station, which withdraws water from the Patuxent River in Maryland. The 1 mm wedgewire screens were found to reduce entrainment by 80 percent. No impingement data were available. Some biofouling and clogging were observed during the tests. In the late 1970s, Delmarva Power and Light conducted laboratory testing of fine-mesh wedgewire screens for the proposed 1,540 MW Summit Power Plant. This testing showed that entrainment of fish eggs (including

[44] EPA conducted site visits to Westchester RESCO and Logan in April 2008 and January 2008, respectively. See DCN 10-6517 and DCN 10-6509.

striped bass eggs) could effectively be prevented with slot widths of 1 mm or less, while impingement mortality was expected to be less than 5 percent. Actual field testing in the brackish water of the proposed intake canal required the screens to be removed and cleaned as often as once every 3 weeks.

6.17 Aquatic Filter Barrier

Aquatic Filter (or microfiltration) Barriers (AFBs), also known under the trade name "Gunderboom," are similar to barrier nets in that they extend throughout the area of water withdrawal from the bottom of the water column to the surface (see Exhibit 6-18). However, AFBs consists of fabric panels with very small pores (<20 microns or 0.02 mm) manufactured as a matting of minute unwoven fibers. The fullwater-depth filter curtain is suspended by flotation billets at the surface of the water and anchored to the substrate below. Gunderboom systems also employ an automated "air burst" system to periodically shake the material and pass air bubbles through the curtain system to clean off sediment buildup and release any other material back into the water column. AFBs reduce both impingement and entrainment because they present a physical barrier to all life stages. These systems can be floating, flexible, or fixed. Because these systems usually have such a large surface area, the velocities maintained at the face of the permeable curtain are very low. EPA was aware of one facility that uses an AFB, but notes that this facility recently ceased operations for reasons unrelated to its use of AFB.

Exhibit 6-18. Gunderboom at Lovett Generating Station (image from Gunderboom)[45]

[45] http://www.gunderboom.com/images/lovett.jpg

6.17.1 Technology Performance

At this juncture, the only facility where the Gunderboom was used at a full-scale level is the Lovett Generating Station along the Hudson River in New York, where pilot testing began in the mid-1990s. Initial testing at that facility showed significant potential for reducing entrainment. Entrainment reductions of up to 82 percent were observed for eggs and larvae, and these levels were maintained for extended month-to-month periods from 1999 through 2001. At Lovett, some operational difficulties affected long-term performance. These difficulties, including tearing, overtopping, and plugging/clogging, were addressed, to a large extent, through subsequent design modifications. Gunderboom, Inc. specifically has designed and installed a microburst cleaning system to remove particulates. As noted above, the Lovett Generating Station recently closed operations.

Each of the challenges encountered at Lovett could be of significant concern at marine sites, as these have higher wave action and debris flows. Gunderboom systems have been successfully deployed in marine conditions to prevent migration of particulates and bacteria, including in areas with waves up to 5 feet. The Gunderboom system is being tested for potential use at the Contra Costa Plant along the San Joaquin River (a tidal river) in northern California. An additional question related to the utility of the Gunderboom and other microfiltration systems is sizing and the physical limitations and other uses of the source waterbody. With a 20-micron mesh, 144 MGD and 288 MGD intakes would require filter systems 500 and 1,000 feet long (assuming a 20-foot depth). In some locations, this may preclude the successful deployment of the system because of space limitations or conflicts with other waterbody uses.

AFBs have been installed at other sites for sediment control and exclusion of small debris. More recent improvements to AFBs have reduced the effect of wave action and debris (see DCN 10-6830).

6.17.2 Facilities Examples

As described above, the technology was installed at the Lovett Generating Station which has ceased operations. EPA is not aware of any other existing industrial facilities employing an AFB.

6.18 Other Technologies and Operational Measures

6.18.1 Reduce Intake Velocity

The relationship between intake velocity and impingement is well-established since EPA's Phase I rule (66 FR 65256). Impingement mortality can be greatly reduced by reducing the through-screen velocity in any screen. Reducing the through-screen velocity to 0.5 ft/sec or less reduces impingement of most species by 96 percent because it allows them to escape the intake current.[46] (See DCN 2-028A EPRI Technical Evaluation of the Utility of Intake Approach Velocity as an Indicator of Potential Adverse Environmental Impact Under Clean Water Act 316(b)). As a result, many existing facilities have designed and operate their modified traveling screens or wedgewire screens so as not to exceed a through-screen velocity of 0.5 ft/sec.

Reducing the intake velocity generally does not similarly reduce entrainment.

6.18.2 Substratum Intakes

Studies and pilot projects are being conducted to investigate the viability of subsurface or substratum cooling water intake structures, also known as filter beds. Historically, substratum intakes have only been seriously considered for low flow facilities, smaller than 1 MGD. Desalination drinking water facilities appear to be the predominant industry utilizing substratum intakes in their operations. While extant in the United States, operation of desalination facilities has so far been concentrated in Europe, North Africa, and the Middle East. Some non-desalination drinking water facilities also use substratum water intakes. These facilities most commonly make use of vertical or horizontal beach wells, which are shallow shoreline intake wells that use the overlying rock or sand layers as a filter medium. Early investigations for use as cooling water intake structures have yielded positive results, including 100 percent reduction of impingement and entrainment. See DCN 10-6609 for more information.

A pilot study using a substratum intake was planned for 2008 for a site in New York to withdraw about 245 MGD to operate a 400 MW power plant. The substratum intake was expected to eliminate impingement and entrainment, and offer other benefits by reducing operations and maintenance costs, requiring minimal downtime at installation, and reducing fuel use in the summer. No information about the progress or results of this pilot study is currently available.

6.18.3 Louvers

Louver systems are comprised of a series of vertical panels placed at an angle to the direction of the flow (typically 15 to 20 degrees). Each panel is placed at an angle of 90 degrees to the direction of the flow (Hadderingh, 1979). The louver panels provide an abrupt change in both the flow direction and velocity. This creates a barrier that fish can sense and avoid. Once the change in flow/velocity is sensed by fish, they typically align with the direction of the current and move away laterally from the turbulence. This behavior further guides fish into a current created by the system, which is parallel to the face of the louvers. This current pulls the fish along the line of the louvers until they enter a fish bypass or other fish handling device at the end of the louver line. The louvers may be either fixed or rotated similar to a traveling screen. Flow straighteners are frequently placed behind the louver systems.

[46] 66 FR 65274

In its 2007 *Fish Protection at Cooling Water Intake Structures: A Technical Reference Manual,* EPRI concluded that the technology has produced variable results, but that well-performing louvers can divert over 80 percent of fish to a bypass. Louvers have also not been widely employed at power plant intakes; most installations are at hydroelectric or irrigation facilities.

While showing some promise for diverting fish (thereby reducing impingement), louvers have not been widely used at power plants and have a very limited history of successful deployment. Therefore, EPA has determined that this technology is unlikely to be utilized by many existing facilities.

6.18.4 Intake Location

There are certain areas within every waterbody with increased biological productivity, and therefore where the potential for I&E of organisms is higher. In large lakes and reservoirs, the littoral zone (the shore zone areas where light penetrates to the bottom) serves as the principal spawning and nursery area for most species of freshwater fish and is considered one of the most productive areas of the waterbody. Fish of this zone typically follow a spawning strategy wherein eggs are deposited in prepared nests, on the bottom, or are attached to submerged substrates where they incubate and hatch. As the larvae mature, some species disperse to the open water regions, whereas many others complete their life cycle in the littoral zone. Clearly, the impact potential for intakes located in the littoral zone of lakes and reservoirs is high. The profundal zone of lakes and reservoirs is the deeper, colder area of the waterbody. Rooted plants are absent because of insufficient light, and for the same reason, primary productivity is minimal. A well-oxygenated profundal zone can support benthic macroinvertebrates and cold-water fish; however, most of the fish species seek shallower areas to spawn (either in littoral areas or in adjacent streams and rivers). Use of the deepest open water region of a lake or reservoir (e.g., within the profundal zone) as a source of cooling water typically offers lower I&E impact potential than use of littoral zone waters.

As with lakes and reservoirs, rivers are managed for numerous benefits, which include sustainable and robust fisheries. Unlike lakes and reservoirs, the hydrodynamics of rivers typically result in a mixed water column and overall unidirectional flow. There are many similarities in the reproductive strategies of shoreline fish populations in rivers and the reproductive strategies of fish within the littoral zone of lakes and reservoirs. Planktonic movement of eggs, larvae, post larvae, and early juvenile organisms along the shore zone is generally limited to relatively short distances. As a result, the shore zone placement of CWISs in rivers might potentially impact local spawning populations of fish. The impact potential associated with entrainment might be diminished if the main source of cooling water is recruited from near the bottom strata of the open water channel region of the river. With such an intake configuration, entrainment of shore zone eggs and larvae, as well as the near-surface drift community of ichthyoplankton, is minimized. Impacts could also be minimized by controlling the timing and frequency of withdrawals from rivers. In temperate regions, the number of entrainable or impingeable organisms of rivers increases during spring and summer (when many riverine fishes reproduce). The number of eggs and larvae peak at that time, whereas entrainment potential during the remainder of the year can be minimal.

In estuaries, species distribution and abundance are determined by a number of physical and chemical attributes, including geographic location, estuary origin (or type), salinity, temperature, oxygen, circulation (currents), and substrate. These factors, in conjunction with the degree of vertical and horizontal stratification (mixing) in the estuary, help dictate the spatial distribution and movement of estuarine organisms. With local knowledge of these characteristics, however, the entrainment effects of a CWIS could be minimized by adjusting the intake design to areas (e.g., depths) least likely to affect concentrated numbers and species of organisms. In oceans, nearshore coastal waters are typically the most biologically productive areas. The euphotic zone (zone light available for photosynthesis) typically does not extend beyond the first 100 meters (328 feet) of depth. Therefore, inshore waters are generally more productive due to photosynthetic activity and due to the input from estuaries and runoff of nutrients from land.

During the development of the Phase III rule, EPA obtained data on densities of ichthyoplankton in the Gulf of Mexico from the Southeast Area Monitoring and Assessment Program (SEAMAP). This long-term sampling program collects information on the density of fish larvae and eggs throughout the Gulf of Mexico.[47] EPA's analysis showed that in general, ichthyoplankton densities are highest at sampling stations in the shallower regions of the Gulf and lowest at sampling stations in the deepest regions. Over 600 different fish taxa were identified in the SEAMAP samples, including species of commercial and recreational value.

There are only limited published data, however, quantifying the locational differences in I&E rates at individual power plants. Some information, however, is available for selected sites. For example:

- For the St. Lucie plant in Florida, EPA Region 4 permitted the use of a once through cooling system instead of closed-cycle cooling by locating the outfall 1,200 feet offshore (with a velocity cap) in the Atlantic Ocean. This approach avoided impacts on the biologically sensitive Indian River estuary.
- In *Entrainment of Fish Larvae and Eggs on the Great Lakes, with Special Reference to the D.C. Cook Nuclear Plant, Southeastern Lake Michigan* (1976), researchers noted that larval abundance is greatest within the area from the 12.2-m (40-ft) contour to shore in Lake Michigan and that the abundance of larvae tends to decrease as one proceeds deeper and farther offshore. This finding led to the suggestion of locating CWISs in deep waters.
- During biological studies near the Fort Calhoun Power Station along the Missouri River, results of transect studies indicated significantly higher fish larvae densities along the cutting bank of the river, adjacent to the station's intake structure. Densities were generally were lowest in the middle of the channel.

[47] EPA analyzed SEAMAP data in considering requirements for offshore facilities in the Phase III rule. While this data is not directly relevant to existing facilities subject to the proposed rule, it does offer similar insights to the importance of intake location. See 71 FR 35013.

- Wisconsin Energy's Elm Road facility was recently constructed with a submerged intake 1.5 miles offshore at a depth of 43 feet. The facility is using coarse mesh cylindrical wedgewire screens with a through-slot velocity of 0.5 fps.

As discussed above, intake location can play an important role in determining the potential for impingement and entrainment. However, for existing facilities, changing the intake location is very limited in practice; many facilities simply do not have the option available to them and when available, intake relocation tends to be among the most expensive alternatives. Selecting an appropriate intake location is best considered when siting a new intake or new facility. EPA included retrofit costs for a limited number of facilities to relocate to a new location (with a new wedgewire screen) but did not consider this approach for national requirements. See chapter 12 for more information on distance and depth of offshore intakes on performance in reducing impingement and entrainment.

6.19 References

California Ocean Protection Council. 2008. California's Coastal Power Plants: Alternate Cooling System Analysis. Available at http://www.opc.ca.gov/webmaster/ftp/project_pages/OTC/engineering%20study/CA_Power_Plant_Analysis_Complete.pdf. Accessed March 2011.

Dixon, D. and J. Black. 2008. Fine-mesh Traveling Screens. Presentation for EPRI-EPA Meeting. August 26, 2008.

EEA, Inc. 2005. Keyspan Generation LLC studies the substratum intake system: An Innovative water intake system for power generation facilities. *Environmental Consulting Insights Newsletter*. Spring, 2005.

Electric Power Research Institute. 2009. Beaudrey Water Intake Protection (WIP) Screen Pilot-Scale Impingement Survival Study.

Electric Power Research Institute. 2008. Net Environmental Effects of Retrofitting Power Plants with Once-Through Cooling to Closed-Cycle Cooling, May 2008

Electric Power Research Institute. 2007. Fish Protection at Cooling Water Intakes: A Technical Reference Manual.

Electric Power Research Institute. 1999. Fish Protection at Cooling Water Intakes: Status Report. TR-114013. EPRI, Palo Alto, CA.

Fletcher, I. R. 1990. Flow Dynamics and Fish Recovery Experiments: Water Intake Systems. *Transactions of the American Fisheries Society* 119: 393-415

Gathright, Trent (EIMCO). 2008. Email to John Sunda, SAIC. Re: Question about Traveling screen mesh area and fish buckets. August 22, 2008.

Hadderingh, R.H. 1979. Fish Intake Mortality at Power Stations, the Problem and its Remedy. N.V. Kema, Arnheem, Netherlands. *Hydrological Bulletin* 13(2-3): 83-93.

Pagano, R. and W.H.B. Smith. 1977. Recent Developments in Techniques to Protect Aquatic Organisms at the Intakes Steam-Electric Power Plants. MITRE Technical Report 7671. November 1977.

U.S. Environmental Protection Agency (EPA). 2002. Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule. EPA-R-02-003. U.S. Environmental Protection Agency, Washington, DC.

Voutchkov, N. 2005. SWRO desalination process: on the beach – seawater intakes. *Filtration & Separation* 42(8):24-27, October 2005.

White, J.C. and M.L. Brehmer. 1976. "Eighteen-Month Evaluation of the Ristroph Traveling Fish Screens". In Third National Workshop on Entrainment and Impingement. L.D. Jensen (Editor). Ecological Analysts, Inc., Melville, N.Y. 1976.

Chapter 7: Regulatory Options

7.0 Introduction

This chapter briefly discusses the technology bases and regulatory options EPA considered for proposed impingement and entrainment reduction controls. For a complete discussion, refer to the preamble to the proposed rule.

7.1 Technology Basis Considered for the Proposed Regulation

After examining the technologies described in Chapter 6, EPA rejected all but three technologies as BTA as they were the only technologies that consistently and predictably reduced impingement mortality and entrainment mortality. These technologies are: 1) impingement mortality reductions based on modified Ristroph screens, 2) impingement mortality reductions for shellfish based on barrier nets and 3) flow reduction in the form of closed-cycle wet cooling towers.[1] The following section provides a discussion of these technologies.

7.1.1 Modified Ristroph Screens

EPA's analysis identified modified Ristroph screens as the technology basis for impingement mortality BTA requirements for all existing facilities.

As described in Chapter 6, traveling screens have been widely used at existing facilities for decades. These screens were originally designed to prevent debris from entering the cooling water system, but can also be used to prevent certain types of fish and shellfish from entering the system by similarly impinging them on the screen surface. Because fish and shellfish are impinged on the screen, unless these screens are modified and also accompanied by a system that allows for their return, or unless the through screen velocity is reduced to 0.5 ft/sec or less and there is no entrapment of the fish, mortality associated with impingement on traveling screens alone can be high. In an effort to reduce impingement mortality associated with coarse mesh traveling screens, industry has conducted various studies and implemented various modifications and additions to screen design and operation including fish return.

The impingement mortality requirements considered are based on "modified traveling screens." Modified traveling screens include all of the "Ristroph" and "Fletcher" modifications including: smooth mesh; a low pressure wash spray designed and operated for gentle removal of impinged organisms; and a bucket and/or lip design that maintains adequate water to promote survival of impinged organisms.[2] Modified traveling screens also includes a fish handling and return system that is designed, maintained, and operated

[1]EPA earlier considered, but rejected, dry closed-cycle cooling towers as BTA at the national level. See 66 FR 65282 (Phase I), Chapter 4 of the Phase I TDD (DCN 3-0002), 69 FR 41608 (Phase II) and Appendix D of the Phase II TDD (DCN 6-0004, EPA-OW-HQ-2002-0049-1459).
[2] See Chapter 6 of the TDD and DCNs 10-6801, 10-6829, and 5-4387.

to ensure adequate water to promote return of impinged organisms to the source water body; minimized predation of the collected impinged organisms; and a discharge location of the fish return that is sufficiently far from the cooling water intake to minimize re-impingement. Throughout the supporting documents and associated docket, EPA's reference to modified traveling screens assumes all of the aforementioned characteristics. Any traveling screens (with or without fish returns) that do not incorporate all of these characteristics are not considered BTA.

Unlike closed-cycle cooling towers and other flow reduction strategies, impingement mortality reductions resulting from the application of modified traveling screens can vary from site to site. While the effectiveness of modified traveling screens may vary from site to site, data in the record demonstrate that their collective effectiveness approximates an 88 percent reduction in impingement mortality on an annual basis (that is, 88 percent of impinged organisms survive).[3]

Facilities may also comply with impingement mortality requirements by demonstrating that they withdraw cooling water at an intake velocity that does not exceed 0.5 feet per second. EPA's data still shows that over 94 percent of fish can escape from 0.5 ft/sec (burst swim speed), therefore reducing the intake velocity is protective of a large percentage of impingeable organisms.[4]

7.1.2 Barrier Nets

The proposed impingement mortality requirements also require that facilities located on an ocean or tidal river reduce the impingement of shellfish at locations where shellfish are present; EPA's technical basis for this requirement is the addition of barrier nets to the existing intake structure (and in addition to any traveling screen upgrades). Unlike fish, some shellfish, in addition to being impinged on modified traveling screens due to intake flows (similar to fish), may even attach to the screen itself (crabs may latch onto screens panels and hold on while the panels rotate). During its site visits, EPA observed facilities where shellfish (e.g., crabs) comprised a major portion of the impinged organisms. Because of the larger physical size and irregular shape of most shellfish, barrier nets prevent the shellfish from contacting the screen leading to large reductions in impingement (and impingement mortality). As explained in Chapter 6, where facilities have installed barrier nets, shellfish impingement can be reduced by as much as 98 percent (see DCN 10-6804).

7.1.3 Closed-cycle Cooling Towers

As explained in Chapter 6, there is a direct relationship between the quantity of water withdrawn and impingement and entrainment. Available data demonstrate that closed-cycle wet recirculating cooling systems (e.g., cooling towers or ponds) typically

[3] The survival rate of 88% reflects a beta distribution with a 95% confidence interval. EPA also excluded studies showing poorly performing screens from its data set. See Chapter 11 of the TDD for a complete discussion.
[4] See DCNs 2-028A-D, 2-029, and 2-030 in the Phase I NODA docket. Additionally, the final Phase I rule, the 2004 Phase II rule, and the Phase III rule all contained similar provisions regarding intake velocity.

reduce mortality from impingement and entrainment by up to 97.5 percent when compared with conventional once-through systems. Reducing the cooling water intake structure's capacity is one of the most effective means of reducing entrainment (and impingement).

For the traditional steam electric utility industry, facilities located in freshwater areas that have closed-cycle, recirculating cooling water systems can, depending on the quality of the make-up water, reduce water use by up to 97.5 percent from the amount they would use if they had once-through cooling water systems. Steam electric generating facilities that have closed-cycle, recirculating cooling systems using salt or brackish water are somewhat less efficient but still reduce water usage by up to 94.9 percent when make-up and blowdown flows are minimized. EPA estimates that approximately one third of power generation and manufacturing facilities currently have closed-cycle cooling. (See Chapter 4 for more information.) The effectiveness of closed-cycle cooling technology is widely demonstrated and the number of existing facilities initiating retrofits to closed-cycle cooling is increasing.[5]

7.2 Options Considered

After careful consideration of the technologies available, EPA developed four primary options based on these technologies for today's proposed rule. Three of the options would require the same impingement mortality standards, but would vary the approach to entrainment mortality controls. The fourth option would allow both impingement and entrainment mortality controls to be established on a site-specific BPJ basis for facilities with a DIF less than 50 MGD. The options are described briefly below, followed by a discussion of EPA's evaluation of each option as BTA. Also see the preamble for additional discussion.

1. Option 1 – Uniform Impingement Mortality Controls at All Existing Facilities; Site-Specific Entrainment Controls for Existing Facilities (other than New Units) that Withdraw over 2 MGD DIF; Uniform Entrainment Controls for All New Units at Existing Facilities

Under this option, all existing facilities withdrawing more than 2 MGD would be required to meet either the design or the performance standard for impingement mortality. Entrainment controls would be established by the permitting authority on a case-by-case basis taking into account those factors at a particular facility. New units at an existing facility that withdraws more than 2 MGD would have requirements similar to the requirements of a new facility in Phase I. Under this option, new units would be required to reduce flow commensurate with closed-cycle cooling for the new unit. Under the proposal, as with Track II of the Phase I rule, a facility could demonstrate compliance with entrainment control requirements by establishing reductions in entrainment mortality for the new unit that are 90 percent of the reductions that would be achieved by closed-cycle cooling.

[5] For example, Dominion Energy's Brayton Point Station is retrofitting to natural draft cooling towers to meet NPDES permit requirements.

2. Option 2 – Impingement Mortality Controls at All Existing Facilities that Withdraw over 2 MGD DIF; Require Flow Reduction Commensurate with Closed-cycle Cooling By Facilities Greater Than 125 MGD DIF and at New Units at Existing Facilities

Under Option 2, all in-scope existing facilities would be required to achieve the numeric impingement mortality limits described in Option 1 above. In addition, this option would require flow reduction commensurate with closed-cycle cooling by facilities greater than 125 MGD DIF and at new units. Option 2 explores using the facility size, in terms of design intake flow (DIF), as a factor for establishing different BTA for different subcategories. EPA's analysis shows that a DIF of 125 MGD would be an appropriate threshold for this purpose. For all facilities that withdraw over 2 MGD but less than or equal to 125 MGD DIF, entrainment controls would be determined by the permitting authority on a case-by-case basis taking into account the factors at a particular facility. Requirements for new units at an existing facility would be the same as described in Option 1.

3. Option 3 – Establish Impingement Mortality Controls at All Existing Facilities that Withdraw over 2 MGD DIF; Require Flow Reduction Commensurate with Closed-Cycle Cooling at All Existing Facilities over 2 MGD DIF

Under this option, all in-scope existing facilities would be required to achieve numeric impingement mortality limits as described in Option 1 above. In addition, this option would require flow reduction commensurate with closed-cycle cooling by all facilities (including new units at existing facilities) as described in Option 2. Requirements for new units at an existing facility would be the same as described in Option 1.

4. Option 4 – Uniform Impingement Mortality Controls at Existing Facilities with Design Intake Flow of 50 MGD or more; BPJ Permits for Existing Facilities with Design Intake Flow Less Than 50 MGD; that Withdraw over 2 MGD DIF; Uniform Entrainment Controls for All New Units at Existing Facilities

Under Option 4, only in-scope existing facilities with a design intake flow of 50 MGD or more would be required to comply with uniform national impingement regulatory requirements as described in Option 1 above. In-scope facilities with a design intake flow less than 50 MGD would not be subject to the national impingement requirements in today's proposed rule but would continue to have their 316(b) permit requirements established on a case-by-case, best professional judgment basis. In the case of an existing facility below 50 MGD that adds a new unit, the flow associated with the new unit would be subject to the uniform entrainment requirements based on closed-cycle cooling. Finally, all existing facilities withdrawing in excess of 2 MGD of design intake flow would be subject to entrainment controls established on a site-specific basis.

Other Options Considered

In addition to the options discussed above and in the preamble, EPA also explored a number of other options that it ultimately rejected. No national-level compliance costs for these options are provided in Chapter 8; see Chapter 6 for unit-level costs. These options are presented below.

Other variations on the primary options: EPA evaluated numerous options that used the same principles as the options above, with impingement mortality addressed by screens and entrainment mortality based on closed-cycle cooling. Primarily, these options examined flow thresholds other than 125 MGD. EPA also evaluated various cost scenarios using the EPRI cooling tower cost tool, such as using "difficult" costs for all facilities.

Fine mesh screens: EPA evaluated an option where impingement mortality and entrainment mortality would be addressed jointly by the use of fine mesh (0.5 or 2 mm) screens. This analysis also included various design intake flow thresholds. As discussed in Chapter 6, EPA believes that due to the need to significantly expand the size of the intake at a large number of facilities, fine mesh screens are not an available and demonstrated candidate BTA technology for national standards.

Partial closed-cycle cooling: EPA evaluated an option that would have required facilities to install partial closed-cycle cooling; this option would achieve moderate levels of flow reduction (as compared to fully closed-cycle systems) but at a lower cost.

Seasonal closed-cycle cooling: This option would have required facilities to install closed-cycle cooling, but only operate the closed-cycle system during parts of the year that correspond to the most biologically sensitive periods in the source waterbody. This option would achieve moderate levels of flow reduction on an annualized basis but at a lower cost (primarily due to reduced O&M costs over the life of the equipment).

Capacity utilization: EPA evaluated options that included a facility's capacity utilization rate, including the 15 percent threshold used in the 2004 Phase II rule. These options included requirements for closed-cycle cooling for facilities above 15 percent.

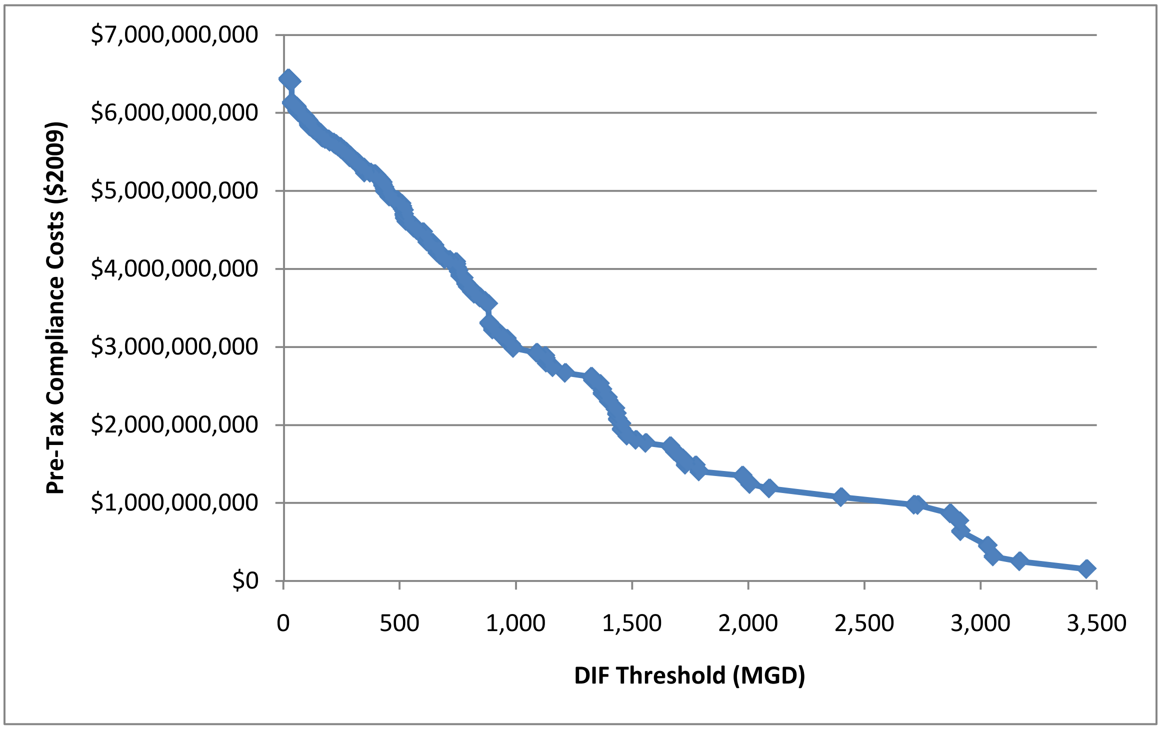
Waterbody type: EPA evaluated options that would establish different requirements for facilities located on different waterbody types, including the approach used in the 2004 Phase II rule.

Water efficiency: EPA examined various approaches to assess a facility's water use efficiency by comparing the volume of water withdrawn to the amount of electricity produced.

Extended implementation: EPA evaluated an extended compliance timeline for several options (especially those involving closed-cycle cooling) to mitigate concerns over grid reliability and add flexibility. As part of Options 2 and 3, EPA would provide flexibility to the Director to establish compliance timelines for each existing facility to mitigate grid reliability and local electricity reliability. For example, the Director could schedule facility compliance timelines to avoid multiple baseload facilities from being offline at the same time. In some cases, additional time to comply would allow opportunity for transmission system upgrades to further mitigate local reliability. Further, this would allow installation outages (downtime) to be coordinated with each specific facility's maintenance schedule. Under this option, most existing facilities would have no more than 10 years to complete the retrofit to closed-cycle cooling. The Director would determine when and if any such schedule for compliance is necessary, and if the facility is implementing closed-cycle as soon as possible. This provision would give the Director the discretion to provide nuclear facilities with up to 15 years to complete the retrofit, because all nuclear facilities are baseload generating units and the additional flexibility in timelines would further mitigate energy reliability, and because the retrofits at these types of facilities in particular involve additional complexities and safety issues. The 15 years for nuclear facilities also provides an opportunity to schedule the installation outage to coincide with safety inspections, uprates, and other outages due to major facility modifications. Manufacturing facilities could also receive up to 15 years to complete the retrofit to closed-cycle due to the complexity of manufacturing facilities, multiple process units and product lines, and to allow consideration of production schedules in setting such a timeline.[6]

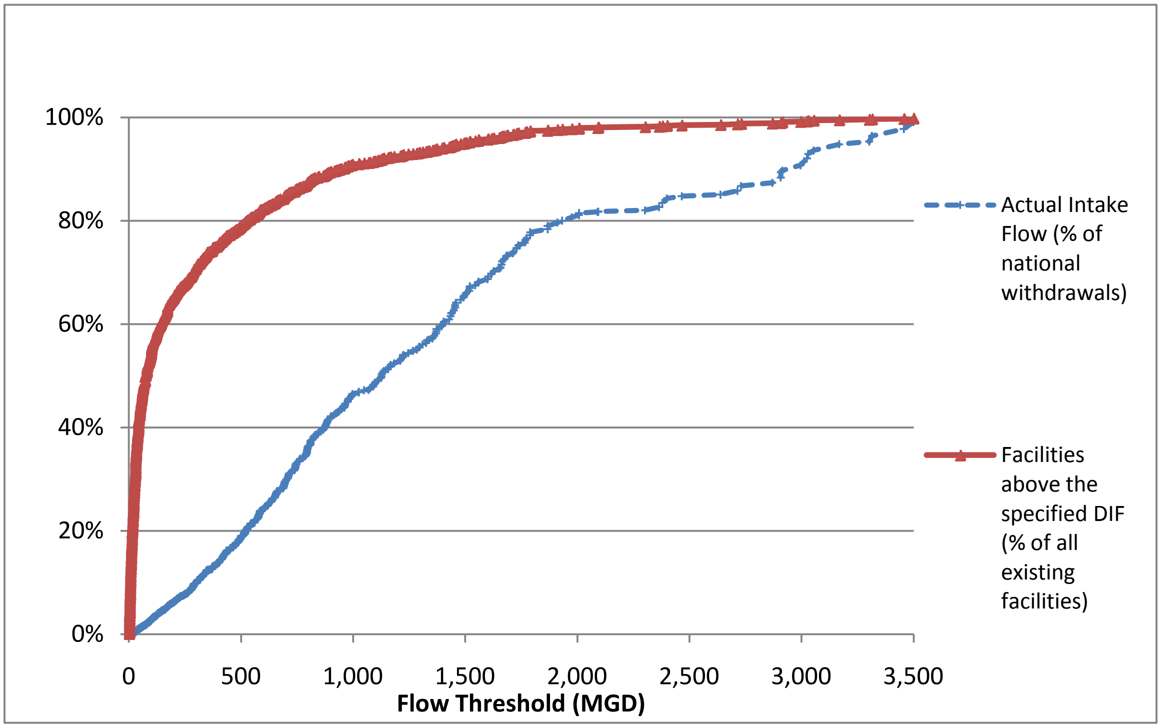
Exhibits 7-1 and 7-2 show cumulative plots by design intake flow of costs, flow, and facility counts.

Exhibit 7-1. Weighted Pre-Tax Compliance Costs ($2009) by DIF Threshold (MGD)



[6] While EPA's analyses show that there would be no national problems with grid reliability, it is possible that localized issues could arise if multiple plants in one area experience downtime simultaneously. For example, during EPA's site visits to the Los Angeles and Chicago areas, facility representatives noted that extended outages in those areas could be especially problematic given the limited transmission and generating capabilities within those cities. By allowing an extended timeframe for compliance, facilities, parent companies, and regulatory authorities could properly examine local and regional schedules to optimize when a given facility would go offline. Nuclear facilities were permitted a longer timeline to account for additional requirements due to NRC licensing and approvals, while manufacturers were allotted more time due to the fact that they have less frequent extended outages for some operating units, making scheduling for closed-cycle tie-ins more complicated.

Exhibit 7-2. Number of Facilities by Flow Threshold (MGD)



7.3 BTA Evaluation and Selection of Proposed Standards

EPA examined a range of technologies that reduce impingement and/ or entrainment, and evaluated these technologies based on a number of factors. As described above, closed-cycle cooling is the most effective technology for minimizing impingement mortality and entrainment mortality. However, after considering all of the relevant factors, EPA identified four factors that lead the Agency to conclude closed-cycle cooling is not the "best technology available" for a uniform national entrainment mortality standard for all facilities under Section 316(b). The four key factors for rejecting Options 2 and 3 in the BTA determination are: local energy reliability, particulate emissions, land availability inasmuch as it relates to the feasibility of entrainment technology, and remaining useful plant life. See the preamble for additional details on EPA's process for selecting BTA.

7.4 Site-Specific Studies to Inform the Selection of Appropriate Entrainment Controls

The proposed rule would require a site-specific determination of BTA. In that process, the permit writer would have access to all the information necessary for an informed decision about whether to adopt closed-cycle cooling or some other technology to reduce entrainment mortality at facilities above 125 MGD AIF. Thus, the proposed rule requires that the facility's permit application must include information to support such an evaluation. (See the permit application requirements at 122.21(r) for more information.) Following review of this information by the permit writer, the permit writer must determine what BTA standard for entrainment reductions to adopt and explain in writing the basis for that decision. The written explanation and the draft permit would then be available for comment from the interested public under EPA's normal permitting program.

Chapter 8: Costing Methodology

8.0 Introduction

This section describes the methodology and assumptions used to derive the technology compliance costs for facilities required to meet the proposed rule. For existing facilities, the Agency developed costs for 723 intakes at 519 model plants and these were then used in the economic analysis to scale to the total universe of in-scope facilities. For new units subject to entrainment mortality reduction requirements, the Agency derived estimates of new unit capacity and cooling water requirements and derived estimated annual compliance costs. In many ways, EPA used a similar, standardized approach to what was used in the previous 316(b) rules. For regulatory options where facilities were required to meet impingement mortality requirements (for which the technical basis is modified Ristroph screens) or make intake technology upgrades, EPA used a revised version of the cost tool developed in the Phase III regulation (and largely based on the cost modules developed for the 2004 Phase II rule). For regulatory options where facilities were required to meet entrainment mortality requirements (for which the technical basis is wet cooling towers), EPA used a cost model developed by the Electric Power Research Institute (EPRI) to develop costs for retrofitting wet cooling towers. EPA used facility-specific data from each facility that completed a detailed technical questionnaire (DQ) to create model facilities. By providing facility-specific data as an input to the cost models, EPA determined compliance costs for each DQ facility or intake structure.

EPA diverged from the cost methodology in the 2004 Phase II rule in one key respect: the costs derived for today's proposed rule use a model facility approach.[1] In contrast, the 2004 Phase II rule used a facility-specific costing approach where compliance costs attributed to every facility were calculated. For reasons discussed below, EPA determined that a model facility approach (where costs for a set of model facilities are calculated and then scaled to a national level) was more appropriate in determining the compliance costs for today's proposed rule. By costing each DQ facility as a model facility, and by using the survey weights developed for the DQ,[2] EPA is able to estimate total national costs.

EPA also developed costs for manufacturers and small power plants (formerly addressed under the Phase III rule), which are subject to the same requirements as large power plants under today's proposed rule. The general process of developing costs for these facilities was the same as that for large power plants, with some differences as discussed below.

EPA analyzed the compliance costs on two levels. First, as described in Chapter 7, EPA analyzed several regulatory options to address impingement mortality (IM) and

[1] Model facilities are statistical representations of existing facilities (or fractions of existing facilities); only those facilities that completed a DQ in EPA's survey effort in 2000 were included in cost development.

[2] The weighting factors were statistically derived from the industry questionnaire data using survey sample sizes. Weights range from 1 to 8.7. By weighting each model facility, the traits of the model facility (e.g., flow, technology type, capital costs) are extrapolated to represent the entire universe of facilities.

entrainment mortality (EM), including intake screens and flow reduction commensurate with closed-cycle cooling. Second, EPA assessed the national economic impacts of each regulatory option. The sections below describe these costs further.

8.1 Compliance Costs Developed for the Proposed Rule

The proposed rule requires that all existing facilities must meet impingement mortality requirements. Entrainment requirements for existing units may be established on a best professional judgment basis by the Director. For new units not subject to Phase I, the proposed rule requires intake flow reduction commensurate with closed-cycle cooling. The cost methodology used to estimate compliance costs for new units is described in Section 8.4 below. EPA also considered three other options involving closed-cycle cooling: one where all existing facilities would be required to reduce their intake flow to that commensurate with closed-cycle cooling; one where all existing facilities with an average intake flow (AIF) above 125 million gallons per day (MGD) would be required to reduce their intake flow to that commensurate with closed-cycle cooling, and one where repowered/rebuilt existing units would be required to reduce their intake flow to that commensurate with closed-cycle cooling. As described in the preamble to today's rule, the technology basis for these requirements is jointly based on the performance of modified Ristroph screens (for impingement mortality) and the performance of closed-cycle wet cooling towers (for entrainment mortality).

To develop appropriate compliance costs, EPA assigned costs for both sets of facilities. For facilities that are required to upgrade their screens, EPA used an updated version of the cost tool developed in the Phase III rule. In addition, facilities with intakes on oceans were assigned costs for seasonal deployment of barrier nets to reduce impingement of shellfish. For the facilities that are required to reduce their intake flow, EPA used a cost model developed by EPRI to develop capital and operation and maintenance (O&M) costs for retrofitting cooling towers at each model facility.[3]

8.1.1 Model Facility Approach

The model facility approach used in this effort involved calculating compliance costs for individual facilities for which EPA had detailed technical data regarding the intake design and technology. Specifically, these are the in-scope facilities that completed the year 2000 DQ survey. For facilities with screen upgrades, where facilities reported data for separate cooling water intake structures (CWISs), compliance costs were derived using the design intake flow for each intake and then these intake costs were summed to obtain total costs for each facility. For facilities required to reduce their flow, the EPRI model was applied to the maximum intake flow reported for each intake over the period 1996 to 1998. The facility's total costs were then multiplied by a weighting factor specific to each facility to obtain industry-wide costs for the national economic impacts analyses by extrapolating the impacts of the DQ facilities to all existing facilities.

[3] In some cases, a facility may have been assigned costs for both cooling towers and screen upgrades; if a facility's characteristics suggested that, even after reducing flow, its intake velocity would still exceed 0.5 ft/sec, costs for Ristroph screens were also included. See section 5 below.

The reasons for using a model facility approach include the following:

- Technical data for non-DQ facilities[4] was limited; specifically:
    - Design intake flow (DIF) volume was not requested, and values used previously by EPA were estimated on the basis of reported average flow.
    - Available intake technology data was generalized, and EPA could not be certain how reported technologies were distributed among multiple intakes.
    - Available intake technology data was not detailed enough to reliably ascertain whether the technology design met compliance requirements.
- EPA's industry questionnaire conducted a census of power plants expected to be within the scope of the regulations, but conducted a stratified sampling of manufacturers. As a result, EPA's survey data only encompasses a representative sample of manufacturers; information on unsurveyed facilities is not available.
- The survey sample frame did not include facilities in U.S. territories such as Puerto Rico and Guam, and the model facility approach allowed their inclusion using the weighting factors.
- Implementation of the 2004 Phase II rule revealed inconsistencies and errors in the costs for non-DQ facilities.

8.2 Impingement Mortality Compliance Costs

Compliance with IM requirements was based on the performance of an upgraded traveling screen technology—a modified Ristroph-type traveling screen or equivalent, plus a fish-friendly fish return system. Facilities may also comply with IM requirements by demonstrating that their design intake velocity is 0.5 feet per second of less.

For both power generation and manufacturing facility intakes, IM reduction compliance technology costs were estimated on a per-intake basis using data from the model facilities' DQs in the cost tool. Other input data were derived primarily from the information used to develop the Phase II cost modules. As much as possible, EPA used similar input data and cost calculation methodologies as were used in the 2004 Phase II rule in developing the estimated compliance costs for assigned compliance technology modules.

Using the model facility's input data, the cost tool assigns a compliance intake technology to each facility (or intake). A detailed discussion of how the cost tool makes technology assignments is provided below. EPA notes that the assigned technology for each model facility intake in the proposed rule may be different than that assigned for the 2004 Phase II Rule, because EPA made a number of revisions to the cost tool.[5] Through

[4] Facilities were sent either a DQ or an abbreviated short technical questionnaire (STQ). The STQ requested much less detailed information about the facility, its CWIS, and its operations. Of the approximately 1,200 surveys that EPA sent to electric generators, approximately 62 percent were STQs. All surveys sent to manufacturers were DQ surveys. For more information, see DCN 3-3077 (Statistical Summary for the Cooling Water Intake Structure Surveys).

[5] Revisions included adding more flexibility in assigning technology modules and revising some modules to reflect EPA's proposed regulatory framework.

the cost tool, EPA also accounts for any model facilities that have already installed technologies that meet the performance requirements in the proposed rule.[6] These facilities are assigned no compliance costs.

The cost tool output includes capital costs, O&M costs, pilot study costs, and the duration of facility downtime.

8.2.1 Selection of Technology to Address IM

Since the 2004 Phase II rule, EPA has revised and simplified the method for selecting IM reduction compliance technology. The IM technology used for estimating compliance cost was selected for each facility intake based on criteria such as existing through-screen velocity, presence of traveling screens, intake location, water depth, and total intake flow. A different technology selection decision tree was used for facilities with total intake design flows in the 2-10 MGD range, due to the facts that: (1) survey data indicated that fewer facilities in this flow range employed traveling screens as a baseline technology and (2) the availability of wedgewire screens as a technology option was greater at lower-flow intakes since the screens are smaller and site constraints such as water depth and conflicts with navigation are less problematic.

Since the compliance standard is based on the performance of modified Ristroph traveling screens, for the purpose of estimating compliance technology costs, EPA limited the applied technology options to the following:

- Replacement of existing traveling screen(s) with coarse-mesh modified Ristroph traveling screen(s) with fish return
- Installation of near-shore coarse-mesh wedgewire screen(s)
- Installation of larger intake with modified Ristroph traveling screen(s) with fish return
- Installation of velocity cap(s)
- Installation of fish barrier net(s) in addition to traveling screen(s) in marine environments.

The application of Ristroph screens is consistent with the levels of performance used to calculate the performance standard for IM. The other technologies (coarse mesh wedgewire and velocity caps) were not included in the calculations for the performance standard, but have shown that they are capable of consistently meeting the alternative standard for intake velocity. Barrier nets are intended to address problems with the impingement of shellfish.

[6] For example, a facility might already employ closed-cycle cooling or a technology that EPA deemed would meet the performance requirements. Some facilities also have unusually low intake flows and achieve similar performance to closed-cycle cooling.

8.2.2 EPA's Cost Tool

For the Phase III rule, EPA developed a cost tool to model the general methodology used in developing the compliance costs in the 2004 Phase II rule. For today's proposed rule, this cost tool was further modified to mimic the 2004 Phase II rule cost methodology as much as possible, as well as to increase its versatility. The modified cost tool used for today's proposed rule costs each intake structure independently, which could result in somewhat higher costs; facilities installing a technology at multiple intake structures would likely realize some economies of scale or other cost reductions. The cost tool was used to develop costs for both power plants and manufacturers.

The following modifications were made to the Phase III cost tool:

- The methodology for assigning compliance technology cost modules was modified (see below for more details).
- A model input value for Selected Technology Module was added to allow the user to specify which cost module(s) are applied.
- A model input value for Selected *Engineering News-Record* (ENR) Construction Cost Index (CCI) was added to allow the user to adjust costs for inflation.
- A model input value for Regional Cost Factor was added to allow specific regional cost factors to be used. Default values are average values for the state.
- Cost Modules 10, 10.1, and 10.2 were created to represent the costs for adding fish barrier nets (Module 5) to Modules 2, 2a, and 3 (combinations of fine mesh traveling screens and expanded intake structures). (See Exhibit 8-1 for a description of each module.)
- The same waterbody-specific default distances offshore were applied for relocating intakes to submerged offshore for all types of intake locations.
- The technology service life was added to the output.
- The input page was revised to allow selection of the Module 3 compliance screen velocity.
- An existing impingement technology code was added for wedgewire screens.
- The cost modules for new larger intakes (Module 3) and wedgewire screens (Modules 4, 7, and 9) were based on a design including fine mesh screens. However, compliance with the IM reduction technology requirements requires only coarse mesh. As a result, Module 3 was modified so that the traveling screens were sized based on a through-screen velocity of 1.0 fps and coarse (3/8-in) mesh instead of fine mesh screens. The cost for wedgewire screens, however, was not modified. Since smaller mesh sizes require larger screens due to the lower percent open area, the associated capital costs for Modules 4, 7 and 9 represent a conservative overestimate. Module 1 (replacing existing screens with modified Ristroph traveling screens and adding a fish return) always assumed use of coarse mesh and did not change.

A very important modification of the cost tool was the change to the methodology for selecting the compliance cost module for each model facility/intake. As noted above, facilities/intakes determined to already be in compliance were assigned no compliance technology costs. The methodology used to determine which facilities already met the compliance requirements is described below. All model facility intake structures determined to not be in compliance were assigned technology compliance modules as described below.

Facilities with a design intake flow between 2 and 10 MGD were assigned technology compliance modules using a slightly different decision process; in reviewing the questionnaire data, EPA noted that many facilities in this group did not use traveling screens. As a result, the technology choices these facilities would make are likely different than a facility that has an existing traveling screen that it can modify. This alternative process is also discussed below.

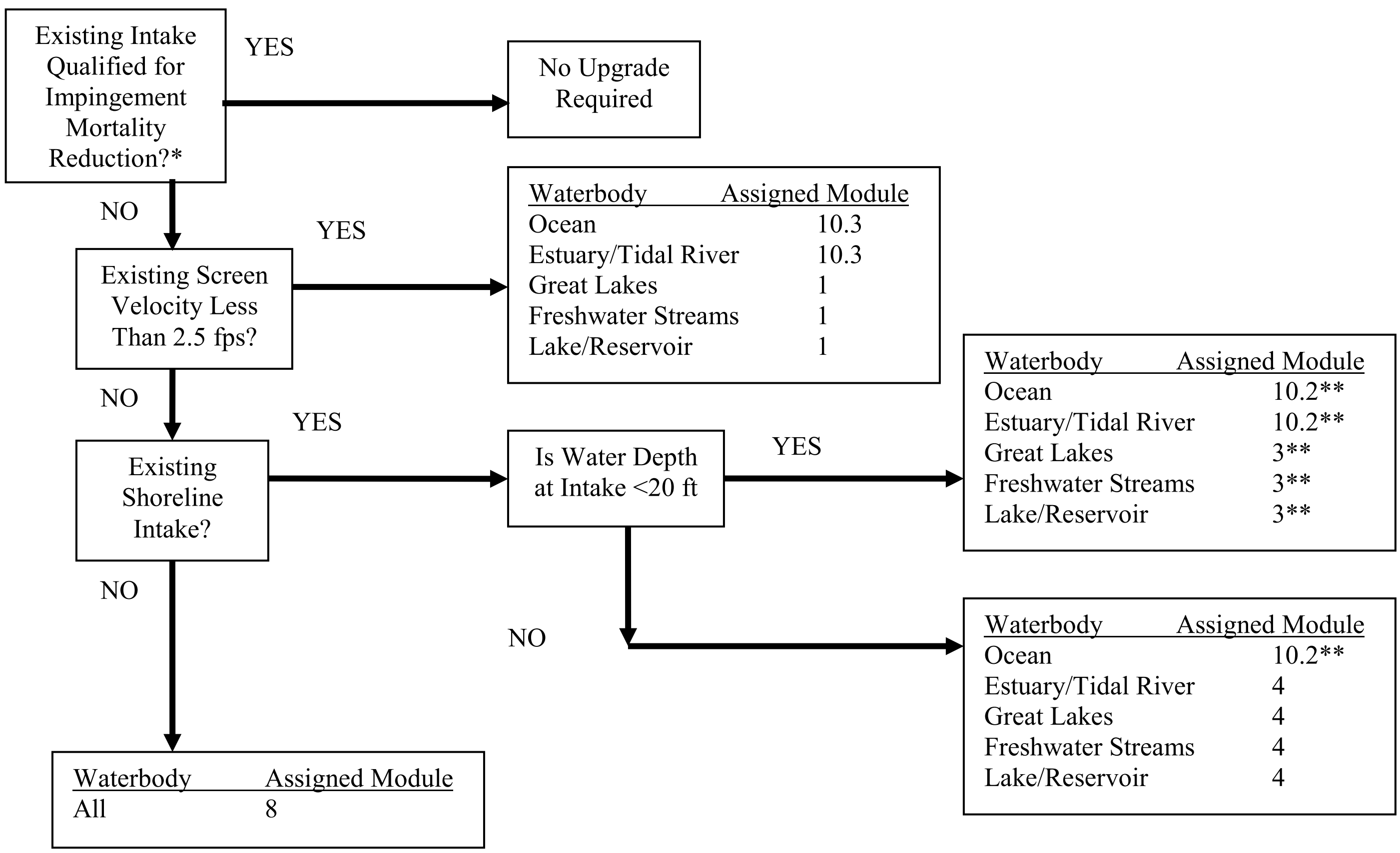
The addition of barrier nets to some technologies (e.g., Modules 10, 10.1, and 10.2) involved simply calculating the sum of the individual component cost modules. Because each cost module has a different O&M fixed factor, the fixed factor used in the combined modules was calculated as a weighted average using the gross compliance O&M for each component.

Exhibit 8-1 presents a decision flow chart that shows how the IM compliance cost modules were assigned to each facility/intake structure (with a DIF greater than 10 MGD) by the cost tool. Exhibit 8-2 shows the decision tree for facilities with a DIF between 2 and 10 MGD. The subsequent text describes the decision points in the flowchart (e.g., screen velocity) and other assumptions. Note that the second decision in the top row assumes that a facility with a fish handling and return system is already employing a traveling screen. Passive screens (e.g., cylindrical wedgewire screens) do not have separate fish handling and return systems.

Capital and O&M Costs

The modified cost tool provides individual facility/intake cost values for capital costs, fixed and variable O&M costs (baseline, gross, and net), estimated net construction downtime, and technology service life. The cost tool provides an inflation cost adjustment from the year 2002 dollars which were the basis for the 2004 Phase II rule. The data presented are adjusted using the ENR CCI. Cost data presented are adjusted for inflation using the February 2009 ENR CCI (8532.75).

Exhibit 8-1. Flow Chart for Assigning Cost Modules for Impingement Mortality Reduction Requirements for Facilities with Design Intake Flow >10 MGD Based on Meeting Performance of Modified Ristroph Traveling Screens



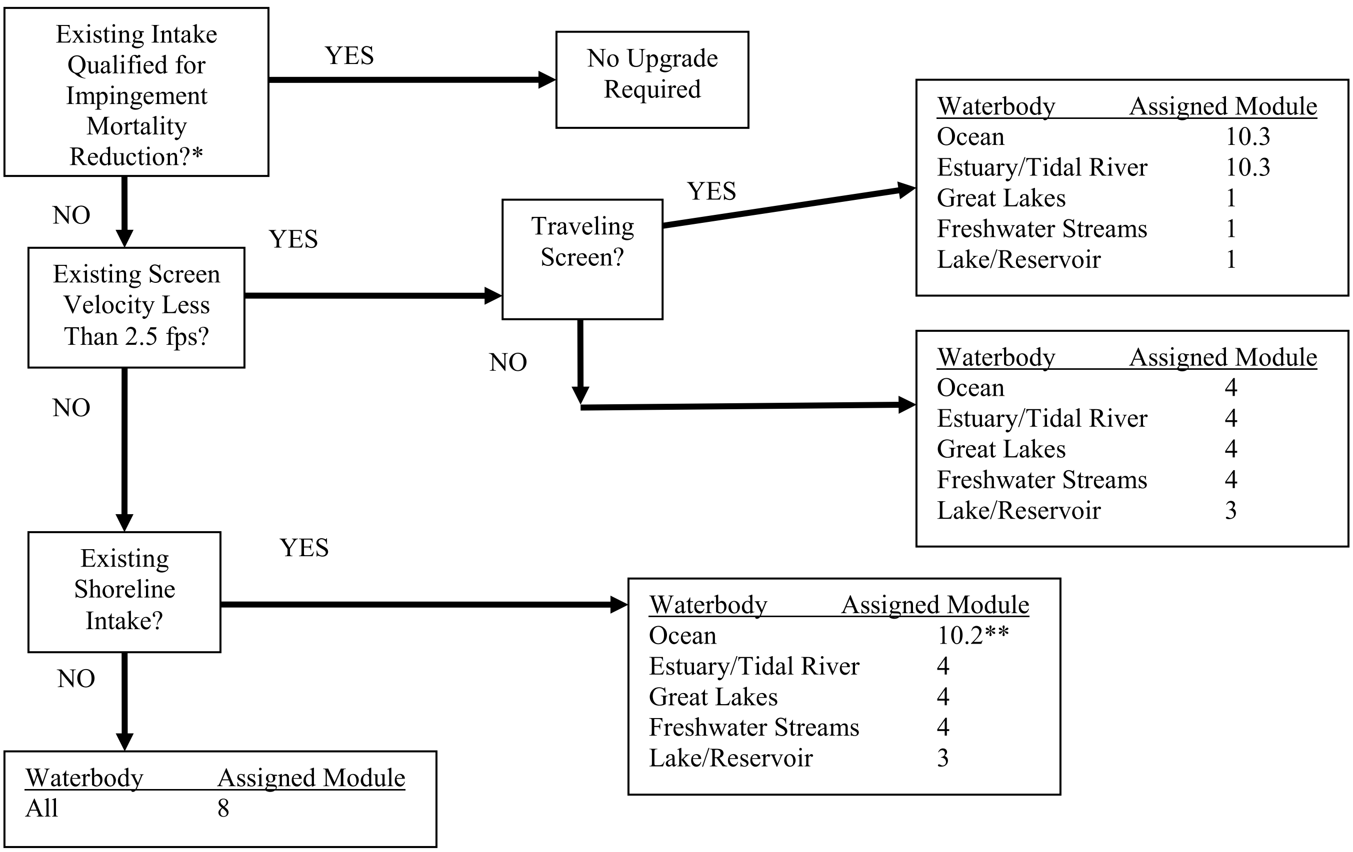
Cost Module Legend

*IM Qualifications Include:
- Modified Ristroph Type Screen
- Velocity Cap (≤0.5 fps)
- Wedgewire Screen

** Larger intakes are sized using design screen velocity of 1.0 fps and percent open area for 9.5 mm screen mesh (68%)

Module	Technology Description
1	Add Fish Handling and Return System (includes screen replacement)
2	Add Fine Mesh Traveling Screens with Fish Handling and Return
2a	Add Fine Mesh Overlay Screens Only
3	Add New Larger Intake Structure with Fish Handling and Return
4	Relocate Intake to Submerged Near-shore (20 M) with passive fine mesh screen (1.75 mm mesh)
5	Add Fish Barrier Net
6	Aquatic Fish Barrier (Gunderboom)
7	Relocate Intake to Submerged Offshore with passive screen (1.75 mm mesh)
8	Add Velocity Cap at Inlet
9	Add Passive Fine Mesh Screen (1.75 mm mesh) at Existing Inlet of Offshore Submerged
10	Module 2 plus Module 5
10.1	Module 2a plus Module 5
10.2	Module 3 plus Module 5
10.3	Module 1 plus Module 5
11	Add Double-Entry, Single-Exit with Fine Mesh, Handling and Return
12	Relocate Intake to Submerged Near-shore (20 M) with passive fine mesh screen (0.75 mm mesh)
13	Add 0.75 mm Passive Fine Mesh Screen at Existing Inlet of Offshore Submerged
14	Relocate Intake to Submerged Offshore with 0.75 mm passive screen

Exhibit 8-2. Flow Chart for Assigning Cost Modules for Impingement Mortality Reduction Requirements for Facilities with Design Intake Flow 2-10 MGD Based on Meeting Performance of Modified Ristroph Traveling Screens



Cost Module Legend

*IM Qualifications Include:
- Modified Ristroph Type Screen
-- Velocity Cap (≤0.5 fps)
- Wedgewire Screen

** Larger intakes are sized using design screen velocity of 1.0 fps and percent open area for 9.5 mm screen mesh (68%)

Module	Technology Description
1	Add Fish Handling and Return System (includes screen replacement)
2	Add Fine Mesh Traveling Screens with Fish Handling and Return
2a	Add Fine Mesh Overlay Screens Only
3	Add New Larger Intake Structure with Fish Handling and Return
4	Relocate Intake to Submerged Near-shore (20 M) with passive fine mesh screen (1.75 mm mesh)
5	Add Fish Barrier Net
6	Aquatic Fish Barrier (Gunderboom)
7	Relocate Intake to Submerged Offshore with passive screen (1.75 mm mesh)
8	Add Velocity Cap at Inlet
9	Add Passive Fine Mesh Screen (1.75 mm mesh) at Existing Inlet of Offshore Submerged
10	Module 2 plus Module 5
10.1	Module 2a plus Module 5
10.2	Module 3 plus Module 5
10.3	Module 1 plus Module 5
11	Add Double-Entry, Single-Exit with Fine Mesh, Handling and Return
12	Relocate Intake to Submerged Near-shore (20 M) with passive fine mesh screen (0.75 mm mesh)
13	Add 0.75 mm Passive Fine Mesh Screen at Existing Inlet of Offshore Submerged
14	Relocate Intake to Submerged Offshore with 0.75 mm passive screen

Pilot Study Costs

Pilot study costs were estimated in a similar manner as was done for the 2004 Phase II rule. Each technology is assigned a pilot study cost factor of either 0 or 0.1. The capital cost is multiplied by the pilot study cost factor to derive the estimated pilot study cost for the facility/intake.[7] A minimum pilot study cost of $150,000 in 2002 dollars was assigned if the calculated pilot study cost in 2002 dollars was lower than the minimum. For facilities with multiple intakes assigned the same technology, it was assumed that a pilot study would be performed at only one of the intakes and thus the highest individual intake pilot study cost was assigned to the facility.

For the proposed rule, few facilities were assigned pilot study costs. As described above, the process for assigning compliance technologies led many facilities to be projected to install Ristroph screens. This is a well-developed technology and typically does not require a pilot study. Facilities that were projected to install Cost Module 4 (relocate the intake to an offshore location with a fine mesh passive screen) were assigned pilot study costs, as this is a significant shift in operations and may be well-served by conducting a pilot study.

Construction Downtime

Construction downtime estimates are based on the estimated total downtime defined for each technology cost module in the 2004 Phase II Technical Development Document. It is assumed that the construction downtime will be scheduled to coincide with the normally scheduled facility maintenance downtime. Net downtime values are equal to the total estimated downtime minus the estimated average duration of the normally scheduled maintenance downtime period of 4 weeks.

The 2004 Phase II and Phase III downtime estimates generally focused on facilities with large intake flows, with the Phase II estimates being for facilities with DIF >50 MGD. For manufacturers, these values were then adjusted downward based on structural, process, and operational differences but not necessarily size. Similarly, a design flow in the 2 to 10 MGD range would tend to involve smaller structures with pipes in the 10-in to 22-in diameter range, rather than the 4-ft to 6-ft or more range for the larger systems. Thus, the scope of these intake construction projects is much smaller and the duration of each task should be correspondingly smaller as well. Accordingly, the net construction downtime for wedgewire screens for design flows of 2 to 10 MGD was assumed to be 3 weeks based on BPJ. Exhibit 8-3 presents the downtime estimates used for the assigned compliance technology cost modules.

[7] Typically, facilities with calculated capital costs below $500,000 (in 2002 dollars) are not assigned pilot study costs, because EPA assumes that facilities incurring smaller capital costs were unlikely to conduct a pilot study.

Exhibit 8-3. Net Construction Downtime for Impingement Mortality Compliance Technologies

Cost Module Number[1]	Power Generators (Weeks)				Manufacturers (Weeks)			
	Flow < 6,944 gpm	Flow 6,944 to 400,000 gpm	Flow 400,000 to 800,000 gpm	Flow > 800,000 gpm	Flow < 6,944 gpm	Flow 6,944 to 400,000 gpm	Flow 400,000 to 800,000 gpm	Flow > 800,000 gpm
1	0	0	0	0	0	0	0	0
3	2	2	3	4	0	0	1	2
4	3	9	10	11	3	7	8	9
5	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
10.2 (3 & 5)	0	2	3	4	0	0	1	2
10.3 (1 & 5)	0	0	0	0	0	0	0	0

[1]See Exhibit 8-1 for key to module numbers.

8.2.3 Identifying Intakes That Are Already Compliant With Impingement Mortality Requirements

Existing intakes that were considered to be IM compliant included those that:

- Employed modified Ristroph Traveling screens or equivalent[8] with a fish return
- Had a through-screen or through-technology velocity of ≤ 0.5 fps
- Employed velocity caps with an approach velocity of ≤ 0.5 fps
- Employed wedgewire screens with a through-screen velocity of ≤ 0.5 fps.[9]

Data from the 2000 DQ survey were used to determine intake compliance. Existing intakes for systems that employed closed-cycle cooling were not assumed to be IM-compliant and thus were assigned IM compliance technology costs unless the intake technologies met the above criteria.[10]

8.2.4 Development of Cost Tool Input Data

This section describes the development of the data input file for calculating technology upgrade compliance costs using the modified version of the Phase III cost tool. Where available, the same data used to develop the compliance technology upgrade costs for the

[8] Traveling screens were considered as equivalent to modified Ristroph if the survey reported use of a fish return, fish buckets, and low pressure spray, regardless of whether they were specifically identified as Ristroph in the survey.
[9] If wedgewire screen velocity data was not reported, the wedgewire screens were assumed to be compliant; EPA's experience has been that wedgewire screens are typically designed with a through-screen velocity of 0.5 fps.
[10] EPA expects that many facilities with existing closed-cycle cooling systems (particularly wet cooling towers) already meet the specified intake velocity threshold.

2004 Phase II rule were used as the basis for this effort. It is important to note that, in the 2004 Phase II rule, separate costs were derived for different CWISs at the same facility where such detailed data were reported. Such data was available for facilities that completed the DQ surveys. The use of multiple CWISs for costing has been retained in today's proposed rule. Therefore, for the DQ survey facilities, multiple intakes were included in the cost data input list, and separate costs were derived for each intake structure. For power generation facilities, separate cost estimates were derived for 406 intakes at 284 facilities. For manufacturers, separate cost estimates were derived for 317 intakes at 235 facilities.

Data Sources and Assumptions

Exhibit 8-4 below describes the source data and assumptions used in deriving the data value for each cost tool input variable.[11] Data from the DQ surveys is generally denoted as being derived from Question Qxx, which corresponds to the question on the survey instrument.[12] The assumptions and analysis of several inputs are more complex than the others and are further discussed immediately following the table.

Exhibit 8-4. Input Data Sources and Assumptions

Input #	Description	Assumptions/Discussion
1	Facility type	All power generation facility/intakes are assigned Code 2 and manufacturers are assigned Code 3.
2	Cooling system type	Based on response to DQ question Q1d. Assigned Code 1 (Full Recirculation) if the only items checked are recirculating cooling systems. System consisting of recirculating ponds were assigned Code 2. All else Code 0.
3	State	Data from Phase II and III Master.*
4	Waterbody type	Data from Phase II and III Master. Data was compared to survey data. Three facilities had portions of multiple intakes reassigned due to different waterbody types for different intakes.
5	Fuel type	Data from 2004 Phase II costing and confirmed with survey database. Primarily used to distinguish nuclear from non-nuclear facilities. Field not applicable to manufacturers.
6	Capacity utilization percent	Steam Capacity Utilization Rate (CUR) from Phase II Master with updates for facilities previously assigned CUR of 0 and with missing values. Updates are based on year 1999 EIA data. Field not applicable to manufacturers.
7	Input (intake) location	Coded using survey data. If multiple intake types were reported, then assigned codes using the following hierarchy: Submerged Offshore (Codes 4 or 5); Intake Canal; Embayment Bay, or Cove; Shoreline Intake (Codes 1 or 6). Two facilities did not report intake type and were assigned Shoreline Intake (Code 1).
8	Distance offshore, ft	Used survey data for DQ facilities with data in survey. Cost tool will assign defaults on the basis of the waterbody type if the survey value is zero or blank.

[11] See DCN 10-6655A for a blank cost tool with the input page.
[12] See http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/index.cfm for blank copies of the surveys.

Input #	Description	Assumptions/Discussion
9	Canal length, ft	Used survey data for DQ facilities with data in survey. Cost tool will assign defaults on the basis of the waterbody type if the survey value is zero or blank.
10	Waterbody use/ navigation	This field was not used for today's proposed rule.
11	Mean intake depth, ft	Used data from 2004 Phase II Rule and Phase III Rule cost development spreadsheets and survey data. Default value is 18 ft for power generators and 19 ft for manufacturers.
12	Intake well depth, ft	See detailed description below.
13	Exceeds 5 percent mean annual stream flow (1=Yes)	This field was not used for today's proposed rule.
14	Design intake flow, gpm	DIF data taken from Phase II and III Master. For facilities with multiple intakes, individual intake flow was obtained from survey database. Confirmed that sum was equal to total in Phase II and III Master.
15	New design intake flow, gpm	Used to estimate costs for Modules 3, 4, 7, 12, and 14. Set equal to maximum reported intake flow in DQ Question 25. Set equal to reduced intake flow if Closed-cycle cooling technology is applied.
16	Average intake flow, gpm	Average Intake Flow (AIF) data taken from Phase II and III Master. For facilities with multiple intakes, individual intake flow was taken from survey database. Confirmed that sum was equal to total in Phase II and III Master.
17	Design screen velocity (fps)	Values taken from 2004 Phase II Rule and Phase II Rule cost development spreadsheet and survey data. Default value is 1.5 fps for power generators and 1.2 fps for manufacturers.
18	Through-screen velocity flow basis	Survey requested design through-screen velocity. Therefore, Code 1 (Existing Equipment Design Intake Flow) was assigned to all.
19	Water type (1=marine, 0=fresh)	Code assigned according to waterbody type. Assumed Ocean and Estuary/Tidal River are marine. All others are fresh.
20	Debris loading (1=high, 0 = typical)	Values taken from 2004 Phase II and Phase III Rule costing. Blanks in spreadsheet were not assigned codes.
21	Impingement tech in-place	See detailed description below.
22	Qualified impingement?	See detailed description below.
23	Entrainment tech in-place	This field was not used for today's proposed rule.
24	Qualified entrainment?	This field was not used for today's proposed rule.
25	Avg annual Generation MWh (95-99)	This field was left blank.
26	Selected technology module	This field is used for specifying a compliance module for which costs are desired; if filled in, it will override the cost tool technology assignment.

*The Phase II and III Master files are confidential business information (CBI) files containing the most recent information for data fields that have been revised, such as DIF or a facility's being subject to the rule. Other data fields (such as intake location, facility state, and so on) are unlikely to change and are maintained in the original survey database.

Screen Well Depth (Input #12)

Compliance modules involving replacement or modifications of existing traveling screens (including the baseline O&M costs) require a cost input value for the total height of the traveling screens from the base to the deck, which is referred to as the screen well depth. This data was not reported in the technical surveys and the previous estimates were derived using the sum of the distances between top and bottom of the intake opening and the mean water level, which was not necessarily a correct interpretation of the data, especially for submerged intakes.

In this revised approach, EPA reviewed available screen well design data including data from facilities that were visited. Waterbody type appeared to be an important factor, since screen decks are generally situated at elevations that exceed expected extreme high water levels and the degree of variation in water levels tends to be similar among similar waterbody types. The data indicated that the difference between extreme high and mean water levels tended to be greater for rivers and streams and lower for tidal applications.

Exhibit 8-5 presents the assumed distance from the mean water surface to the screen deck that was derived from trends in the available data. The estimated screen well depth of each traveling screen was derived by adding the distances shown in Exhibit 8-5 to the mean intake water depth (Input #11). The resulting values in most cases resulted in greater assumed well depths than those that were used to derive the previous compliance cost estimates for the Phase II and Phase III Rules. This resulted in generally higher cost estimates for cost modules involving replacement or upgrade of existing traveling screens and for new larger intakes with traveling screens.

Exhibit 8-5. Assumed Height of Traveling Screen Deck Above Mean Water Level.

Waterbody	Assumed Distance from Mean Water Surface to Screen Deck (ft)
Ocean	15
Estuaries/Tidal Rivers	15
Great Lakes	15
Rivers and Streams	30
Lakes/Reservoirs	20

New Design Intake Flow (Input #15)

Depending on the selected compliance technology, the design flow used to estimate compliance technology costs was either the design intake flow for each intake (DIF) or the New Design Intake Flow. The New Design Intake Flow (NDIF) was set equal to the maximum flow volume that was reported for the years 1996 through 1998 in question 25 of the detailed survey or the DIF if no detailed flow data were reported. This maximum reported intake flow (MRIF) is assumed to be the maximum flow volume required for cooling and other purposes. For most intakes, the MRIF is smaller than the DIF because the reported DIF often included excess pump capacity that is either no longer needed or serves as backup. When calculating intake technology costs for compliance options that required closed-cycle cooling, the New Design Intake Flow was calculated by reducing the DIF by 93 percent of the non-contact cooling flow volume used to estimate the closed-cycle cooling system costs.

The DIF was used to estimate IM compliance if the selected compliance technology involved modification/replacement of the existing intake traveling screens (e.g., replace existing traveling screens with modified Ristroph traveling screens). The NDIF was used to estimate IM compliance if the selected compliance technology could be sized independently of the existing intake technology (e.g., wedgewire screens, velocity caps, or a new intake).

In the current approach, the cost for Module 5 (barrier net) was developed as a separate technology for each intake. In the 2004 Phase II rule, the barrier net costs were developed using the combined flow of multiple intakes at the same facility. This is based on the assumption that the multiple intakes are close enough together that they can be protected by a single barrier net.

Impingement Technology In-place (Input # 21)

The following criteria were used to assign impingement technology codes:

- Assigned Code 1 (Traveling Screens) if answered Yes to Q19c Traveling Screen Codes E1, E2, E3, E4, E5, E6, F (Other) if description qualified.
- Assigned Code 5 (Wedgewire Screen) if answered Yes to Q21b Passive Intake Code G.
- Assigned Code 2 (Passive Intake) if answered Yes to Q21b Passive Intake Codes H, I, J, K.
- Assigned Code 3 (Barrier Net) if reported Fish Barrier Net Code P in Q22b.
- Assigned Code 4 (Fish Diversion or Avoidance System) if answered Yes to Q22 Fish Diversion or Avoidance System Codes M, N, O, Q, R, S, T, U, V.

Qualified Impingement? (Input # 22)

As described above, some intakes utilize technologies that were considered to already meet the performance standard for impingement mortality. The following criteria were used to make this assessment:

- Assigned Code 1 (qualified) if design screen velocity was $\leq$ 0.5 fps.
- Assigned Code 1 (qualified) if survey indicated there was a combination of technology components associated with a Ristroph-type, fish-friendly traveling screen, including a separate fish return trough present. Included only intakes answering Yes to Q20a (are screens used to reduce impingement and entrainment?) and reporting several of the following:
  - Q20b (I&E Reduction System-Spray Wash/Fish Spray);
  - Q20b2 (I&E Reduction System-Fish/Debris Troughs);
  - Q20b4 (I&E Reduction System-Fish Buckets/Baskets/Trays);
  - Q23b Code W (Fish Pump);
  - Q23b Code X (Fish Conveyance Systems);

  - Q23b Code Y Fish Elevators/Lift Baskets);
  - Q23b Code AA (Fish Holding Tank);
  - Q23b Code BB (Other) provided description qualified.
- Assigned Code 1 (qualified) if there was a qualifying Fish Diversion or Avoidance System intake technology reported in Q22b including:
  - Code M (Velocity Cap); and
  - The design intake velocity of the technology is 0.5 ft/sec or less.
- Assigned Code 1 (qualified) if there was a qualifying Passive Intake System intake technology reported in Q 21b including:
  - Code G (Wedgewire Screen); and
  - The design intake velocity of the technology is 0.5 ft/sec or less.

If a technology applied to only a portion of parallel equipment (e.g., Ristroph screens on only a portion of screens), it was assumed that the lesser qualified technology was present on all equipment (i.e., the entire intake was designated as not qualified).

8.3 Entrainment Mortality Compliance Costs

To estimate costs of entrainment mortality (EM) controls using flow reduction, EPA developed an option that would retrofit facilities with once-through cooling systems to closed-cycle recirculating systems in the form of mechanical draft wet cooling towers. Costs were derived for cooling systems associated with individual intakes.

In September 2007, EPA obtained an Excel spreadsheet from EPRI that contained a set of calculations for estimating cooling tower retrofit costs at existing steam power plants. EPA compared the EPRI model to the methodology used in the Phase II NODA and found that the two methods produced similar costs. Because these methods produced similar costs and the EPRI method was simpler and more flexible, the EPRI methodology was chosen to develop the model facility cost equations for the proposed rule.

The EPRI methodology distinguishes between three separate capital cost values related to the degree of difficulty associated with the cooling tower retrofit. The costs are representative of an *easy* (lowest cost), *average* (intermediate cost) or *difficult* (highest cost) retrofit. EPA derived model facility capital costs equations for both the *average* and *difficult* retrofit scenarios for use in the applicable cost analyses.[13] These different levels of costs were applied differently to power generators and manufacturers.

[13] EPA used the average scenario for the power generator compliance cost scenarios that include closed-cycle cooling, because the costs were derived from power generation applications and are representative of costs on a national scale (i.e., some facilities might face a difficult scenario, but others will have an easy scenario, balancing costs on a national scale). For some IPM analyses, EPA used the difficult scenario because it represented the highest cost scenario and would provide an indication of worst case economic impacts. For more information, see the EEBA.

EPRI lists the factors that affect the selection of the degree of difficulty rating for capital costs as:

- Availability of tower space nearby
- Need to remove or demolish existing structures
- Whether the tower site elevation is higher than the existing cooling system intake bay so cold water can flow by gravity to the intake bay
- Whether there are underground interferences in the path of the new circulating water lines or at the location of the hot water sump and new circulating water pumps
- Whether the tower site has overhead interferences, including transmission lines
- Whether the tower design might have to work around excluded areas where activities that cannot not be moved or blocked occur (e.g., hazardous materials storage, vehicle turn-around areas, and security areas)
- The degree of construction work needed to convert the existing intake to handle the lower intake flow volume needed for make-up water
- How difficult it will be to tie the towers in to the existing cooling system
- Whether the site has unfavorable soil or geological conditions
- Whether the site has contamination that might require remediation

EPRI states that there is no simple way to determine how consideration of each of these items will translate into assigning the project into the easy, average, or difficult categories. If none of the items presents any obvious problems, an easy retrofit might be expected. If two or three do, average is probably appropriate. If more than three, then difficult is appropriate (DCN 10-6930).

EPA's costs for closed-cycle cooling include capital costs, O&M costs, energy penalty losses, and downtime costs.[14] EPA also included additional costs to account for noise and plume abatement, which will be required at some sites. Cooling tower costs were derived in a different manner than the intake technology costs (see below for more information). In the case of the intake technology costs, technologies were assigned to individual model facilities and the associated costs were calculated and scaled upward (using survey weights) to determine the national model facility costs. For the cooling tower costs, preliminary costs for individual DQ facilities were derived using the EPRI spreadsheet and then aggregated to generate cost equations representing the national average. The preliminary costs calculated for each intake using the EPRI calculation worksheet were then adjusted using the regional cost factor derived for that plant in the 2004 Phase II rule.[15] The model facility costs were then generated using these equations. As in the case of the intake technology costs, the model facility cooling tower costs were

[14] There are no pilot study costs for cooling towers (i.e., pilot study factor = 0). These technologies are well studied, and the performance can be predicted using meteorological and other site specific data.
[15] EPRI's cost methodology did not account for facility location. Construction costs do vary regionally, so EPA applied the regional cost factor.

then multiplied by a weighting factor specific to each facility to obtain national model facility costs.

8.3.1 Capital Costs

Power Generators

Since the EPRI costs were derived from cooling tower retrofit costs for power generation systems, it is reasonable to select the "average" difficulty costs as the basis for the compliance costs for cooling towers for power generation cooling systems. It was assumed that the recirculating flow rate of the cooling tower would be equal to the MRIF of the existing cooling system. Intake-specific costs were derived for the facilities with once-through cooling water systems that provided design flow data in the 2000 detailed surveys. Facilities were included in this portion of the analysis regardless of the capacity utilization rate (CUR), as this rate does not affect the DIF.

The ratio of capital cost to DIF (dollars/gpm) was then calculated for each plant. Various methods for using this data to estimate costs were evaluated, including using cost curve trend lines that varied with flow derived using Excel (which uses a least squares method) and a linear approach using the between-facility average or median of the dollars/gpm ratios. So as not to make assumptions that would lead to underestimating costs, EPA assumed that a simple linear equation using the overall between-facility average of the individual facility capital cost to DIF ratios (dollars/gpm) represented a reasonable estimate for the national model facility costs.

EPA also evaluated whether applying the facility weighting factors to the calculation of the average had any effect on the resulting average ratio of dollars/gpm and found that the value changed by less than 1 percent. The same was true for the O&M cost components as well.

EPA also recognizes that some generators are situated in locations that may require plume and/or noise abatement. It is not clear from the EPRI tower calculation support documentation whether the mix of retrofit projects from which the "average" difficulty costs were derived are representative of the universe of facilities that would be required to install closed-cycle cooling under the proposed rule. One concern is that the compliance universe will include a larger proportion of facilities requiring additional costs for requirements such as plume abatement, noise abatement, and space constraints.

EPA adopted a conservative approach to account for this possibility by modifying the cost for closed-cycle cooling systems at power generators. An analysis determined that approximately 25 percent of existing power generators may require additional costs associated with plume and/or noise abatement and space constraints. Rather than attempt to assign specific technology upgrade additional costs to specific facilities,[16] EPA spread these added costs throughout the entire universe of facilities that would be required to

[16] EPA's concluded that the estimated costs of plume abatement was close to the capital cost of the EPRI "difficult" scenario and should be representative of the cost of the mix of additional abatement technologies.

undergo closed-cycle cooling retrofits since the existing plant database did not contain sufficient detailed data to make a reliable determination regarding which specific facilities would be subject to these requirements. These added costs were spread across all facilities by adding the equivalent of 25 percent of the estimated additional costs for plume abatement technology to the cost assessed for all facilities. The estimated additional costs for plume abatement were considered as representative of the mix of costs associated with plume abatement, noise abatement, and/or space constraints. (See DCNs 10-6652 and 10-6653.)

Exhibit 8-6 presents the capital and O&M cooling tower cost formulas for the "average" difficulty cooling tower retrofit. Exhibit 8-7 presents the adjusted "average" retrofit cost factors modified to account for 25 percent plume abatement costs. The cost equations in Exhibit 8-6 were also used to estimate compliance costs for manufacturers where non-contact cooling water (NCCW) was used primarily for power generation purposes.[17] The cost equation factors in Exhibit 8-7 were used to estimate costs for power generating facilities.

Exhibit 8-6. Cooling Tower Costs for Average Difficulty Retrofit

Costs and Generating Output Reduction	Equation	Constant (2009)
Capital Cost (CC)	CC = MRIF(gpm) x Constant	$263
Fixed O&M Cost (OMF)	OMF = MRIF(gpm) x Constant	$1.27
Variable O&M - Chemicals (OMC)	OMC= MRIF(gpm) x Constant	$1.25
Variable O&M - Pump & Fan Power (OMV)	OMV= MRIF(gpm) x Constant	0.0000237
Energy Penalty -Heat Rate (EP) Non-nuclear	EP=MWS[a] x Constant	0.015
Energy Penalty -Heat Rate (EP) Nuclear	EP=MWS x Constant	0.025

[a] MWS is the total steam generating capacity in MW.

Exhibit 8-7. Capital and O&M Cost Factors for Average Difficulty Cooling Tower Retrofit with 25 percent Plume Abatement

	Capital Cost (2009 Dollars)	Fixed O&M (2009 Dollars)	Variable O&M – Chemicals[a] (2009 Dollars)	Variable O&M - Pump & Fan Power
	Dollars/gpm	Dollars/gpm	Dollars/gpm	MW/gpm
Average Retrofit	**$263**	**$1.27**	**$1.25**	**0.0000237**
Add for Plume Abatement at a Single Facility	$120	$1.00	$0.00	0.0000031
Average Increase if Applied to 25 percent of Facilities	$30	$0.25	$0.00	0.0000008
Adjusted Constant	**$293**	**$1.52**	**$1.25**	**0.0000245**

[a] Non-power variable O&M costs are for additional treatment chemical for optimized tower operation at higher cycles of concentration

[17] The NCCW flow was considered as being primarily for power generation if the answer to question 4a and 4b in the DQ survey indicated that >85 percent of the cooling water was used for power generation purposes.

Manufacturing Facilities

For manufacturing facilities, EPA recognizes that cooling tower retrofits will need to be integrated into the existing manufacturing processes at different locations within the plant and it is expected that in many instances difficulties will be encountered to a greater degree and frequency than at power generators. Such difficulties may involve space constraints, reconfiguration of process piping, long piping runs, conflicts with existing piping and infrastructure, and utilities. These are some of the factors that EPRI cited as contributing to a "difficult" designation for a cooling tower retrofit. In addition, the cooling towers are likely to be installed as smaller units serving individual processes throughout the plant, thus reducing the opportunity for savings from economies of scale that may be achievable at power generators.

As a result of these considerations, EPA applied the "difficult" retrofit capital costs to any closed-cycle cooling system retrofit at a manufacturer, with the exception of instances where cooling water was used primarily for power generation purposes, as described above. In such cases, the "average" difficulty costs shown in Exhibit 8-6 were applied.

Exhibit 8-8 presents the "difficult" retrofit cost equations utilized for estimating closed-cycle cooling system costs for manufacturing facilities. Like power plants, the costs for manufacturers are also based on the MRIF; however, as described below, manufacturers have some key differences that were incorporated into determining the appropriate flow for designing a cooling tower system.

Exhibit 8-8. Cooling Tower Costs for Difficult Retrofit

Costs and Generating Output Reduction	Equation	Constant (2009)	Units
Capital Cost (CC)	CC = MRIF(gpm) x Constant	$411	Dollars
Fixed O&M Cost (OMF)	OMF = MRIF(gpm) x Constant	$1.27	Dollars
Variable O&M - Chemicals (OMC)	OMC= MRIF(gpm) x Constant	$1.25	Dollars
Variable O&M - Pump & Fan Power (OMV)	OMV= MRIF(gpm) x Constant	0.0000237	MW
Energy Penalty - Heat Rate (EP) Non-nuclear	EP=MWS[a] x Constant	0	MW
Energy Penalty - Heat Rate (EP) Nuclear	EP=MWS x Constant	0	MW

[a] MWS is the total steam generating capacity in MW.

Intake Flow Used To Estimate Costs

Aside from the difficulty of installation and retrofit, there is generally little difference in the operation of cooling water intake structures and cooling systems between power plants and manufacturers. Both types of facilities use cooling water in similar ways. However, manufacturers have one fundamental difference—they tend to use more process water and contact cooling water. In many cases, process water is withdrawn via the same intake structure as cooling water, creating a more complicated water balance diagram.[18]

[18] Reuse of cooling water as process water also presents a regulatory challenge, as these flows are no longer considered cooling water.

Cooling water can consist of both non-contact cooling water (NCCW) and process contact cooling water (CCW). Contact cooling water which comes into direct contact with process chemicals and materials can pick up contaminants during the cooling process and may require treatment to remove contaminants if it is to be recirculated through a cooling tower and reused in the process. In some cases (e.g., certain steel-making processes), the required treatment process may be minimal (e.g, settling), but in others, flow reduction is not possible without materially affecting the facility's operations or products since the water quality requirements for the contact cooling water may render recirculation of CCW impractical since manufactured product quality and/or process performance may suffer without costly treatment. For this reason, EPA did not consider flow reduction using closed-cycle cooling as a readily available technology option for CCW or combined flows that included CCW or process water that could not be segregated. Therefore, closed-cycle cooling was only applied to the estimated NCCW component of the intake flow for manufacturers.

As a result, EPA reviewed a number of flow balance diagrams from the DQ industry questionnaires for facilities in multiple industrial sectors and developed an estimated proportion of total intake flow that is dedicated to cooling.

At power generators, the majority of intake water is used as non-contact cooling water for condensing steam and equipment cooling (service water). Only a small portion is used for process water or contact cooling. Therefore, for cost estimation purposes, the NCCW flow was assumed to be the entire intake flow. For power plants that provided intake flow data in question 25 of the technical survey, the MRIF was used as the cooling tower design flow. Otherwise, the DIF was used.

For manufacturing facilities, the proportion of intake water used for process, NCCW, and CCW purposes varied widely between industry types and facilities within each industry. In order to determine water use trends at manufacturers, EPA examined data reported in the 2000 detailed technical surveys for the large flow facilities with DIF >100 MGD. The detailed technical survey requested information concerning percent of cooling water flow used for: 1) electric generation; 2) air conditioning; and 3) contact or non-contact process cooling. Unfortunately the survey did not distinguish between contact and non-contact process cooling water, so schematic flow diagrams were also examined since they often contained additional data concerning flow volumes and specific water uses. All available data concerning the following items from both the survey responses and the schematic flow diagrams were then summarized in a database with the following components:

- Plant ID
- Design intake flow (DIF)
- Maximum reported intake flow (MRIF)
- Average intake flow (AIF)
- Cooling system type
- Industry type
- Non-contact cooling flow (NCCW)

- Non-contact cooling flow used mostly for electricity generation
- Process and/or contact cooling flow
- Answer to survey question 4a or 4b (percent cooling water used for electricity generation)
- Answer to survey question 3h (estimated percent of design capacity used for cooling)
- Detailed notes

"Type of cooling water use" and "flow volume" data was available in only a portion of the schematic diagrams. However, enough data was available to estimate NCCW flow for four or more facilities that could be categorized into one of the following industrial groups:

- Chemicals
- Paper
- Petroleum
- Metals
- Other

With NCCW flow data now available for this subset of facilities, a methodology was derived to estimate NCCW flows for other facilities in the database. In order to simplify the approach, it was assumed that the general mix of process water, NCCW, and CCW use would be somewhat similar within each of these major industry groups.

The NCCW flow for each facility was then compared to available flow data representing total flow. Three factors based on the total NCCW flow were then evaluated to see if they would be suitable for estimating the NCCW component at facilities where detailed data were not available. For each factor, the total NCCW flow value taken from the schematic diagrams was divided by the total process and cooling flow from the diagrams, the DIF and the MRIF. Facilities with low NCCW flow values that employed cooling systems other than once-through or where the total flow (from the flow diagram in the survey) was much lower than the AIF were not included in the analysis, since the NCCW flow data for these facilities may not have included the volume of recirculating cooling water. The remaining ratios were then averaged for all facilities with such data in each industry group. Exhibit 8-9 presents the results of this analysis.

Exhibit 8-9. Ratio of Non-Contact Cooling Water Flow to Total Facility Flow for Evaluated Manufacturing Facilities With DIF >100 MGD

Plant Type	NCCW /Diagram Total (%)	Number with Data	NCCW /MRIF (%)	Number with Data	NCCW /DIF (%)	Number with Data	Value Selected for Estimation
Chemicals	80.2%	5	**70.5%**	2	50.2%	5	**70.5%**
Other	96.0%	5	**75.5%**	3	65.4%	5	**75.5%**
Paper	77.6%	3	**64.0%**	1	33.9%	4	**64.0%**
Petroleum	81.6%	4	**82.4%**	3	31.6%	4	**82.4%**
Metals	83.8%	7	46.3%	2	**53.5%**	6	**53.5%**

As can be seen from Exhibit 8-9, the trend is for the ratio of "NCCW/Diagram Total" to be greater than the ratio of "NCCW/MRIF" which is greater than the ratio of "NCCW/DIF." EPA concluded that the ratios of "NCCW/Diagram Total" were less suitable for extrapolating to other facilities since the values were on the high side and corresponding diagram totals would not be available for the majority of facilities that were not evaluated. The ratio of NCCW/DIF tended to be lower than the ratio of NCCW/MRIF due to the fact that the MRIF was often lower, since the DIF often included intake capacity that was seldom, if ever, actually utilized. Therefore, with the exception of the metals category, the average ratio of NCCW/MRIF was selected as the factor to be used in estimating NCCW flows using MRIF data. In the case of the metals category, the ratio of NCCW/DIF was greater and was selected as the factor to be used in estimating NCCW flows since it was the median of the three values and was based on a larger number of data points.

The selected factors were then used to estimate the total NCCW flow for each manufacturing facility in their respective categories by multiplying the factor times the MRIF. In cases where MRIF data were not available, the DIF was used which may result in some overestimation of the NCCW flow volume. For those facilities used to derive these factors where actual NCCW data were derived from the flow schematics, the actual NCCW value was used instead.

8.3.2 O&M Costs

The EPRI Tower Calculation Worksheet also produces a general O&M cost on the basis of the facility's DIF. This cost is assumed to be a fixed O&M cost component consisting primarily of labor and materials. The general fixed O&M cost was then adjusted using the regional cost factor. Unlike the O&M costs calculated for intake technologies, the O&M costs for the baseline intake technology were not deducted (except as noted below under pumping height) for facilities converting to cooling towers. The use of a closed-cycle cooling system will still require an intake system for make-up water. Although the intake volume will be smaller, it will require O&M costs, which are assumed to be more than offset by the existing intake O&M costs.

The EPRI worksheet also generates an O&M cost associated with pump and fan energy requirements. This is assumed to be a variable cost component that would vary with the operation of the generating units. The value derived here is associated with generating units operating at full capacity. Unlike the fixed O&M cost, this component was not adjusted using the regional factor because it is expressed in units of power consumption, which is not dependent on the facility's region.[19]

As with the capital costs, the fixed O&M to DIF ratio (dollars/gpm) and variable O&M to DIF ratio (MW/gpm) were calculated. The Excel trend lines for the O&M costs and power requirements were plotted against DIF, and average and median ratios of costs and power requirements versus DIF were then compared. As with the capital costs, the average of the facility ratios of fixed O&M to DIF (dollars/gpm) and variable O&M to DIF (MW/gpm) represented reasonable estimates for the national model facility costs.

The EPRI worksheet contains numerous assumptions and default values that can be modified using site-specific data. Specific relevant assumptions and default values are listed below:

- Tower configuration was in-line rather than back-to-back, meaning towers are oriented in single rows rather than rows of two towers side by side.
- ΔH1 (Elevation rise from sump level to pump level) was set at 0 ft.[20]
- ΔH2 (Elevation rise from pump to tower site) was set at 0 ft.
- ΔH3 (Height of tower hot water distribution deck) was set at 25 ft.
- Recirculating water pipe flow velocity was set at 8 fps.
- Tower loading rate was 10,000 gpm/cell

The EPRI cost worksheet also assumes that O&M costs are the same for cooling towers with different retrofit difficulties. Thus, the same O&M costs were applied to all cooling tower retrofits, regardless of the difficulty of the retrofit. EPA assumed the EPRI O&M costs were based on current operating methods employed at power generators, which often involved minimal use of chemical treatment and operation at lower cycles of concentration. As described below, further adjustments to O&M costs were made for plume abatement and for optimized operation with regards to flow reduction.

[19] The EPRI worksheet can also derive pump and fan energy costs in dollars using heat rate and fuel cost data, but this feature was not used. The input value for the national economic impacts analysis O&M pump and fan energy component is the electric energy requirement in MW, not the cost in dollars. The MW value derived from the equation represents the maximum energy requirement at full-capacity operation and is expected to be reduced when the plant is operating at less than full capacity.

[20] Although the default values of ΔH1 and ΔH2 were 5 ft and 10 ft, respectively (15 ft total), they were set equal to 0 in EPA's cost estimates to offset a portion of the baseline once-through surface water intake pumping energy requirement that would no longer be needed (i.e., the facility's intake structure will be withdrawing less water and will require less energy; these savings were recouped by using different assumptions for ΔH1 and ΔH2).

Plume Abatement Costs

Adjustments to O&M for cooling towers with plume abatement technology included an increase in energy requirements and fixed O&M costs. The increase in energy requirements was based on an assumed 8 ft increase in pumping head and a 10 percent increase in fan energy to account for additional demands created by addition of the dry section coils. The increase in the fixed O&M component was based on an assumed 80 percent increase in O&M costs for the additional maintenance associated with the dry cooling section equipment. A more detailed discussion can be found in the "Cooling Tower Noise Abatement and Plume Abatement Costs." (See DCN 10-6652.) These costs are shown as the cost adjustment factors in Exhibit 8-7 above.

Optimization Costs

EPA found that current practice regarding chemical treatment of circulating water at power generators mostly involved treatment with biocides such as chlorine, and that there was often no incentive to optimize (reduce) makeup flows by operating at higher cycles of concentration. Operating a closed-cycle cooling system at higher make-up and blowdown volumes results in higher intake flow volumes and lower cycles of concentration. Lower cycles of concentration generally reduce the need for careful operational control and chemical treatment for scale formation or suspended solids deposition. EPA assumed that compliance with the regulatory options for flow reduction would include the operation of closed-cycle systems in an optimized manner, which may include operating at higher cycles of concentration.[21]

To account for this, EPA increased the O&M cost estimates derived from the EPRI model by adding another variable cost component to cover increased use of chemical treatment. This component included additional costs for both increased chemical treatment and added labor (See "Water Balance, Flow Reduction, and Optimization of Recirculating Wet Cooling Towers," DCN 10-6673). Capital costs were not adjusted, since the estimated cost of flow monitoring and chemical feed systems was very small—equal to about 0.2 percent of the "average" difficulty retrofit cost. These costs are shown as the chemical treatment cost component equations and factors in Exhibits 8-6 and 8-8 above.

8.3.3 Energy Penalty

The term "energy penalty" as associated with conversion to closed-cycle cooling has two components. One is the extra power required to operate cooling tower fans and additional pumping requirements, referred to as the parasitic energy penalty. The other is the lost power output due to the reduction in steam turbine efficiency due to an increase in cooling water temperature, referred to as the turbine efficiency penalty.

[21] As noted in the preamble, EPA assumed 3.0 and 1.5 cycles of concentration for fresh and marine waters, respectively.

Parasitic Loss

The parasitic fan and pump energy penalty is included as a separate component in the O&M costs described above and was applied in all cases. The parasitic penalty was estimated as MW of power required, which was then converted to costs in the economic model.

Turbine Efficiency Loss

The energy penalty associated with turbine efficiency loss due to the conversion from once-through to recirculating cooling towers is best expressed as a percentage of power generation.[22] To offset the efficiency loss, a facility can increase its fuel consumption if the steam boilers are operating below full capacity or it could experience a reduction in electricity generated if the steam boilers are operating at full capacity and are unable to increase steam output.

The turbine efficiency penalty is typically expressed as a percentage of power output. In the Phase I Rule, EPA estimated an annual average energy penalty of 1.7 percent for nuclear and fossil-fuel plants and 0.4 percent for combined cycle plants. The estimated maximum summer penalty was 1.9 percent. The EPRI supporting documentation (DCN 10-6930) estimates the energy penalty to range between 1.5 percent and 2.0 percent, and the EPRI cost model uses 2.0 percent as the built-in default.

To reflect the differences in steam pressure for facilities using different fuels,[23] EPA distinguished between nuclear and fossil plants. Fossil plants experience a lower turbine efficiency loss due to the higher system pressures, while nuclear plants would realize a higher efficiency loss. As a result, EPA selected a turbine efficiency loss value of 1.5 percent for fossil plants and 2.5 percent for nuclear facilities, which is consistent with the default value of 2.0. This value applies directly to the generation rate of the steam generating units, and thus the cost will vary with the amount of electricity being generated. (See "Cooling Tower Energy Penalties" [DCN 10-6670] for a more detailed discussion).

For closed-cycle cooling retrofits at manufacturing facilities or intakes that do not primarily generate electricity, no turbine efficiency energy penalty was assigned since no power is being generated. For manufacturing power generation systems, the energy penalty for turbine efficiency loss for non-nuclear power plants (i.e., 1.5 percent) was applied.

[22] Typically, cooling towers do not cool the circulating water to the same temperature as surface water used in once-through cooling. As a result, the steam is not cooled as effectively leading to a higher steam turbine backpressure and a loss of generating efficiency.
[23] Steam turbines at nuclear facilities tend to operate at lower steam temperatures and pressures; therefore the energy penalty associated with turbine efficiency is expected to be higher for nuclear power facilities than for fossil-fuel facilities.

8.3.4 Construction Downtime

Power Generators

In addition to the costs described above, a facility might also incur downtime costs. The duration or cost of the construction downtime is not estimated by the EPRI worksheet. In the Phase II NODA, EPA assumed net construction downtimes of 4 weeks for non-nuclear plants and 7 months for nuclear plants. These net values assume that the construction tie-in would be scheduled to coincide with the plant's routine scheduled maintenance event. Thus, the net value includes a deduction of the estimated maintenance downtime period (4 weeks for non-nuclear facilities) from the total estimated downtime. EPA asked for comments in the Phase II NODA regarding these assumptions but then did not make any conclusions regarding the comments because the cooling tower option was not included as part of the basis for the 2004 final rule.

While most comments stated that site-specific analyses would be required for downtime estimates, one commenter (DCN 6-5049A, Comment ID 316bEFR.303.010) did cite an estimate that each generating unit at Brayton Point (a non-nuclear facility) would require 7 months' downtime in addition to scheduled maintenance. However, this was a projection based on information at the time. Since then, Dominion Energy purchased Brayton Point and agreed to retrofit natural draft cooling towers. Construction is currently underway and construction schedules indicate that tie-in for each unit will require approximately one month.

Riverkeeper (DCN 6-5049A, Comment ID 316bEFR.332.001) argued that the 7-month period for nuclear plants was too long and that the extended duration for the Palisades plant included additional activities not associated with the cooling tower retrofit. EPA responded to Riverkeeper's comments by suggesting that the 7-month period might be on the low side because it is based on historical refueling duration of 2 to 3 months, which has recently dropped to 30 to 40 days. These offsetting arguments support a decision to retain the 7-month net downtime for nuclear power plants.

Another commenter (DCN 6-5049A, Comment ID 316bEFR.041.023) stated,

> [I]nquiries made by [the Edison Electric Institute (EEI)] to engineering experts with extensive experience in this field suggest that, for a fairly simple retrofit, two months would be a more reasonable estimate, while for more complicated situations three to four month outages would be the minimum expected.

Besides the type of plant, another factor investigated for consideration in estimating construction downtime was CUR. Presumably facilities with low CUR values would have greater opportunity to schedule cooling tower tie-in construction activities such that they coincide with downtime periods of greater duration than the 4-week scheduled maintenance period assumed in the 2004 Phase II rule. A review of monthly flow data reported in the surveys for a sample of facilities with year 2000 CUR values in the 15 percent to 30 percent range was conducted. The data indicated that the cooling water systems at most of these facilities operated at least a portion of every month during each of the three years reported in the survey (1996, 1997, 1998). Thus, there did not appear to be additional scheduled downtime available for these facilities, so CUR was not considered further.

In the 2004 Phase II rule, EPA assumed that most power plants schedule periodic maintenance outages with an average duration of 4 weeks. As a result, the net lost generation downtime for economic estimation was assumed to be the estimated construction downtime minus 4 weeks.

While Hunton & Williams gives a range of 2 to 4 months depending on difficulty, EPA has examples of retrofit tie-ins of even shorter duration from its site visits, ranging from 83 hours at Jefferies Station (South Carolina) to 30 days for each unit at Canadys Station (SC). Given this range of from less than 1 up to 4 months (or longer for a few exceptions) depending on the difficulty, the original assumption of 2 months total for non-nuclear plants appears reasonable. Thus, the assumed net downtime for non-nuclear power plants remains 4 weeks. Exhibit 8-10 below summarizes the net downtime estimates.

Exhibit 8-10. Net Construction Downtime

Fuel type	Net Downtime (Weeks)
Nuclear	28
Non-nuclear	4

Manufacturers

Downtime for manufacturers was assumed to be less than downtime for electric generators, as manufacturers are often more segmented in their production and use of cooling water and are more likely to be able to shut down individual intakes or process lines without interrupting the production of the entire facility.

Given that the Phase III rule did not consider regulatory options requiring closed-cycle cooling, EPA has not previously developed estimates for downtime at manufacturers for cooling tower retrofits. For today's proposed rule, EPA is assuming that manufacturers will experience no downtime for these retrofits in excess of maintenance downtime that may already occur.

EPA recognizes that some manufacturers or individual process lines/units may operate 100 percent of the time and scheduled outages for maintenance on these units is rare and may be several years between outages.[24] However, EPA also recognizes that most manufacturing facilities or individual lines/units do not operate under these conditions and would be able to schedule downtime for a tie-in for a closed-cycle cooling system. Additionally, some facilities may be able to take advantage of stored or stockpiled raw materials (to avoid a bottleneck created by the offline unit) or may purchase or transfer these intermediate materials from other vendors or parts of their facility. As a result, for

[24] See EPA's site visit reports for manufacturing facilities.

a national-scale assumption, EPA determined that zero downtime was a reasonable assumption for manufacturers.

8.3.5 Identifying Intakes That Are Already Compliant With Entrainment Mortality Requirements

Existing intakes that were considered to be EM compliant included those that:

- Reported using a closed-cycle cooling system using towers only (i.e., not in conjunction with any other type of cooling system)

Data from the 2000 detailed technical survey were used to determine intake compliance.

Existing intakes for systems that employed closed-cycle cooling were not assumed to be IM-compliant and thus were assigned IM compliance technology costs unless the intake technologies also met the criteria for IM compliance.

Combination Cooling Systems

Intakes for cooling systems that reported using a combination of cooling system types (e.g., one intake is used to supply a once-through unit and a closed-cycle unit) were treated as if all cooling water flow was once-through. Intakes that reported closed-cycle cooling systems using ponds were also treated as if all cooling water flow was once-through. This was done because there was insufficient data available to determine which portion of the intake water was used for once-through and which as make-up for existing closed-cycle cooling, or whether the cooling pond operation represented closed-cycle cooling. This approach is expected to produce conservative cost estimates for these mixed cooling system facilities, since a portion of the flow may be make-up water and not amenable to application of closed-cycle cooling technology.

Exhibit 8-11 below summarizes the number of facilities and intakes that were determined to supply cooling water to closed-cycle cooling systems

Exhibit 8-11. Number of Model Facilities/CWISs Classified as Closed-Cycle

	Electric Generators		Manufacturers	
	Number of Model Facilities	Number of Model Intakes with Separate Cost Data	Number of Model Facilities	Number of Model Intakes with Separate Cost Data
Intakes with full or partial once-through in-place	221	319	186	267
Intakes with pond cooling system	12	26	7	7
Intakes with full closed-cycle recirculation in-place	51	61	42	43
Facilities with both full closed-cycle and full once-through intakes	7	8*	0	0
Total facilities or intakes	284	406	235	317

* Number of closed-cycle intakes.

8.4 Entrainment Mortality Compliance Costs for New Units

Power generation and manufacturing units that meet the definition of a "new unit" will be required to meet EM reduction requirements. Closed-cycle cooling or an equivalent reduction in entrainment for the cooling water component of the intake flow based on the average intake flow (AIF) will be required for new units. The estimates for compliance costs for such new units should be based on the net difference in costs between what cooling system technologies would have been built under the current regulatory structure and what will be built given the change in requirements imposed by the Proposed Regulation. Compliance costs are derived using estimates of the new generating capacity that will be subject to the requirement.

EPA expects that for Manufacturers, compliance costs associated with new units will be negligible. A discussion of the rationale is provided in Section 8.4.2 below. The following section describes cost development for the new unit provision for Electric Generators only.

8.4.1 Compliance Costs for New Power Generation Units

New generating capacity at existing facilities can result from new units added adjacent to existing units, repowering/replacement and major upgrades of existing units, and minor increases in system efficiency and output. While a small portion of this new capacity may result from minor improvements in plant efficiency and output, this analysis assumes all new capacity will be associated with new units, repowered units, or major unit rebuild/upgrades.

In the cost analysis, EPA considered separately two categories of new unit that are covered by this provision:

1. New generating units
2. Repowered existing units

New Generating Unit Costs

New generating units will be constructed at either "greenfield" facilities subject to the Phase I Regulation or at existing facilities where they may be subject to the new unit requirements for entrainment reduction. The scope of new unit activity was estimated using estimates of new power generation capacity by fuel/plant type derived from IPM modeling. For the new unit costs analysis, EPA focused on coal, combined cycle, and nuclear since these comprise the majority of increased capacity that utilize a steam cycle and are most likely to be constructed at existing generation facilities.

EPA used the analysis performed for Phase I as the basis for determining what portion of new capacity would be subject to this regulation. In the Phase I analysis, EPA determined that 76 percent of new coal and 88 percent of new combined cycle capacity would be constructed at new "greenfield" facilities and would be subject to Phase I, while the remainder (24 percent of coal and 12 percent of combined cycle) would be constructed at existing facilities and be subject to existing facility regulations. Using this as the basis, EPA has selected a value of 30 percent for both coal and combined cycle to serve as a conservative (high side) estimate for the portion of new capacity that would be constructed at existing facilities.

At existing nuclear facilities, only new capacity associated with construction of new generating units will be subject to the new unit requirements. Because of their considerable size and heat discharge, it is assumed that any new nuclear units will be required by the permitting authorities to utilize closed-cycle cooling and so the capacity for new nuclear units has not been estimated. Exhibit 8-12 presents a summary of new capacity estimates.

Exhibit 8-12. Estimated Annual New Capacity Subject to New Unit Requirements

Fuel Type	Projected Annual Average New Capacity (MW)[a]	Estimated New Capacity Subject to Phase I	New Capacity Subject to Existing Facility Rule Requirements (MW)
Coal	3,573	2,501	1,072
Combined Cycle	1,491	1,044	447

New nuclear capacity is assumed to use closed-cycle and was not estimated.
[a] Based on IPM projections for coal and combined cycle.

Baseline Compliance

New units will either use once-through, closed-cycle, or dry cooling systems[25]. For the baseline condition, an estimate is needed for the occurrence of each type of system that would have been utilized if there were no change in the regulatory requirements for new units. The occurrence of each type in existing cooling systems can serve as a guide since both new and replaced units will, at a minimum, use a similar technology. In some cases, more effective technology may be required. About 32 percent of existing facility steam generating capacity already employs closed-cycle and another 11 percent employs a combination including closed-cycle for at least part of the plant. It is reasonable to assume that, at existing plants where closed-cycle cooling is already employed for at least part of the generating capacity, closed-cycle would be required for any new or repowered capacity. Thus, based on current practice, at least 43 percent of new capacity is estimated to be compliant in the baseline.

While permitting authorities are not required to impose closed-cycle cooling requirements on new units that do not strictly meet the definition of a new facility under Phase I, EPA notes that a number of NPDES regulatory authorities have been pursuing closed-cycle cooling requirements for a number of existing facilities (e.g., New York, California). EPA expects this to be particularly true where the new unit would result in a substantial increase in the volume of once-through cooling water withdrawn above what is currently permitted. Thus, an assumption that baseline compliance would comprise at least 50 percent of new units at existing facilities appears to be a reasonable and possibly conservative (low side) estimate. At the same time, it is assumed that in many cases,

[25] Dry cooling is generally used in only a small portion of facilities in locations where water resources are limited. Estimates of closed cycle cooling are assumed to include dry cooling.

baseline repowered units will be allowed to continue to withdraw once-through cooling water at current flow volumes and discharge heat at current rates even though units at the plant may be completely reconstructed.

Repowering Versus New Units

The increased capacity at existing facilities is divided into two types of projects. The first is new unit(s) added adjacent to the existing generating units, which would require a new intake or the existing intake to be substantially modified to meet once-through cooling water requirements. The second is a repowered unit which replaces existing generating unit(s) and is assumed to be sized such that the existing once-through cooling water intake volume will provide sufficient flow to meet heat discharge requirements. The estimation of the distribution of new unit capacity between these categories is based on earlier (2007) IPM projections, since more recent projections do not include this distinction.

For combined cycle, approximately 88 percent of projected total new combined capacity was estimated to consist of repowered oil and gas units. Based on this, EPA chose a slightly lower value of 85 percent. The estimate for repowered coal capacity was very small (<1 percent). However, since there are significant economic advantages to repowering, EPA believes this value to be an underestimate and selected a value of 10 percent based on BPJ.

Exhibits 8-14 and 8-15 present the distribution of the estimated new capacity estimates across each cost category for coal and combined cycle, respectively. Exhibit 8-13 presents the capacity values in Exhibit 8-12 that are assumed to be compliant in the baseline or that require costs associated with closed-cycle cooling for new units. Only the capacity increase shown in the far right-hand column was used to derive the costs for new units. The capacity increase for existing units does not include existing capacity that is replaced and, therefore, a separate approach was used for the compliance options considered for repowered existing units and their associated compliance costs.

Exhibit 8-13. New Capacity Subject to New Unit Requirement by Cost Category

Fuel Type	New Capacity Subject to Existing Facility Rule Requirements (MW)[a]	New Capacity Compliant in Baseline (MW)[b]	New Capacity Subject to New Unit Compliance Costs (MW)	Capacity Increase for Existing Units (MW)	Capacity Increase for New Units (MW)
Coal	1,072	536	536	54	482
Combined Cycle	447	224	224	190	34

New nuclear capacity is assumed to use closed-cycle and was not estimated.

[a] Values are from Exhibit 8-12.

[b] Facilities will install entrainment reduction technology independent of Rule requirements.

Exhibit 8-14. Cost Category Distribution of New Coal Capacity

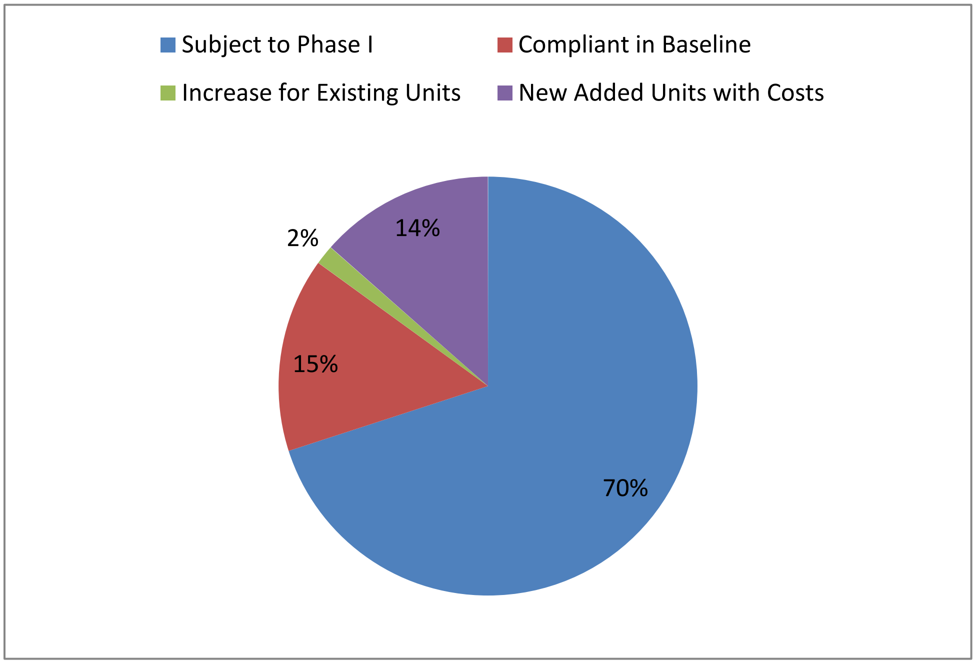
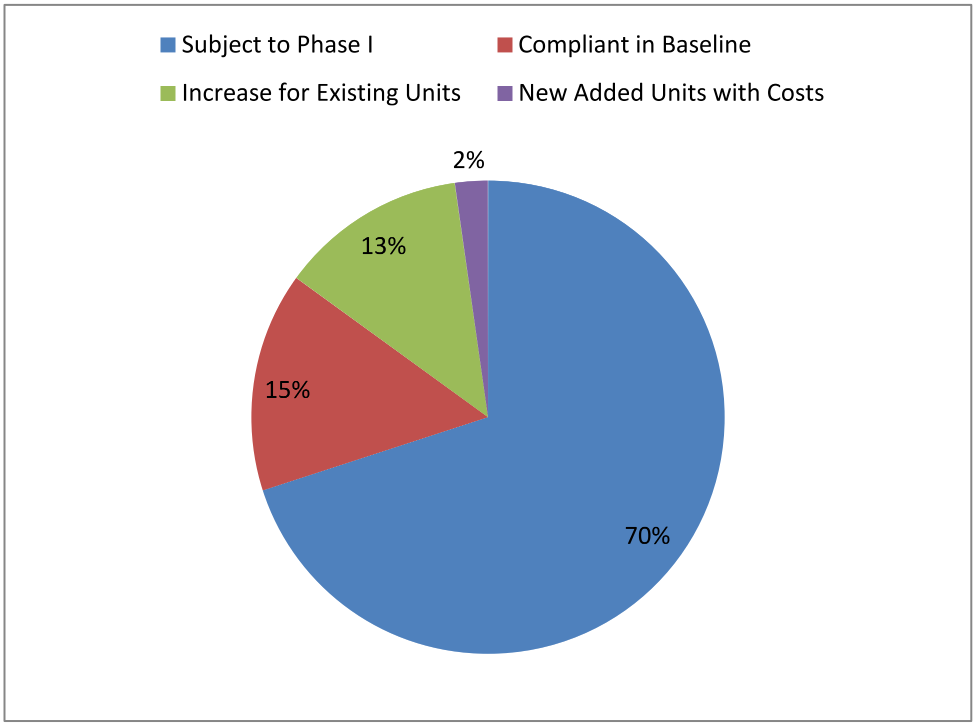


Exhibit 8-15. Cost Category Distribution of New Combined Cycle Capacity



Compliance Cost Estimation

Compliance costs were considered for new units and for existing capacity that is repowered. EPA investigated closed-cycle compliance costs for repowered units for consideration under different compliance options, but did not include this option in the proposed rule. Different approaches were used for estimating costs for new unit capacity versus repowering of existing capacity. For new unit capacity, costs are derived using the new unit capacity in MW as the input variable. For the repowering of existing capacity, EPA estimated the annual average occurrence of repowerings[26] as a percent of the total number of generating units present in the 316(b) universe analyzed at the earlier stages of rule development. Compliance costs for this repowered capacity are developed using this factor applied to the corresponding current design intake flow volume.

Compliance costs for new units use the EPA estimates for retrofitting a closed-cycle cooling system at existing facilities as the starting point. EPA developed the existing facility retrofit costs using existing flow data and cost equations that used cooling flow in gpm as the basis. The cost equations for new units are instead based on capacity in MW, with costs derived using assumed cooling water requirements in gpm/MW. These cooling water requirements assume that the typical existing plant design includes a once-through cooling system with a condenser temperature rise (ΔT) of 15 ^{o}F, and that the closed-cycle cooling system that replaces a once-though system will be optimized using a ΔT of 20 ^{o}F. The cooling water flow estimates are based on a ΔT of 20 ^{o}F and plant efficiency values of 42 percent for coal (which is the average of values for super-critical and ultra-critical steam), 57 percent for combined cycle, and 33.5 percent for nuclear.

Capital Costs

EPA has found that the total estimated capital costs for a once-through cooling system including a new intake are comparable to the capital costs of a closed-cycle cooling system. Therefore, the compliance capital costs are assumed to be $0 for new added units.

For repowered units, the existing once-through intake and pump system can be utilized and so capital costs should more closely resemble existing facility closed-cycle retrofit costs. However, since the repowering construction activities can still be quite extensive, the full costs for an existing facility retrofit are not assessed because they include extra costs for working around existing equipment and structures. For example, the retrofits often include installing a separate pumping system for the cooling tower in addition to the existing recirculating pumps, while a repowered unit can be designed to use one set of pumps as is often the case in new construction. In addition, much of the higher costs associated with the “average” and “difficult” retrofit scenarios will be avoided. Thus, a cost value midway between an “easy” difficulty retrofit and the cost of a cooling tower alone was chosen. The capital costs include adjustments associated with the assumption that 25 percent of facilities will require plume abatement. EPA has estimated that the

[26] EPA estimated that approximately 0.2 percent of existing capacity will be repowered each year and applied this factor equally across all three fuel type. See Section 3 of the “Economic and Benefits Analysis for Proposed 316(b) Existing Facilities Rule” for more details.

cost of the cooling tower alone would be $80/gpm (See "Cooling Tower Noise, Plume and Drift Abatement Costs" [DCN 10-6652]).

O&M Costs

The same O&M costs are used for both new added units and repowered units. These O&M costs include costs associated with the assumption that 25 percent of facilities will require plume abatement. Fixed and variable O&M costs are adjusted by deducting the O&M costs estimated for the traveling screens that would have been used in the baseline once-through system. The baseline O&M cost estimate is based on the cost tool output for gross O&M for once-through traveling screens (Cost Module 1) using design input values of: DIF = 132,500 gpm, screen velocity = 0.5 fps; well depth = 25 ft; freshwater. The resulting gross O&M cost was equivalent to $1.6/gpm, which was then reduced by 10 percent to account for the new makeup system O&M and then divided into fixed and variable components using a fixed factor of 0.4.

Energy costs are also adjusted to account for the reduced pumping volume associated with changing the ΔT from 15 ^oF to 20 ^oF and to account for an estimated increase in pumping head of 25 ft for closed-cycle versus once-through operation.

Exhibit 8-16 presents the new unit costs on a $/gpm basis. Exhibit 8-17 presents the equations used for estimating costs based on unit generating capacity derived from Exhibit 8-16 data using the gpm/MW values shown.

Exhibit 8-16. Costs for New Units and Repowering Based on GPM

Costs and Generating Output Reduction	Equation	Constant Adjusted for Optimization (2009)	Add for 25% Plume Abatement	Baseline O&M Adjustment[b]	Total Adjusted Net Cost
Capital Cost - Repowering (CC)	CC = DIF(gpm) x Constant	$124[a]	$30		$154
Capital Cost - New Unit with Intake (CC)	CC = DIF(gpm) x Constant	$0	$0		$0
Fixed O&M Cost (OMF)	OMF = DIF(gpm) x Constant	$1.27	$0.25	-$0.58	$0.94
Variable O&M - Chemicals (OMC)	OMC= DIF(gpm) x Constant	$1.25	$0.00	-$0.86	$0.39
Variable O&M - Pump & Fan Power (OMV)	OMV= DIF(gpm) x Constant	0.0000237	0.00000078		0.0000245
Energy Penalty - Heat Rate (EP) Non-nuclear	EP=MWS x Constant	0.000	0		0
Energy Penalty - Heat Rate (EP) Nuclear	EP=MWS x Constant	0.000	0		0

[a] Based on midpoint between easy retrofit ($169/gpm) and tower only ($80/gpm).

[b] Adjustment reflects deduction of O&M costs associated with traveling screens that would have been installed in the baseline once-through system.

Exhibit 8-17 Costs for New Units Based on Generating Capacity

Costs and Generating Output Reduction	Equation	Units	Coal (42% Efficient)	Combined Cycle (57% Efficient)	Nuclear (33.5% Efficient)
		GPM/MW	390	200	680
Capital Cost - New Unit with New Intake (CC)	CC = MWS x Constant	Dollars	$0	$0	$0
Fixed O&M Cost (OMF)	OMF = MWS x Constant	Dollars	$366	$188	$639
Variable O&M - Chemicals (OMC)	OMC= MWS x Constant	Dollars	$151	$77	$262
Variable O&M - Pump & Fan Power (OMV)	OMV= MWS x Constant	MW	0.0077	0.0040	0.0134
Energy Penalty -Heat Rate (EP) Non-nuclear	EP=MWS x Constant	MW	0	0	0
Energy Penalty -Heat Rate (EP) Nuclear	EP=MWS x Constant	MW	0	0	0

Downtime

Each of the new units will involve extensive construction activities that would result in a prolonged construction downtime regardless of the cooling system requirements. Thus, no downtime costs are assessed for new unit compliance. The same assumption was used for repowering.

Energy Penalty

Energy penalty costs associated with net changes in parasitic energy requirements between once-through and closed-cycle cooling are included in the O&M cost estimates shown in Exhibit 8-17. For the heat rate penalty, new unit construction will involve new steam turbines, condensers, and cooling towers using an optimized design. As such, the system design can be tuned such that heat rate penalty that would otherwise be associated with replacing the once-through system with a closed-cycle cooling system at an existing facility is assumed to be minimal. Thus, no costs are assessed for the heat rate penalty. Also, no costs for heat rate penalty were assessed for repowering, since it is assumed that in most cases the project will involve the replacement of the steam turbines, condensers, and cooling towers using an optimized design as well.

8.4.2 Compliance Costs for New Manufacturing Units

The projected baseline manufacturing unit process design and cooling water technology would be based on an estimate of the response to the permitting authorities' application of existing requirements including 316(b), applicable industrial water use and discharge standards (e.g., categorical standards), and BPJ. Also, it has become standard practice for industries to adopt water use reduction and reuse practices wherever practical. The construction of a new unit provides a perfect opportunity to employ such measures to an extent that would not be possible for existing units. In many cases, it is likely that the existing regulatory requirements and practices would have resulted in a further reduction in the cooling flow than for similar but older units. Thus, the baseline cooling AIF for "new units" at manufacturers should, in most cases, be much smaller than the AIF for a comparable existing unit. This is especially true for replacement units that perform a similar function or produce a similar product, since economic factors such as the need to increase process efficiencies are often driving factors in the decision to replace an existing unit.

For new units in general, EPA has noted the following differences in costs between a closed-cycle cooling retrofit at an existing facility compared to closed-cycle cooling at a "new unit:"

- New units can incorporate closed-cycle cooling in a more cost-effective manner.
- The duration of new unit construction is sufficiently long that there would be, in nearly all circumstances, no net increase in "construction downtime."
- Where new intakes or major components of the existing once-through intake and cooling system must be constructed/upgraded, the capital costs of closed-cycle cooling for new units are comparable to the capital costs of once-through cooling.
- The cooling system costs usually comprise less than 1 percent of the total costs of a new unit.
- Reconstruction allows the use of an optimized cooling system design that can minimize any system efficiency losses associated with conversion to closed-cycle.
- The fact that a large proportion of intake flow is used for process water and other non-cooling purposes greatly increases the opportunity to design and incorporate cooling water reuse strategies within the new unit.
- Where the new unit comprises only a portion of the plant upgrades, cooling water reduction may be accomplished through reuse at other units within the plant.
- The modular nature of closed-cycle cooling allows for the limited application of closed-cycle cooling only to the portion of cooling flow necessary to meet any additional reductions not accounted for by any other reuse/reduction strategies employed.
- The modular nature of closed-cycle cooling allows for the use of cooling system designs specifically tailored to process requirements and vice versa.
- The modular nature of closed-cycle cooling and the flexibility inherent in rebuilding a process system allows for more optimum placement of cooling tower units, thus minimizing piping costs.
- New unit construction provides a lower cost opportunity to install variable speed pumps and other system controls in cooling system applications. Flow reductions associated with the use of variable speed pumps and other controls can result in benefits associated with reduced flow and pumping energy costs and better process control.

For power generation facilities that use once-through cooling, process water typically constitutes a few percent or less of the total intake volume and the majority of the intake flow is used for non-contact cooling purposes. A review of the responses to the detailed technical survey showed that the median and average values for the percent of design intake flow used for cooling purposes reported for each separate cooling water intake at power generation facilities were 100 percent and 85 percent, respectively.

In contrast, most industrial manufacturing operations utilize a substantial portion of intake water for non-cooling purposes and the same median and average values for manufacturing facilities were 50 percent and 52 percent, respectively. In addition, the cooling flow component at manufacturers will in many instances include contact cooling water which would not be subject to the "new unit" requirements, thus decreasing the proportion of cooling flow subject to the "new unit" requirements. This is consistent with the NCCW/DIF ratios shown in Exhibit 8-9 ranging from 32 percent to 65 percent. Given this, it is reasonable to assume a "typical" manufacturing unit may use less than 50 percent of flow for cooling purposes of the type that may be subject to the "new unit" requirements. Theoretically, this "typical" facility should be able to reuse 100 percent of the cooling water in place of the process component. Thus, the "typical" manufacturing facility should be capable of designing a "new" process that could meet the "new unit" requirements through water reuse alone. EPA observed extensive use of innovation and water reuse during site visits at some manufacturing facilities. Such reuse opportunities may be limited at facilities that use brackish or saltwater for cooling, but EPA estimates that only 7 percent of manufacturing plants do so.

Since this 50 percent value is the median of all reported manufacturing cooling water intake systems, at least half of manufacturing cooling water systems have the potential to meet the "new unit" requirements simply by reusing non-contact cooling water as process water. For the remainder, modifications to the process that reduce cooling water use (e.g., use of variable speed pumps) may provide additional reduction. For some, there may be a need to install cooling towers for the cooling flow component that cannot be reused. This, however, will in most instances be a small portion of the total intake flow. Also, in many cases the "new unit" will comprise only a portion of the entire manufacturing facility and there may be other process units and plant operations nearby that could reuse the cooling water in order to meet the flow reduction requirements.

For new units that would require building or rebuilding a once-through intake, EPA has found that the capital costs of the new intake and screen technology which requires deeper pump and intake wells to accommodate source water depth variations will be comparable and possibly higher than the capital costs for closed-cycle technology. In these cases, closed-cycle may have slightly higher O&M costs for pump and fan energy, but these costs may be offset by other cost savings such as reductions in water treatment costs.

The definition of new manufacturing units limits the applicability of closed-cycle requirements to new units that involve major construction activities that would involve construction of substantial portions of the process and ancillary equipment. As such, it is assumed that the reconstruction activities would involve substantial downtime periods that would be of similar or more likely greater duration than required for construction and tie-in activities associated with the closed-cycle cooling technology alone.

Given all of this, EPA concluded that only a small portion of new units would need to meet new unit flow reduction requirements through increased use of closed-cycle cooling over what would have been built under existing regulatory requirements. As a result, EPA concluded that the associated net costs would be minimal. Due to the fact that costs are expected to be minimal and due to the difficulty inherent in developing estimates given the complexities of water use within multiple industries and multiple processes within each industry, EPA chose not to assign any cost for entrainment mortality reduction compliance for this small component.

8.5 Impingement Mortality Costs at Intakes with Cooling Systems Required to Install Closed-Cycle Cooling

Even after installation of a closed-cycle cooling system, the intake for the remaining water withdrawals (i.e., makeup flow) still must comply with the IM requirements. If the existing intakes at a facility retrofitting to cooling towers were determined to be IM-compliant under current (i.e., once-through) operating conditions, then no additional costs were assigned. For intakes that were not currently compliant, the intakes were re-evaluated to determine if the flow reduction from installation of a closed-cycle cooling system would result in IM compliance via the 0.5 ft/sec intake velocity threshold. This was done by first estimating the reduced total intake flow after installing closed-cycle technology based on the assumption that the NCCW flow component would reduce flow by a minimum of 92 percent.[27] The flow reduction volume was subtracted from the MRIF to determine the reduced total flow volume.

The intake screen velocity after implementation of closed-cycle cooling was then estimated assuming the screen velocity reduction would be proportional to the flow reduction. This was based on the assumption that the existing total screen or intake surface area would remain the same. If the revised screen velocity was lower than 0.45 fps,[28] then it was assumed the existing intake would become IM compliant after implementation of closed-cycle cooling. For nearly all of the power generation facilities, the estimated through-screen velocity after implementation of closed-cycle cooling was lower than 0.5 fps and therefore no IM technology compliance costs were assessed at power plant intakes required to install closed-cycle cooling.

For those manufacturing plant intakes deemed not IM compliant after retrofitting to closed-cycle cooling, the IM technology cost methodology was the same as described above for intakes not required to install closed-cycle cooling. The only difference was that, for those technologies that could be sized independently of the existing intake technology (e.g., wedgewire screens, larger intakes, or velocity caps), the design flow (MRIF) was further reduced by subtracting the estimated reduction in the NCCW flow component associated with closed-cycle cooling.

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[27] A closed-cycle flow reduction value of 92 percent was selected as a conservative (smaller flow reduction) estimate. Actual reductions are expected to be higher depending on condenser temperature rise and cycles of concentration.

[28] Instead of 0.5 fps, a more conservative value of 0.45 fps was selected as the compliance threshold to account for potential unequal distribution of flow reductions between intakes and pumps.

8.6 Costs for Each Regulatory Alternative

As described in the preamble, EPA is presenting three regulatory options in the proposed rule. One option would require only impingement mortality at all facilities (i.e., modified Ristroph screens everywhere), a second would require impingement mortality and entrainment mortality at all facilities (i.e., wet cooling towers everywhere), and a third would require impingement mortality at all facilities and entrainment mortality at facilities with a design intake flow greater than 125 MGD. In addition, entrainment reduction is required for all "new units" as defined in the preamble.

The sections above describe how facility-level costs were derived for each set of requirements (either impingement mortality or entrainment mortality). To calculate the total cost for a regulatory alternative, the facility-level costs for the applicable requirements were simply summed. For example, for the option where cooling towers are required at each facility with a DIF greater than 125 MGD, EPA used facility-specific data to identify model facilities that fell above and below the flow threshold and used the cost that corresponded to the appropriate compliance response. These facility-level costs are then used to calculate national level economic impacts, as described below.

8.7 Compliance Costs Developed for Analysis of National Economic Impacts

To assess the national economic impacts of its regulatory options, EPA conducted several analyses; these are documented in the EBA. As part of these analyses, EPA conducted a modeling analysis using the Integrated Planning Model (IPM) to develop a worst-case impact analysis for power generators.[29] EPA can conclude that if no national economic impacts were observed as a result of the worst-case option, then less costly regulatory options would also have no national economic impacts. This section describes the technical data used in developing the IPM modeling; for more information, see the EBA.

In contrast to the model facility costing approach, the IPM model requires an estimate of facility-level costs for all existing facilities (including those facilities that completed an STQ).[30] Facility-level costs were calculated by first estimating costs for the same subset of facilities used in the model facility approach described above. To derive costs for STQ facilities, EPA then aggregated the data to derive cost equations that were used to calculate STQ facility-level costs using DIF as a scaling factor.

8.7.1 Selection of DIF as the Primary Scaling Factor for Power Plants

Several power plant attributes related to facility size were evaluated to determine which would best serve as input values for the IPM model cost equations. The use of plant generating capacity was evaluated by comparing the year 2000 steam generating capacity to the DIF reported in the detailed year 2000 surveys for plants with once-through cooling systems. It was concluded that there was insufficient correlation between steam

[29] For a detailed discussion of the IPM analysis, see the EBA.
[30] The DIF for facilities that completed the short technical questionnaire was estimated on the basis of the average daily flow as described in the preamble to the 2004 Phase II final rule. See 69 FR 41650.

generating capacity and the DIF to use the generating capacity as the sole basis for estimating cooling system size and costs.[31]

Because the cost derivation methodologies used by EPA in the past and by EPRI for developing cooling tower retrofit costs used the design cooling water flow rate (i.e., the DIF), the DIF was selected as the basis for estimating model facility costs. Where such data were not available, the DIF was estimated using the average ratio of DIF to steam generating capacity (gpm/MW) for those facilities with once-through cooling systems. The cost data used to derive the national average technology cost equations relied on data only from facilities that reported design cooling water intake flow volumes in the detailed surveys. Exhibit 8-18 below shows the equation used to estimate DIF on the basis of steam generating capacity for facilities where insufficient design or actual flow data were available to estimate the DIF. This equation was used only for facilities that did not complete a technical questionnaire (short or detailed) and was estimated using a formula based on the overall average DIF/MW ratio for power generators with once-through cooling systems with DIF greater than 50 MGD.

Exhibit 8-18. Estimation of DIF Where No DIF Data Exists

	Equation	Constant	Units
Design Intake Flow (DIF)	DIF = MWS x constant	707	gpm

MWS = Megawatts of steam = Total facility steam electric generating capacity.

The reported or estimated DIF volumes are used as input values in the cost-estimating equations so that the average national technology costs can be scaled to account for differences in plant/intake size.

8.7.2 Development of IM&EM Control Costs for IPM Model

The IPM Model facility cost equations for IM&EM controls were derived using the intake technology cost data described above for each model facility intake. As described above, cost modules were assigned as shown in Exhibits 8-1 and 8-2.

The first step to derive the IPM model facility cost equations was to derive a single value for each cost item for each facility. Total costs for each facility were derived by summing the capital, O&M, and pilot study costs of each intake. For most facilities, the cost module was the same for all intakes, so single facility-level values were assigned for the net downtime and the service life on the basis of the most common cost module assigned to the intakes.

Various methods for using this data to estimate costs were evaluated, including using the between-facility average or median of the $/gpm ratios, and using trend lines derived by

[31] Theoretically, for once-through cooling systems, cooling water flow should have correlated well with steam generating capacity, but it did not. The following are likely reasons for the lack of good correlation: the fact that the temperature rise across the condenser (ΔT) can vary between plants, the fact that even those plants considered as once-through can use varying amounts of closed-cycle cooling for some of the generating capacity, and the fact that reported design intake flow might include substantial volumes of water used for other purposes.

Excel (which uses a least squares method). It was concluded that a simple straight-line equation with Y-intercept equal to "0" using the overall between-facility average of the individual facility cost to DIF ratios ($/gpm) represented a reasonable estimate for the national model facility costs.

After deriving the facility-level costs, weighted averages of the cost to DIF ratio ($/gpm) were calculated for all facilities that had compliance costs (i.e., facilities with zero costs were not included). The same facility weights described above were used. Weighted average values for the facility net construction downtime and technology service life were also calculated. The net O&M fixed component was calculated as a portion of the net O&M costs using a factor derived from the weighted average of the ratio of fixed gross technology O&M to the total gross technology O&M. Exhibits 8-19 and 8-20 below present the model facility cost equations for IM reduction technology based on modified Ristroph traveling screens or equivalent for facilities with DIF greater than or equal to 10 MGD and DIF less than 10 MGD, respectively.[32] Exhibits 8-21 and 8-22 present the service life and calculated technology net construction downtime.

Exhibit 8-19. Cost Equations for Estimating Model Facility Costs of Impingement Mortality Controls for the IPM Analysis for Facilities with DIF ≥ 10 MGD

Cost Item	Equation	Constant	Output Units
Capital Cost (CC)	CC = DIF(gpm) x Constant	13.1	2009 Dollars
Pilot Study costs (PC)	PC = DIF(gpm) x Constant	0	2009 Dollars
Net O&M Cost (OM)	OM = DIF(gpm) x Constant	0.78	2009 Dollars
Fixed Net O&M Cost (OMF)[a]	OMF = DIF(gpm) x Constant	0.45	2009 Dollars
Variable Net O&M (OMV)	OMV = DIF(gpm) x Constant	0.33	2009 Dollars

[a] Fixed O&M component based on values for compliance gross O&M

Exhibit 8-20. Cost Equations for Estimating Model Facility Costs of Impingement Mortality Controls for the IPM Analysis for Facilities with DIF < 10 MGD

Cost Item	Equation	Constant	Output Units
Capital Cost (CC)	CC = DIF(gpm) x Constant	120.4	2009 Dollars
Pilot Study costs (PC)	PC = DIF(gpm) x Constant	0	2009 Dollars
Net O&M Cost (OM)	OM = DIF(gpm) x Constant	8.06	2009 Dollars
Fixed Net O&M Cost (OMF)[a]	OMF = DIF(gpm) x Constant	3.42	2009 Dollars
Variable Net O&M (OMV)	OMV = DIF(gpm) x Constant	4.64	2009 Dollars

[a] Fixed O&M component based on values for compliance gross O&M

[32] EPA also derived separate model facility cost equations for facilities with DIF less than 10 MGD and those with DIF greater than or equal to 10 MGD to account for the notable difference in unit costs for the low-flow intakes that results from the different approach used in assigning compliance technologies, plus the fact that the equations used to derive the cost module cost estimates tended to produce higher $/gpm rates at lower flow levels.

Technology Service Life

Estimates of technology service life were also required for the economic models. In the 2004 Phase II economic analysis, EPA assumed a useful life of 10 years for nearly all of the compliance technologies, with the exceptions that a useful life of 30 years was used for cooling towers and a useful life of 20 years was used for condenser upgrades associated with the cooling tower retrofit. Also, one-time costs such as initial permitting and connection downtime were annualized over a 30-year period, which was the maximum time period for the technology cost analysis.

EPA has re-evaluated the estimated service life of each compliance technology based on various sources of information and BPJ. Exhibit 8-21 presents the revised service life estimates for all of the compliance technology modules used or considered for use in the economic analyses.

Exhibit 8-21. Estimated Technology Service Life

Module No.	Module Description	Service Life (Years)
-	Cooling Towers	30
1	Replace Screen with Coarse Mesh Ristroph Traveling Screen with Fish Handling and Return System	20
2	Replace Screen with Fine Mesh Ristroph Traveling Screen with Fish Handling and Return System	20
2a	Add Fine Mesh Overlay Screens Only	20
3	Add New Larger Intake Structure with Coarse Mesh Ristroph Traveling Screen and Fish Handling and Return	25
4	Relocate Intake to Submerged Near-shore (20 M) with Passive Screen (1.75 mm mesh)	30
5	Add Fish Barrier Net	30
6	Aquatic Fish Barrier (Gunderboom)	30
7	Relocate Intake to Submerged Offshore with passive screen (1.75 mm mesh)	30
8	Add Velocity Cap at Inlet	30
9	Add Passive Fine Mesh Screen (1.75 mm mesh) at Existing Inlet of Offshore Submerged	30
10	Module 2 plus Module 5	20
10.1	Module 2a plus Module 5	20
10.2	Module 3 plus Module 5	25
10.3	Module 1 plus Module 5	20
11	Add Double-Entry, Single-Exit with Fine Mesh, Handling and Return	20
12	Relocate Intake to Submerged Near-shore (20 M) with Passive Fine Mesh Screen (0.75 mm mesh)	30
13	Add 0.75 mm Passive Fine Mesh Screen at Existing Inlet of Offshore Submerged	30
14	Relocate Intake to Submerged Offshore with 0.75 mm Passive Screen	30

Exhibit 8-22 presents the model facility technology net construction downtime and service life.

Exhibit 8-22. Technology Downtime and Service Life for Model Facility Costs of Impingement Mortality Controls for the IPM Analysis

	Units	Facilities with DIF ≥10 MGD	Facilities with DIF <10 MGD
Net Construction Downtime	Weeks	0.3	1.9
Service Life	Years	20[a]	25[a]

[a] Actual calculated values were 20.7 years for ≥10 MGD and 27.5 years for <10 MGD. Values were revised to obtain conservative rounded values more amenable to use with IPM model.

8.7.3 Development of Closed-Cycle Cooling Tower Costs for IPM Model

For the IPM analysis, the model facility costs for closed-cycle cooling have already been derived; they are the same equations from Exhibit 8-8. The difficult cooling tower retrofit capital costs were used to further reflect worst-case conditions. The net construction downtime estimates used to derive the IPM model costs are shown in Exhibit 8-10.

Chapter 9: Impingement Mortality and Entrainment Mortality Reduction Estimates

9.0 Introduction

This chapter presents impingement mortality and entrainment mortality reduction estimates associated with each of the regulatory options EPA considered in developing the proposed Existing Facilities rule. EPA estimated impingement mortality and entrainment mortality reductions to evaluate the effectiveness of different treatment technologies. EPA also used this information in analyzing potential benefits associated with the proposed rule. See the EEBA for more details on these analyses.

9.1 Technology Reduction Estimates

EPA's regulatory options (see the preamble for discussion of the options) are based on the following technologies:

- Modified Ristroph traveling screens with a fish return
- Low intake velocity
- Barrier nets
- Flow reduction as achieved by wet mechanical draft cooling towers

EPA's methodology for estimating impingement mortality and entrainment reduction for these technologies varies depending on available data.

9.1.1 Screens

As explained in Chapters 2 and 11 of this document, EPA developed a performance database that analyzed quantitative data on the efficacy and impingement mortality and entrainment reduction associated with various technologies. This analysis formed the basis for establishing the performance standard for impingement mortality at 88 percent annual survival.

This analysis does not include an estimate of shellfish morality reductions because EPA does not have comprehensive source water characterization data for shellfish. Therefore, EPA is unable to estimate shellfish counts either before or after impingement controls. As a result, the reductions are understated.

9.1.2 Low Intake Velocity

A facility that reduces its intake velocity to 0.5 ft/sec or below is assumed to meet the performance standard for impingement mortality. As with screens, the reduction in mortality is also assumed to be 88 percent. This likely understates organism survival, because EPRI's fish swim speed study (in addition to other data collected by EPA; see

DCN 10-6705) shows that greater than 94 percent of studied fish can avoid an intake structure when the intake velocity is 0.5 ft/sec or less.

9.1.3 Barrier Nets

Facilities located on oceans, tidal rivers and estuaries are required to install barrier nets (or equivalent performing technologies). Passive intake technologies (such as cylindrical wedgewire) and screens with no carry-over (such as dual flow screens) are assumed to also meet this standard. Facilities with traveling screens were also costed for the installation of barrier nets.

As discussed in 9.1.1, EPA was unable to estimate any impingement mortality reductions for shellfish. As a result, the reductions are understated.

9.1.4 Flow Reduction Commensurate with Closed-Cycle Cooling

As explained in Chapter 6, both entrainment and impingement (and associated mortality) at a particular site are generally considered to be proportional to intake flow. In other words, if a facility reduces its intake flow by 50 percent, it similarly reduces the amount of organisms subject to impingement and entrainment by 50 percent. For the traditional steam electric utility industry, available data[1] demonstrate that facilities located in freshwater areas that have closed-cycle, recirculating cooling water systems can, depending on the quality of the make-up water, reduce water use by up to 97.5 percent from the amount they would used if they had once-through cooling water systems. Similarly, steam electric generating facilities that have closed-cycle, recirculating cooling systems using salt water can reduce water usage by up to 94.9 percent when make-up and blowdown flows are minimized.[2]

Accordingly, a facility that is required to reduce its flow commensurate with closed-cycle cooling would realize a significant reduction in its impingement and entrainment impacts.

9.2 Assigning a Reduction to Each Model Facility

As explained in Chapter 8 of this document, EPA estimated costs for each model facility to comply with the regulatory options it considered for the proposed rule. In general, to develop model facility costs, EPA reviewed the impingement mortality and entrainment mortality requirements for a particular option and determined if each model facility would be able comply with the requirements based on their existing technologies (e.g., has existing intake technologies that serve as the basis for the option or exhibit equivalent performance). For each model facility that EPA projected would not be able comply with the regulatory option requirements, EPA estimated costs to install and operate additional impingement mortality and entrainment mortality minimization technologies. EPA's assignment of costs to model facilities is relevant to its impingement mortality and

[1] See Chapter 6 of the TDD.

[2] See Chapter 2 of the TDD for additional discussion of how these flow reduction values were derived.

entrainment mortality reduction estimates because EPA only assigns reduction estimates to model facilities that incur compliance costs.

For example, if a facility is subject to impingement mortality requirements but has only a conventional coarse mesh traveling screen, it would have been assigned costs to replace the screen with a modified Ristroph screen (or similar technology). Accordingly, a reduction in impingement mortality of 88 percent was assigned to this facility to reflect the improved performance of the new screens.[3]

Once EPA determined a compliance response for each model facility under a given regulatory option, EPA similarly assigned impingement mortality and entrainment reductions, as applicable. EPA assigned impingement mortality and entrainment mortality reductions as illustrated in Exhibit 9-1 below:

Exhibit 9-1. Reductions in Impingement Mortality and Entrainment Mortality

Control Technology Assigned	Impingement Mortality Reduction	Entrainment Mortality Reduction
Closed-cycle cooling (fresh water)	97.5%	97.5%
Closed-cycle cooling (salt water)	94.9%	94.9%
Modified Ristroph Screens	88%	0%

A facility may be subject to one or both requirements, as shown in the examples below:

- a facility that does not have modified Ristroph screens (or an intake velocity of 0.5 ft/sec) would reduce impingement mortality by retrofitting to one of the two impingement mortality technologies
- under Option 2, a facility with a design intake flow over 125 MGD with no flow-reduction technologies would be subject to both impingement mortality and entrainment mortality requirements
- under Option 3, any facility with a design intake flow over 2 MGD with no flow-reduction technologies would be subject to both impingement mortality and entrainment mortality requirements
- a facility with an existing closed-cycle cooling system that has poor performing traveling screens would reduce impingement mortality by retrofitting to one of the two impingement mortality technologies
- a facility that was projected to retrofit closed-cycle cooling also often accrues benefits from both flow reduction and impingement mortality reduction. In other words, a facility that would be required to reduce its flow commensurate with closed-cycle cooling would be assigned a 97.5 percent or 94.9 percent reduction in both IM and EM. However, because these facilities are still subject to IM requirements, EPA assumed that these facilities would also reduce IM by 88 percent over and above the reduction realized by the reduction in flow (due to either installing new screens or by significantly reducing the intake velocity). As a result,

[3] Note that this does not imply an 88 percent improvement over conventional screens; it simply represents the improved survival of organisms.

many of these facilities were assigned 99.7 percent (97.5 percent + 88 percent of remaining 2.5 percent) or 99.39 percent (94.9 percent + 88 percent of 5.1 percent).

- no reductions in shellfish were estimated under any option

A large number of existing facilities use multiple intake structures. To account for this configuration, a flow-weighted average was used across each intake. As before, reductions are based on the engineering costs and compliance response for each intake; intakes that are assigned a new technology were also assigned a reduction. For example, if a facility has two intakes with equal design intake flows but one uses a modified Ristroph screen and one does not, the impingement mortality reduction would be 44 percent--the flow-weighted result of having one compliant intake and one non-compliant intake.

As such, there are a wide variety of compliance responses among the model facilities. Facilities may also exhibit partial compliance; for example, some facilities have a partial (or combination) closed-cycle system, where some units utilize a closed-cycle system and others use once-through cooling. Other facilities may have one intake with a modified Ristroph screen and another without. In these cases, EPA assumed that those intakes using the compliant technology would be considered as complying with impingement mortality or entrainment mortality requirements and calculated impingement and entrainment reductions using a flow-weighted average across all of the facility's intakes.

9.2.1 Entrainment Mortality

In the 2004 Phase II rule, EPA made the assumption that any entrained organism died (i.e., 100 percent mortality for organisms passing through the facility) and any organism not entrained survived. In other words, if a technology reduced entrainment by 60 percent, then EPA estimated 40 percent of the organisms present in the intake water would die in comparison to 100 percent in the absence of any entrainment reduction. As discussed in the preamble to the proposed Existing Facilities rule, EPA changed its approach from addressing entrainment (i.e., exclusion) to entrainment mortality. The reductions discussed in this chapter reflect those changes.

9.2.2 In-Place Technologies

If a facility has already installed a technology that is compliant with the applicable IM or EM standards, it is not assigned a technology (i.e., it is not assigned technology costs) and therefore is not assigned a reduction in IM or EM. In all other cases, the full reduction for IM or EM is applied to that intake structure. See Exhibits 8-1 and 8-2 for a decision tree of how compliance technologies were assigned.

9.2.3 Summary of Options

Exhibit 9-2 summarizes the percent of flow and environmental impacts addressed by each option under the proposed rule.

Exhibit 9-2. Summary of Options

Option	Percent of Design Flow Covered (%)		Applies To	
	Impingement Mortality	Entrainment Mortality	Impingement Mortality	Entrainment Mortality
1 &4 (IM For All, IM for DIF >50 MGD)	100	0	X	
2 (IM for All, EM for AIF> 125 MGD)	100	87	X	X
3 (IM for All, EM for All)	100	100	X	X

Chapter 10: Non-water Quality Impacts

10.0 Introduction

For the 2004 Phase II rule, EPA conducted an analysis of non-water quality impacts resulting from the conversion of some facilities to recirculating wet cooling towers. These impacts include increased air emissions due to energy penalties, vapor plumes, noise, salt or mineral drift, water consumption through evaporation, and solid waste generation due to wastewater treatment of tower blowdown (see the 2002 proposed rule TDD Chapter 6, DCN 4-0004). For the proposed rule, EPA reviewed these impacts and supplemented the air emissions, vapor plumes, noise, and evaporative consumption analyses as described in the following sections. EPA also briefly reviewed the data available on non-water quality impacts of thermal effluent discharges.

10.1 Air Emissions Increases

In developing the 2002 proposed Phase II rule, EPA estimated the incremental increases in emissions for 59 model power plants expected to retrofit from once-through cooling to recirculating wet cooling towers under the preferred alternative (see the 2002 proposed rule TDD Chapter 6, DCN 4-0004).[1] These model facilities included nuclear, combined-cycle and fossil fuel-fired power plants. As described in the 2002 proposed rule TDD and in the Environmental and Economic Benefits Analysis (EEBA) for the proposed rule, facilities retrofitting to recirculating wet cooling towers incur an energy penalty due to the increased electricity generation needed to compensate for the loss of efficiency caused by the retrofitted cooling towers. This results in a slight increase in emissions from the increased burning of fuel.[2,3] Note that the current emissions rate calculations discussed below do not reflect full implementation of the most recent air rule requirements. For today's proposed rule, EPA used facility-specific power plant emissions (annual average) data to estimate increased emissions under the proposed options presented in the preamble to the proposed rule. EPA also conducted a geographical information system (GIS) analysis of non-attainment areas and Phase II power plant locations to identify areas of potential increased impact.

10.1.1 Incremental Emissions Increases

Facilities that retrofit to a cooling tower will experience a reduction in efficiency, as there is a loss of efficiency in the turbine due to the higher temperature condenser water within the cooling water system. The fans inside the tower also require electricity to operate.

[1] The preferred alternative (Option 1) required facilities to meet performance standards based on waterbody type and proportion of flow withdrawn for cooling. Under this option, 59 facilities were estimated to comply through the installation of cooling towers.

[2] See Table 6-1 from the TDD for the 2002 Phase II proposal for the estimated incremental increase in emissions under the 2002 preferred alternative.

[3] Increased emissions are not caused by the recirculating wet cooling tower itself, but by the fuel deficit created by the additional energy needed for operation of the towers and a loss of turbine efficiency.

Collectively, these inefficiencies are known as the energy penalty. To compensate for the loss of electricity generation, a facility could either operate more frequently (if it is not already a baseload plant) or it could burn additional fuel. Both scenarios would lead to an increase in the emission of air pollutants from the combustion of fossil fuels.

For today's proposed rule, EPA used a methodology similar to the one used in the 2002 proposed rule and TDD to estimate incremental increases in emissions under each of the options considered. The data source for the Agency's air emissions estimates of CO_2, SO_2, NO_x, and Hg is the EPA-developed database titled E-GRID 2005. This database is a compendium of reported air emissions, plant characteristics, and industry profiles for the entire US electricity generation industry in the years 1996 through 2005. The database relies on information from power plant emissions reporting data from the Energy Information Administration of the Department of Energy. E-GRID compiles information on every major power plant in the United States and includes statistics such as plant operating capacity, air emissions, electricity generated, and fuel consumed. This database provided ample data for the Agency to conduct air emissions increases analyses for the proposed rule. The emissions reported in the database are for the power plants' actual emissions to the atmosphere and represent emissions after the influence of any existing air pollution control devices.

E-GRID, however, does not provide information on emissions of particulate matter (PM). The data source for historic emissions rates of PM 2.5 and PM 10 is the EPA-developed database titled National Emission Trends (NET). The NET database is an emission inventory that contains data on stationary and mobile sources that emit criteria air pollutants and their precursors. The NET is released every three years (e.g., 1996 and 1999) and includes emission estimates for all 50 States, the District of Columbia, Puerto Rico, and the Virgin Islands. The database compiles information from EPA air programs and the Department of Energy, and the information it contains for other parameters was found to be consistent with the information found in E-GRID 2005.

The model facility universe for each regulatory option represents those power plants that are in scope for each option, for which some E-GRID and/or NET data is available for the desired parameters of CO_2, SO_2, NO_x, Hg, PM 2.5, and PM 10. Although manufacturing facilities are included in the universe of the proposed rule, there is no readily available data on air emissions from manufacturing facilities. In addition, nuclear power plants and facilities that already have closed cycle cooling towers are excluded from the model universe, as they would not have to retrofit to cooling towers. Furthermore, facilities that did not have readily available air emissions data were also excluded from the model universe. Therefore, the model facility universe for this evaluation only encompasses those power plants for which air emissions data is available that do not already employ cooling towers, making it a subset of the total facilities expected to be affected by the proposed rule.

Site-specific models for calculating air emissions increases are not appropriate for estimating the national impact of the proposed rule and were not used in this analysis. In addition, some studies have suggested that certain methods (e.g., EPA's AP-42 method for estimating PM emissions from cooling towers) may overstate air emissions from recirculating wet cooling towers (SWRCB 2010). One approach to generating an upper bound estimate of air emissions increases at facilities included in the model universe under each proposed option is presented in Tables 10A-1 (Option 2) and 10A-2 (Option 3) in the Appendix to this chapter. These tables represent facility-specific air emissions increases and are based on the estimated energy penalty for each facility, the facility's historic average electricity generation level, and its average historic emission rates.[4] The estimated incremental increases in emissions are not reported for facilities already employing (or partially employing) cooling towers, nuclear and retired facilities, and those facilities for which data is not available. Note that the discussions below on greenhouse gases do not reflect recent or proposed regulations for limiting greenhouse gas emissions, as the data is reported for 2005 and thus reflects operations prior to 2004. These data predate the implementation of recent air rules; therefore, EPA expects that, in most cases, these data do not reflect emissions after installation of scrubbers and other air pollution control equipment. EPA intends to collect current emissions data (i.e., updated E-GRID and NET data through 2010 will be available some time in 2011), including emissions after compliance with recent air rules, and to rescale these estimates.

Carbon dioxide

Carbon dioxide is not a criteria pollutant under the National Ambient Air Quality Standards (NAAQS). Carbon dioxide is, however, a pollutant of concern on a global scale, as it is a greenhouse gas. Several states, including California, Oregon, Washington, Montana and Illinois, currently have rules for limiting carbon dioxide emissions from electric generators. Several Northeastern and Mid-Atlantic states are currently participating in a regional cap-and-trade program that limits carbon dioxide emissions from electric generators, and similar systems are in development in the West and Midwest. The cap and trade programs ensure that total emissions from all covered entities fall below a cap that typically declines over time; however, it does not mandate limits for individual entities, as is the case for performance standards (Pew Article 2010).

Sulfur Dioxide

Sulfur dioxide is one of the most regulated pollutants in the U.S. and is one of the criteria pollutants under NAAQS. Electricity generation is the highest-contributing source of sulfur dioxide emissions in the United States. Regional monitoring levels are generally below NAAQS threshold levels, except for events at three monitoring sites in Hawaii that have been suggested to be attributed to volcanic activity and therefore, as exceptional events, are not considered for regulatory purposes. Annual average ambient sulfur dioxide concentrations, as measured at area-wide monitors, have decreased by more than 70 percent since 1980. Currently, the annual average sulfur dioxide concentrations range from approximately 1 - 6 parts per billion, which is well below the quantities expected to affect human health (EPA 2010a).

[4] Historic generation rates were obtained from E-GRID 2005. Historic emissions rates were obtained from E-GRID 2005 and NET.

Nitrogen dioxide

Nitrogen dioxide is one of the most regulated pollutants in the U.S. and is one of the criteria pollutants under NAAQS. Although electricity generation is the third-highest contributor to nitrogen dioxide emissions in the Unites States, regional monitoring levels have been well below NAAQS threshold levels, so no U.S. counties (as of the summary data collected at the national level through 2008) have been considered to be out of attainment in the past decade for this parameter (EPA 2010b). Annual average ambient nitrogen dioxide concentrations, as measured at area-wide monitors, have decreased by more than 40 percent since 1980. Currently, the annual average nitrogen dioxide concentrations range from approximately 10-20 parts per billion (ppb), which is not considered to be a sufficient quantity to affect human health (EPA 2010c).

EPA expects nitrogen dioxide concentrations will continue to decrease in the future as a result of a number of mobile source (the highest contributing source of nitrogen dioxide emissions in the United States) regulations that are taking effect in the past few years. Nitrogen dioxide is, however, one of the two molecules (with volatile organic compounds [VOCs] being the other) that facilitates the formation of ground level ozone, which is also a criteria pollutant and often exceeds the NAAQS criteria.[5] Therefore, in ground-level ozone non-attainment areas, point sources of nitrogen dioxide and VOCs are tightly controlled. In addition, more stringent controls for nitrogen dioxide and VOCs are expected in the future (Lavalee 2008).

Mercury

Mercury is not one of the criteria pollutants under NAAQS, but is known to cause human health impairments. However, mercury is typically not a pollutant that is sampled by the regional monitoring equipment in each Air Quality Control Region. Many states have begun efforts to inventory sources of mercury but have yet to set limits. Some states have emissions limits, but most are sufficiently high that they are not exceeded (Lavalee 2008).

Particulate Matter

PM is one of the criteria pollutants regulated under NAAQS. It is measured as PM 2.5, particles that are 2.5 micrometers in diameter and smaller, and PM 10, particles that are 10 micrometers in diameter or smaller. These are regulated pollutants because particles smaller than 10 micrometers can, once inhaled, enter the lungs and cause serious health effects. Electricity generation is the fourth highest-contributing source of PM in the United States, both at the PM 2.5 and PM 10 levels (EPA 2010d).

Regional monitoring levels for PM 10 have generally been below NAAQS threshold levels; PM 2.5 monitoring, however, has consistently indicated many areas of periodic nonattainment of NAAQS standards since national regional monitoring began in 1999. Even though annual average ambient PM has been steadily decreasing across the country,

[5] See the maps in Appendix 10A-3; ozone is the pollutant with the largest number of non-attainment areas.

PM remains as a potentially significant environmental and human health concern (EPA 2010d).

As discussed in DCN 10-6954, increased emissions would be approximately 60 tons per year if all drift is PM_{10}. This document also noted minor drift management issues onsite at facilities using salt water cooling towers and no negative consequences off-site.

Total Emissions Increases

Emission increases consist of: (1) stack emissions from increased burning of fuel as a result of the energy penalty for retrofitting to a cooling tower (the turbine backpressure penalty); (2) stack emissions from increased burning of fuel as a result of the energy penalty for operating the cooling tower (the parasitic load); (3) cooling tower emissions including water vapor (drift) and PM. For the options under which no facilities are required to retrofit to wet cooling towers (Options 1 and 4), there would be no incremental increase in air emissions. For those options under which EPA assumes a subset of facilities would retrofit to wet cooling towers, EPA expects an increase in the total air emissions. This increase excludes those facilities already employing cooling towers. As seen in Appendix A to this chapter, the estimated energy penalty for each facility would result in an increase over each facility's historic emissions rates for average electricity generation levels.

Cooling tower particulate emissions can be mitigated through the use of drift eliminators—shaped materials that collect small water droplets as they exit the tower. Drift eliminators are capable of reducing drift to 0.0005 percent of the circulating water volume, or approximately 0.5 gallons per 100,000 gallons of flow (OPC 2008). EPA included capital costs for drift eliminators for all facilities expected to retrofit to wet cooling towers.

In addition, some number of fossil fuel-burning power plants might close due to the additional regulatory burden imposed the proposed rule. See the EBA for more information. Those facilities projected to close are (in general) the oldest, least efficient, and highest air emissions-producing sources. Therefore, the estimate of increased air emissions associated with the retrofit to wet cooling towers reflects an upper bound estimate.

Total Emissions Reductions

EPA believes projected total emissions from retrofits to cooling towers using currently available data (Appendix A) reflect an upper bound estimate for several reasons. The IPM modeling used in EPA's economic analysis indicates baseload generating units and units forecast to continue production are generally comprised of the most efficient (and therefore the lowest emitting) units, resulting in a potential reduction in total air emissions. For example, the baseline closures are coal-fired units that are among the top 50 highest SO_2 emitting plants (Sourcewatch, DCN 10-6857). In addition, the current emissions rate calculations do not reflect full implementation of the most recent air rules or pending actions on greenhouse gases and global climate change. For example, the 2010 Air Transport Rule and other state and EPA actions would reduce remaining power plant SO_2 emissions by 71 percent and NO_x emissions by 52 percent. The mercury rule would require utilities to install controls to reduce mercury emissions by 29 percent. Since the actual emissions data used in EPA's analysis does not reflect full implementation of these air rules, and since in many cases technologies to reduce emissions have yet to be installed, both the baseline and any potential increase in emissions are overstated. Finally, the latest tower fill materials and other cooling tower technology improvements provide increases in cooling capacity. In some cases, cooling towers provide cooling water at lower temperatures than available from the source water, particularly during the summer months, resulting in lower turbine back pressure in the summer when maximum power generation is desired. Despite these conservative estimates, EPA concludes there is the potential for an increase in total emissions. At this time, EPA lacks adequate data to conduct a more precise analysis of incremental emissions.

10.1.2 GIS Analysis

As part of its review of the analyses of increased emissions, EPA conducted a GIS analysis of expected pollutants from potentially affected facilities. Specifically, EPA created maps with the locations of all power plants that would have been covered under the 2004 Phase II rule overlaid with maps of non-attainment areas for the various criteria air pollutants.[6] At the time of the analysis, EPA did not have national data for manufacturers; therefore, manufacturers were excluded from this analysis.

EPA created maps to identify non-attainment areas for the following pollutants:

- Carbon monoxide (CO)
- Lead (Pb)
- Particulate matter (PM10 and PM2.5)
- Ozone
- Sulphur dioxide (SO_2)

Maps for each pollutant are found in Appendix 10A-3. For most pollutants, Phase II power plants are generally located in areas that meet the NAAQS standards (i.e., are in attainment).[7] There are, however, a significant number of facilities are located in nonattainment areas for PM2.5 and Ozone. Exhibits 10-1 and 10-2 show the data from the maps in a tabular format.

[6] EPA used data layers from the EPA Office of Air and Radiation's AQS Database. These data layers reflect attainment status for criteria pollutants under NAAQS. Generally, concentrations of air pollutants are monitored in the ambient air, usually on a county-by-county level. Areas that exceed the pollutant levels specified by NAAQS can be classified by EPA as non-attainment. See www.epa.gov/air/criteria.html for more details.

[7] Facilities in Alaska and Hawaii are not shown; these states are in attainment for all criteria pollutants.

Exhibit 10-1. Phase II facilities in non-attainment areas (by pollutant)

Pollutant	Number of facilities
Carbon monoxide (CO)	0
Lead	1
PM 10	7
PM 2.5	145
Ozone (8 hr)	174
Sulphur dioxide (SO_2)	2

Exhibit 10-2. Phase II facilities in non-attainment areas (by EPA Region)

	Number of facilities by EPA Region									
Pollutant	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VII**	**IX**	**X**
Carbon monoxide (CO)	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	1	0	0	0
PM 10	0	0	0	0	0	0	0	0	7	0
PM 2.5	4	22	37	18	53	0	4	0	7	0
Ozone (8 hr)	23	33	28	11	40	20	0	3	16	0
Sulphur dioxide (SO_2)	0	0	1	0	0	0	0	1	0	0

The geographic analysis shows that there not many Phase II power plants for which nonattainment of carbon monoxide, lead, PM 10, and sulphur dioxide NAAQS standards is likely to be a concern. There are some areas, however, where additional emissions of PM 2.5 and ozone (8-hr) could be a concern, particularly for facilities several in EPA Regions where there are significant numbers of Phase II facilities in non-attainment areas.

10.2 Vapor Plumes

In 2002, EPA's assessment of vapor plumes resulting from a retrofit from once-through cooling to recirculating wet cooling towers showed that these plumes have the potential for exacerbated fogging and icing. High levels of fogging and icing have the potential to create dangerous conditions for local roads and for air and water navigation. There are some cases of wet cooling towers being built in close proximity to airports and highways that could be susceptible to fogging and icing problems. In these cases, however, the potential for dangerous conditions were mitigated by the installation of plume abatement technologies during the construction of the cooling towers.

Plume abatement might also be necessary at certain types of locations, including situations in which local residents or governments object to the visible plume, as it may detract from a view that is valued by the community, or if the plume might create safety problems such as reduced visibility on nearby roadways or icing on roads and bridges. EPA included plume abatement technologies in its cost estimates for one-fourth of the facilities expected to retrofit to wet cooling towers under each proposed option. The Phase I support document (Table A-4) indicates that typical hybrid towers (one treatment technique for vapor plumes) have capital cost factors of 2.5 to 3.0 and operations and maintenance cost factors of 1.25 to 1.5 when compared to standard cooling towers made of Douglas fir. Similarly, the EPRI documentation states that plume abatement capital costs will be 2 to 3 times those of conventional mechanical draft towers. A number of site-specific factors come into play to determine the selection of technology, but appropriate assumptions for estimating national-level compliance costs can be made regarding the impacts of these abatement technologies to the overall cost of the retrofit. A full discussion of the costing methodology and assumptions used for the 2011 proposed rule is presented in Chapter 8 of this TDD.

10.3 Displacement of Wetlands or Other Land Habitats

As described in the 2002 proposed Phase II TDD, mechanical draft cooling towers can require land areas of up to 1.5 acres for an average-sized new cooling tower.[8] In 2002, the Agency concluded that existing Clean Water Act Section 404 programs would more than adequately protect wetlands and habitats for these land uses. EPA also determined that the displacement of wetlands on an industrial site such as a large existing power plant is not a probable outcome of cooling tower construction at most facilities. EPA does not expect habitat displacement to be a significant problem for most facilities. EPA believes for the proposed rule that existing Federal, state, and local programs for maintaining and restoring wetlands are adequate to protect wetlands and no new analyses were conducted.

10.4 Salt or Mineral Drift

As described in the 2002 proposed Phase II TDD, the operation of cooling towers in either brackish or salt water environments can release water droplets containing soluble salts, including sodium, calcium, chloride, and sulfate ions. Salt drift may also occur in freshwater systems that operate recirculating systems at very high levels of concentration, but based on EPA's site visits and the higher O&M costs of operating at the highest cycles of concentration, EPA expects this is unlikely to occur at most facilities. Salt drift from towers may be carried by prevailing winds and settle onto soil, vegetation, and waterbodies. Under normal conditions drift does not carry very far from the originating source and would require sustained high winds and high humidity to reach distances of several hundred feet in any significant quantity (SWRCB 2010). In addition, drift-reducing technologies called drift eliminators are often used to minimize salt and mineral drift. (Also see the above discussion of particulate matter and EPA's assignment of drift eliminators.) A review of GIS mapping of nuclear facilities shows the safety perimeter and setback distances at nuclear facilities are large enough that drift reaching and settling on neighboring properties is highly unlikely. Additional site-specific studies at Chalk Point and St. Johns (Maulbetsch) suggest the impacts of drift are limited to the facility property. As such, EPA does not expect drift to be a significant problem for most facilities under any of the cooling tower options.

[8] Size of "average" cooling tower is based on technology and cost assumptions used in developing the 2002 proposed Phase II rule.

10.5 Noise

Noise from mechanical draft cooling towers is generated by falling water inside the towers plus fan or motor noise or both. However, power plant sites generally do not result in off-site levels of noise more than 10 dB(A) above background (NRC 1996). The amount of noise abatement required is a function of both the local community noise code and the distance from the tower to the nearest sound receptor that must meet the specified noise code. Noise abatement costs will be highest if a tower must be located near areas with highly restrictive noise codes, such as residential areas.

Noise abatement features are an integral and inexpensive component of modern cooling tower designs. (See the 2002 proposed TDD, Appendix B, Charts 2-1 through 2-6 for a comparison of low-noise tower costs and other types of tower modifiers.) Facilities that make use of cooling towers might expect the typical noise level to be approximately 70 dB within 50 feet of the tower (SPX 2009).[9] Because sound levels diminish approximately 5 dB per doubling of distance, and 55 dB falls between the sound level of rainfall and normal conversation (and therefore would not be considered noise pollution), a buffer of 400 feet would suffice for noise abatement at most sites. In addition, EPA's "Protective Noise Levels" guidance found that ambient noise levels of 55 dB was sufficient to protect public health and welfare and, in most cases, did not create an annoyance (EPA 1978). As for noise pollution at the site itself, the New York State Department of Environmental Conservation's "Assessing and Mitigating Noise Impacts" policy states that 60-70 dB is the beginning of the threshold for annoyance in non-industrial sites and that noise can exceed 65 dB (and up to 79 dB) in commercial or industrial sites. A common goal is to keep new noise sources from increasing the overall noise levels by 5-10 dB. Given that noise is measured on a logarithmic scale, adding a cooling tower that operates with a sound level of approximately70 dB will be unlikely to add a significant level of noise to an already noisy industrial site (NYDEC 2000). Given that noise appears to dissipate relatively quickly (and the fact that many industrial sites are large and a 400 foot buffer would not be a significant limitation), effects from noise are not expected to be significant at most sites. There will certainly be some sites that require noise mitigation, but the number of sites is likely to already be represented by the analyses for plume and population density.

The cost contribution of low noise fans would comprise a very small portion of the total installed capital cost of a retrofitted cooling system (on the same order as drift elimination technologies). Where noise abatement materials maintenance costs are higher (such as for larger towers), O&M costs should be commensurately reduced. Thus, the net effect of this noise abatement technology design on cooling tower O&M costs is expected to be minimal.

As such, the Agency is confident that the issue of noise abatement is not critical to the evaluation of the environmental side effects of cooling towers. In addition, this issue is often a matter of adverse public reactions to the noise and not environmental or human health (i.e., hearing) impacts. The NRC adds further, "[n]atural-draft and mechanical-draft cooling towers emit noise of a broadband nature...Because of the broadband

[9] For additional technical discussion of noise mitigation, please see DCN 10-6652.

character of the cooling towers, the noise associated with them is largely indistinguishable and less obtrusive than transformer noise or loudspeaker noise."

EPA included additional costs for noise abatement at approximately 25 percent of existing facilities; see Chapter 8 of the TDD and DCNs 10-6671 and 6672. As such, EPA does not expect noise abatement to be a significant problem for most facilities.

10.6 Solid Waste Generation

Recirculation of cooling water increases the volume of solid wastes generated because some facilities (including most manufacturers) treat the cooling tower blowdown in a wastewater treatment system before discharge, and the concentrated pollutants removed from the blowdown add to the amount of wastewater sludge generated by the facility. For facilities operating cooling towers in brackish or saline waters, the concentration of salts within the tower and blowdown are a primary design factor. As such, these systems can have elevated salt concentrations. However, the concentration of salts is generally a treatable condition for blowdown from towers. In general, manufacturers tend to have systems in place for treating this type of solid. EPA does not expect the impacts of solids waste disposal to be a significant problem and did not further evaluate impacts from solids waste disposal for the proposed rule.[10]

10.7 Evaporative Consumption of Water

Cooling tower operation is designed to result in a measurable evaporation of water drawn from the source water. Depending on the size and flow conditions of the affected waterbody, evaporative water loss can affect the quality of aquatic habitat and recreational fishing. According to NUREG-1437 (NRC 1996), "water lost by evaporation from the heated discharge of once-through cooling is about 60 percent of that which is lost through cooling towers." NUREG-1437 goes on to further state that "with once-through cooling systems, evaporative losses... occur externally in the adjacent body of water instead of in the closed-cycle system." Therefore, evaporation does occur due to heating of water in once-through cooling systems, even though the majority of this loss happens downstream of the plant in the receiving water body due to the evaporation in the heated effluent plume.

EPA acknowledges that evaporative losses from closed-cycle cooling towers are greater than those from once-through cooling systems. At the national level, the rate of evaporation can increase by a factor of 2 to 3 in closed-cycle systems. This conclusion is consistent with research conducted by NUREG-1437 and the Electric Power Research Institute (EPRI) that concluded that losses in closed-cycle systems are approximately 60-80 percent greater (EPRI 2002).

[10] EPA assumed no incremental costs for treatment of blowdown, as the issue is expected to be minor for most facilities. For example, facilities on brackish waters are already discharging to waters with elevated TSS. Additionally, many facilities (particularly manufacturers) already have wastewater treatment capabilities in place.

The differences in evaporative losses are minimal in terms of gallons lost and in most cases are minor compared to river flow. In areas where water resources are limited (e.g., the desert southwest or the recently drought-stricken southeast), once-through cooling may not be a prudent option for new facilities and it may be a liability for existing facilities. EPA witnessed this first hand in its site visits, as several facilities retrofitted to closed-cycle cooling in spite of drought conditions (see, e.g., the site visit report for McDonough). Similarly, for facilities located on smaller waterbodies, evaporative losses from once-through cooling will be higher since the effluent comprises a larger percentage of the receiving stream, won't mix as quickly, and will remain heated longer, leading to additional evaporation. Smaller receiving streams are also more likely to be affected by thermal discharges from the perspective of 316(a), which requires that the discharge not affect the "balanced indigenous population."

Dry cooling and hybrid (wet/dry) cooling are available technologies that reduce evaporative losses. Dry cooling systems require virtually no water withdrawals and hybrid systems consume about 15 percent less water through evaporation. EPA's record shows these systems for reducing evaporative losses have been available and demonstrated for over 30 years.

While EPA did not attempt to identify or quantify the meteorological effects, the water vapor in the evaporative plumes does not simply disappear; it will be incorporated into the atmosphere and may return to the original watershed in the form of precipitation.

Finally, cooling water withdrawals are a very small component of consumptive uses nationwide. As noted in EPA's Closed-cycle Cooling Systems for Steam-electric Power Plants: A State-of-the-art Manual (DCN 10-6845F), consumptive water uses by the steam electric sector was 1.2 percent of consumptive uses nationwide in 1975; agriculture was 85 percent, drinking water was 7 percent and mining was 7 percent. The Nuclear Energy Institute presented similar data, noting that a closed-cycle power plant typically consumes 23 gallons of water per day per household served with electricity, while the same average household uses 94 gallons per day for domestic uses.

10.8 Thermal Effluent

EPA notes that Section 316(a) of the CWA provides EPA the authority to deal with thermal effects and that technologies used to meet 316(b) standards may have impacts and/or benefits for meeting 316(a) requirements. Given the lack of specific data on the impact of thermal effects, EPA did not conduct a formal analysis or quantify the impacts of thermal effluent discharges, although the conversion to cooling towers clearly presents a significant reduction in the discharge of heat, a regulated pollutant. EPA did conduct an overview of thermal discharge data for a sampling of electric generator facilities in the Permit Compliance System, but excluded data from facilities that already use closed cycle cooling. EPA has calculated that mechanical draft evaporative cooling towers are an effective technology for reducing the volume of surface water withdrawn for cooling and can reduce once-through intake flows by 93 percent to 99 percent depending on operating conditions such as the temperature rise and the cycles of concentration.

10.9 References

California Ocean Protection Council (OPC). 2008. California's Coastal Power Plants: Alternative Cooling System Analysis. Available at http://www.opc.ca.gov/webmaster/ftp/project_pages/OTC/engineering%20study/CA_Power_Plant_Analysis_Complete.pdf.

California State Water Resources Control Board and California Environmental Protection Agency (SWRCB). 2010. Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling Final Substitute Environmental Document. Available at http://www.swrcb.ca.gov/water_issues/programs/npdes/docs/cwa316may2010/sed_final.pdf.

Electric Power Research Institute (EPRI). 2002. Water & Sustainability (Volume 3): U.S. Water Consumption for Power Production—The Next Half Century. EPRI, Palo Alto, CA: 2002. 1006786.

Environmental Protection Agency (EPA). 2010a. Sulfur Dioxide. Available at http://www.epa.gov/air/sulfurdioxide/.

Environmental Protection Agency. 2010b. Nitrogen Dioxide Information. Available at http://www.epa.gov/oaqps001/greenbk/nindex.html.

Environmental Protection Agency. 2010c. Nitrogen Dioxide. Available at http://www.epa.gov/airquality/nitrogenoxides/.

Environmental Protection Agency. 2010d. Particulate Matter. Available at http://www.epa.gov/air/particlepollution/.

Environmental Protection Agency. 1978. Protective Noise Levels. EPA 550/9-79-100 November 1978.

Lavalee, Tim. 2008. Personal communication with Kelly Meadows, Tetra Tech. September 16, 2008.

New York Department of Environmental Conservation (NYDEC). 2000. Assessing and Mitigating Noise Impacts. Available at http://www.dec.ny.gov/docs/permits_ej_operations_pdf/noise2000.pdf.

Nuclear Energy Institute (NEI). 2010. Water Use and Nuclear Power Plants. May 2010. Available at http://www.nei.org/filefolder/Water_Use_Fact_Sheet_0510_1.pdf.

Nuclear Regulatory Commission (NRC). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. NUREG-1437 Vol. 1. http://www.nrc.gov/docs/nuregs/staff/sr1437/V1/sr1437v1.html#_1_128

SPX Cooling Technologies (SPX). 2009. Cooling Tower Fundamentals. Ed. John Hensley. SPX Cooling Technologies, Overland Park, Kansas. Available at http://spxcooling.com/pdf/Cooling-Tower-Fundamentals.pdf.

Appendix to Chapter 10: Non-water Quality Impacts

10A.0 Air Emissions Data for Option 2

EPA assumed that the 136 power plants withdrawing 125 MGD or more for which air emissions data is available would retrofit to recirculating wet cooling towers (not including those facilities already employing cooling towers). This table represents facility-specific increases; the data are based on the estimated energy penalty for each facility, the facility's historic average electricity generation level, and its average historic emission rates.

Unit	Total increase in Annual CO_2 (tons)	Total increase in Annual SO_2 (tons)	Total increase in Annual NO_x (tons)	Total increase in Annual Hg (lbs)	Total increase in Annual PM2.5 (tons)	Total increase in AnnualPM10 (tons)
1	47,062.09	462.89	103.63	2.71	21.68	26.24
2	25,758.85	182.78	90.66	1.93	28.65	32.96
3	309.09	0.07	1.23		12.49	15.62
4	17,646.79	174.67	47.89	0.70	5.10	6.39
5	-	-	-		0.04	0.04
6	14,022.39	72.49	38.80	0.52	8.29	23.12
7	26,508.32	0.15	7.26		2.26	2.26
8	37,197.49	66.09	92.44	1.12		5.49
9	17,547.14	120.60	33.08	1.38	9.87	13.32
10	5,114.76	0.27	13.03		-	-
11	3,427.09	44.84	7.85		1.08	1.36
12	45,620.40	181.72	83.39	0.17	27.71	28.22
13	127.92	0.16	0.20		-	-
14	9,982.55	8.94	15.78		-	-
15	5,883.26	1.17	4.81		-	-
16	214,619.09	41.72	64.54		-	-
17	16,853.90	232.41	50.84	0.92	17.41	19.21
18	24,876.82	106.21	40.74	0.20	3.88	4.42
19	41,790.45	349.91	163.05	1.21		
20	38,635.50	551.81	149.18	4.89	5.96	7.86
21	15,647.31	256.38	55.88	0.58	10.84	12.31
22	112,328.50	273.52	51.91	14.10	21.15	27.82
23	2,957.93	0.32	1.53			
24	41,808.74	542.94	97.13	1.92	33.78	38.56
25	9,977.82	2.22	4.40			
26	15,885.15	11.59	25.09		2.30	2.37
27	89,591.31	106.55	82.10	3.80	10.45	17.70
28	41,438.63	107.78	66.59	2.41	6.75	8.98
29	5,627.19	0.03	3.91		0.32	0.32
30	148.85	0.18	0.23		-	-
31	6,955.23	15.62	12.49		0.93	1.22
32	51,350.22	238.61	128.75	1.25	11.88	16.62
33	6,312.31	0.03	1.20		0.25	0.25
34	551.25	0.03	0.47		0.22	0.22
35	98,796.63	209.09	276.70	2.31	13.93	18.60
36	128,643.03	664.68	209.76	5.53	24.91	30.44
37	104,088.03	451.36	456.50	2.28		3.02

Unit	Total increase in Annual CO_2 (tons)	Total increase in Annual SO_2 (tons)	Total increase in Annual NO_x (tons)	Total increase in Annual Hg (lbs)	Total increase in Annual PM2.5 (tons)	Total increase in AnnualPM10 (tons)
38	3,316.93	0.04	3.72		0.32	0.32
39	29,456.81	152.77	57.76	0.87	4.31	5.03
40	125,430.47	1,212.29	180.61	0.69	65.05	71.23
41	24,843.22	122.04	139.03		3.95	3.95
42	100,889.85	387.50	117.70	5.34	36.94	62.39
43	28,645.06	571.47	55.81	1.51	25.13	26.31
44	46,639.02	353.01	63.12		4.56	6.14
45	94,162.18	558.07	171.88	5.06	6.68	15.33
46	43,849.02	179.11	75.57	0.69	5.78	10.05
47	215,723.35	1,736.65	475.96	13.13	42.76	46.92
48	26,284.78	0.17	8.25		-	-
49	83,873.34	398.21	129.19	3.63	15.54	30.98
50	64,350.01	445.24	143.20	2.66	18.85	23.37
51	149,318.10	697.85	287.80	4.18	22.37	23.30
52	54,419.06	13.21	32.41			
53	-	-	-	-	1.33	1.33
54	73,506.91	461.34	129.32	4.77	25.35	29.76
55	33,331.51	209.74	100.16	2.07	11.34	14.04
56	14,929.32	0.09	6.66		1.33	1.33
57	13,141.93	4.91	14.04		1.54	1.54
58	71,845.14	501.61	93.99	3.47	25.92	29.26
59	465,996.64	1,351.75	557.28	8.93	53.92	72.16
60	126,653.35	126,653.35	208.98	11.26	109.14	109.21
61	112,406.67	2,034.33	190.48	4.89	88.06	91.90
62	84,840.09	135.58	277.76	2.39		8.69
63	120,257.80	169.46	442.70	6.48	19.21	28.00
64	109,150.28	495.24	326.70	4.34	7.14	7.65
65	31.63	-	0.01		0.04	0.04
66	86,409.28	396.89	118.42	4.77	17.30	17.91
67	29,407.30	50.62	36.82		7.25	7.25
68	73,475.45	589.60	156.50		16.59	21.11
69	172,555.52	1,356.09	240.19	9.37	104.11	150.21
70	82,741.51	996.05	104.63	9.32	33.03	38.34
71	154,976.34	508.53	243.02	9.37	16.33	21.76
72	47,713.04	106.61	71.76		8.22	10.45
73	151,309.02	972.71	123.17		8.33	8.33
74	21,922.20	0.11	26.27		2.51	2.51
75	11,196.38	1.80	22.64		1.83	1.83
76	41,876.76	0.23	11.94		1.40	1.40
77	14,759.60	23.50	18.14		1.08	1.26
78	55,712.41	149.93	57.41	6.75	8.36	11.74
79	179,421.18	1,251.65	234.68	8.64	59.34	66.27
80	212,738.66	420.00	172.87	33.94	37.44	46.02
81	189,651.05	1,470.08	333.25	5.63	56.97	58.66
82	65,809.54	378.27	156.37			
83	36,324.07	0.30	3.55		-	-
84	15,718.64	0.04	0.87		3.91	3.91
85	191,789.22	857.49	448.65	6.89	16.62	31.56
86	20,216.39	0.11	15.36		1.97	1.97
87	239,320.63	646.69	278.35	7.72	13.14	22.08
88	13,326.31	1.13	19.61		0.86	0.86
89	1.64	-	-		0.39	1.22
90	232,197.58	2,787.33	415.09	8.33	82.10	91.51

Unit	Total increase in Annual CO_2 (tons)	Total increase in Annual SO_2 (tons)	Total increase in Annual NO_x (tons)	Total increase in Annual Hg (lbs)	Total increase in Annual PM2.5 (tons)	Total increase in AnnualPM10 (tons)
91	247,340.42	658.21	521.08	13.43	22.80	29.51
92	133,651.85	1,528.41	413.44	9.32	74.03	74.82
93	181,036.27	1,093.83	345.40	8.97	3.95	7.83
94	3,492.64	0.32	2.92		0.14	0.18
95	318,582.91	932.07	198.31	21.10	28.43	34.54
96	323,849.40	3,755.21	500.13	20.83	168.05	219.49
97	193,434.16	2,397.29	323.89	7.39	100.77	108.27
98	150,672.13	79.21	25.52		7.04	7.43
99	40,719.17	84.37	65.79		6.00	6.79
100	223,448.67	1,630.73	298.85	9.66	54.21	63.36
101	8,555.80	0.04	1.20		10.77	10.95
102	299,311.78	755.68	181.28	12.00	22.33	27.97
103	176,410.50	503.87	247.99	9.53	16.48	22.55
104	74,228.78	355.64	224.72			
105	188,729.21	437.10	166.01	27.27	17.77	28.86
106	10,802.33	0.05	0.79		3.91	3.95
107	72,148.92	115.46	168.23	1.89	19.96	38.41
108	141,882.58	860.39	315.13	5.79	65.19	87.74
109	17,576.18	0.09	4.39		1.69	1.72
110	430,167.67	1,048.36	245.26	27.63	44.05	80.74
111	303,341.43	3,017.74	464.77	36.96	98.33	117.18
112	11,130.96	0.06	13.98		4.38	4.38
113	492,439.33	1,926.14	691.02	18.58	90.54	107.48
114	298,837.98	2,685.20	437.93	23.38	75.71	80.85
115	133,838.18	1,154.35	265.87	4.79	77.87	80.20
116	318,262.91	1,397.99	586.15	14.88	103.57	115.13
117	552,928.93	3,825.75	903.42	22.55	232.81	258.30
118	137,532.97	748.11	317.88			
119	280,145.79	1,444.56	393.03	7.66	57.19	58.05
120	361,319.89	408.45	857.18	5.65	62.47	91.04
121	279,371.93	1,167.42	382.51	9.55	53.17	60.81
122	620,697.97	1,992.54	342.07	32.76	35.43	62.29
123	319,700.75	2,680.25	812.09	18.87	25.49	36.94
124	510,476.19	3,475.57	733.05	19.32	177.96	205.31
125	49,502.38	0.25	13.41		5.89	5.89
126	102,624.92	1.38	251.19		14.25	14.25
127	934,864.48	2,975.95	651.78	56.86	90.00	102.28
128	395,263.14	1,234.25	651.74	16.94	88.53	113.80
129	2,957.39	0.01	3.52		-	-
130	17,817.23	0.09	29.71		1.08	1.08
131	236,556.23	463.21	166.69	10.06	11.99	12.28
132	627,946.34	2,861.15	507.50	77.30	105.22	171.57
133	650,275.69	3,959.99	1,270.78	45.12	101.06	108.63
134	743,242.36	1,985.06	178.47	20.97		
135	606,115.85	627.29	975.98	9.47	94.78	129.49
136	154,739.88	1,181.66	356.45			
TOTAL	18,360,926.72	214,741.34	26,591.23	873.51	3,653.08	4,495.65

10A.1 Air Emissions Data for Option 3

EPA assumed that all 167 power plants for which data is readily available would retrofit to recirculating wet cooling towers. This table represents facility-specific increases; the data are based on the estimated energy penalty for each facility, the facility's historic average electricity generation level, and its average historic emission rates.

Unit	Total increase in Annual CO_2 (tons)	Total increase in Annual SO_2 (tons)	Total increase in Annual NO_x (tons)	Total increase in Annual Hg (lbs)	Total increase in Annual PM2.5 (tons)	Total increase in Annual PM10 (tons)
1	9,603.30	89.47	41.47		-	0.04
2	-	-	37.27	8.21	-	-
3	2,188.80	30.98	9.56		0.07	0.25
4	-	-	-	2.63		0.22
5	289,758.55	936.94	210.06	12.83	18.92	22.08
6	91.61	-	0.02		-	-
7	-	-	25.95	2.32	-	-
8	-	-	23.40	5.06	-	-
9	5,488.98	0.05	1.45		0.86	0.86
10	121,821.75	382.08	495.89	3.33	14.93	14.93
11	20,355.14	23.25	26.52	0.62	1.01	1.33
12	28,787.97	397.72	53.05	1.85	30.98	33.03
13	1,496.18	0.41	2.84		-	-
14	5,718.97	0.03	4.17		19.49	22.04
15	-	-	0.11	0.23	-	-
16	39,262.67	0.60	2.43		-	-
17	321.24	0.01	0.52		-	-
18	15,690.00	110.42	29.83		-	-
19	15,871.58	333.43	39.55	0.71		
20	11,470.36	235.69	25.22	1.69	19.57	20.10
21	3,891.51	16.56	7.37		0.65	0.65
22	2,842.32	14.14	4.19		-	-
23	16,719.07	97.23	56.40	0.63		
24	277.81	0.01	0.45		-	-
25	25,010.72	156.42	52.03	0.71	3.23	5.85
26	24,760.44	85.60	43.78	1.55	8.26	14.75
27	39,923.88	191.76	85.00	1.80	11.34	14.11
28	-	0.01	33.98	0.76	-	-
29	6,312.31	0.03	1.20		0.04	0.04
30	2,136.46	30.26	6.25		-	-
31	2,974.80	7.91	4.96		0.25	0.32
32	47,062.09	462.89	103.63	2.71	21.68	26.24
33	25,758.85	182.78	90.66	1.93	28.65	32.96
34	309.09	0.07	1.23		12.49	15.62
35	17,646.79	174.67	47.89	0.70	5.10	6.39
36	-	-	-		0.04	0.04
37	14,022.39	72.49	38.80	0.52	8.29	23.12
38	26,508.32	0.15	7.26		2.26	2.26
39	37,197.49	66.09	92.44	1.12		5.49
40	17,547.14	120.60	33.08	1.38	9.87	13.32
41	5,114.76	0.27	13.03		-	-
42	3,427.09	44.84	7.85		1.08	1.36

Unit	Total increase in Annual CO_2 (tons)	Total increase in Annual SO_2 (tons)	Total increase in Annual NO_x (tons)	Total increase in Annual Hg (lbs)	Total increase in Annual PM2.5 (tons)	Total increase in Annual PM10 (tons)
43	45,620.40	181.72	83.39	0.17	27.71	28.22
44	127.92	0.16	0.20		-	-
45	9,982.55	8.94	15.78		-	-
46	5,883.26	1.17	4.81		-	-
47	214,619.09	41.72	64.54		-	-
48	16,853.90	232.41	50.84	0.92	17.41	19.21
49	24,876.82	106.21	40.74	0.20	3.88	4.42
50	41,790.45	349.91	163.05	1.21		
51	38,635.50	551.81	149.18	4.89	5.96	7.86
52	15,647.31	256.38	55.88	0.58	10.84	12.31
53	112,328.50	273.52	51.91	14.10	21.15	27.82
54	2,957.93	0.32	1.53			
55	41,808.74	542.94	97.13	1.92	33.78	38.56
56	9,977.82	2.22	4.40			
57	15,885.15	11.59	25.09		2.30	2.37
58	89,591.31	106.55	82.10	3.80	10.45	17.70
59	41,438.63	107.78	66.59	2.41	6.75	8.98
60	5,627.19	0.03	3.91		0.32	0.32
61	148.85	0.18	0.23		-	-
62	6,955.23	15.62	12.49		0.93	1.22
63	51,350.22	238.61	128.75	1.25	11.88	16.62
64	6,312.31	0.03	1.20		0.25	0.25
65	551.25	0.03	0.47		0.22	0.22
66	98,796.63	209.09	276.70	2.31	13.93	18.60
67	128,643.03	664.68	209.76	5.53	24.91	30.44
68	104,088.03	451.36	456.50	2.28		3.02
69	3,316.93	0.04	3.72		0.32	0.32
70	29,456.81	152.77	57.76	0.87	4.31	5.03
71	125,430.47	1,212.29	180.61	0.69	65.05	71.23
72	24,843.22	122.04	139.03		3.95	3.95
73	100,889.85	387.50	117.70	5.34	36.94	62.39
74	28,645.06	571.47	55.81	1.51	25.13	26.31
75	46,639.02	353.01	63.12		4.56	6.14
76	94,162.18	558.07	171.88	5.06	6.68	15.33
77	43,849.02	179.11	75.57	0.69	5.78	10.05
78	215,723.35	1,736.65	475.96	13.13	42.76	46.92
79	26,284.78	0.17	8.25		-	-
80	83,873.34	398.21	129.19	3.63	15.54	30.98
81	64,350.01	445.24	143.20	2.66	18.85	23.37
82	149,318.10	697.85	287.80	4.18	22.37	23.30
83	54,419.06	13.21	32.41			
84	-	-	-	-	1.33	1.33
85	73,506.91	461.34	129.32	4.77	25.35	29.76
86	33,331.51	209.74	100.16	2.07	11.34	14.04
87	14,929.32	0.09	6.66		1.33	1.33
88	13,141.93	4.91	14.04		1.54	1.54
89	71,845.14	501.61	93.99	3.47	25.92	29.26
90	465,996.64	1,351.75	557.28	8.93	53.92	72.16
91	126,653.35	126,653.35	208.98	11.26	109.14	109.21
92	112,406.67	2,034.33	190.48	4.89	88.06	91.90

Unit	Total increase in Annual CO_2 (tons)	Total increase in Annual SO_2 (tons)	Total increase in Annual NO_x (tons)	Total increase in Annual Hg (lbs)	Total increase in Annual PM2.5 (tons)	Total increase in Annual PM10 (tons)
93	84,840.09	135.58	277.76	2.39		8.69
94	120,257.80	169.46	442.70	6.48	19.21	28.00
95	109,150.28	495.24	326.70	4.34	7.14	7.65
96	31.63	-	0.01		0.04	0.04
97	86,409.28	396.89	118.42	4.77	17.30	17.91
98	29,407.30	50.62	36.82		7.25	7.25
99	73,475.45	589.60	156.50		16.59	21.11
100	172,555.52	1,356.09	240.19	9.37	104.11	150.21
101	82,741.51	996.05	104.63	9.32	33.03	38.34
102	154,976.34	508.53	243.02	9.37	16.33	21.76
103	47,713.04	106.61	71.76		8.22	10.45
104	151,309.02	972.71	123.17		8.33	8.33
105	21,922.20	0.11	26.27		2.51	2.51
106	11,196.38	1.80	22.64		1.83	1.83
107	41,876.76	0.23	11.94		1.40	1.40
108	14,759.60	23.50	18.14		1.08	1.26
109	55,712.41	149.93	57.41	6.75	8.36	11.74
110	179,421.18	1,251.65	234.68	8.64	59.34	66.27
111	212,738.66	420.00	172.87	33.94	37.44	46.02
112	189,651.05	1,470.08	333.25	5.63	56.97	58.66
113	65,809.54	378.27	156.37			
114	36,324.07	0.30	3.55		-	-
115	15,718.64	0.04	0.87		3.91	3.91
116	191,789.22	857.49	448.65	6.89	16.62	31.56
117	20,216.39	0.11	15.36		1.97	1.97
118	239,320.63	646.69	278.35	7.72	13.14	22.08
119	13,326.31	1.13	19.61		0.86	0.86
120	1.64	-	-		0.39	1.22
121	232,197.58	2,787.33	415.09	8.33	82.10	91.51
122	247,340.42	658.21	521.08	13.43	22.80	29.51
123	133,651.85	1,528.41	413.44	9.32	74.03	74.82
124	181,036.27	1,093.83	345.40	8.97	3.95	7.83
125	3,492.64	0.32	2.92		0.14	0.18
126	318,582.91	932.07	198.31	21.10	28.43	34.54
127	323,849.40	3,755.21	500.13	20.83	168.05	219.49
128	193,434.16	2,397.29	323.89	7.39	100.77	108.27
129	150,672.13	79.21	25.52		7.04	7.43
130	40,719.17	84.37	65.79		6.00	6.79
131	223,448.67	1,630.73	298.85	9.66	54.21	63.36
132	8,555.80	0.04	1.20		10.77	10.95
133	299,311.78	755.68	181.28	12.00	22.33	27.97
134	176,410.50	503.87	247.99	9.53	16.48	22.55
135	74,228.78	355.64	224.72			
136	188,729.21	437.10	166.01	27.27	17.77	28.86
137	10,802.33	0.05	0.79		3.91	3.95
138	72,148.92	115.46	168.23	1.89	19.96	38.41
139	141,882.58	860.39	315.13	5.79	65.19	87.74
140	17,576.18	0.09	4.39		1.69	1.72
141	430,167.67	1,048.36	245.26	27.63	44.05	80.74
142	303,341.43	3,017.74	464.77	36.96	98.33	117.18

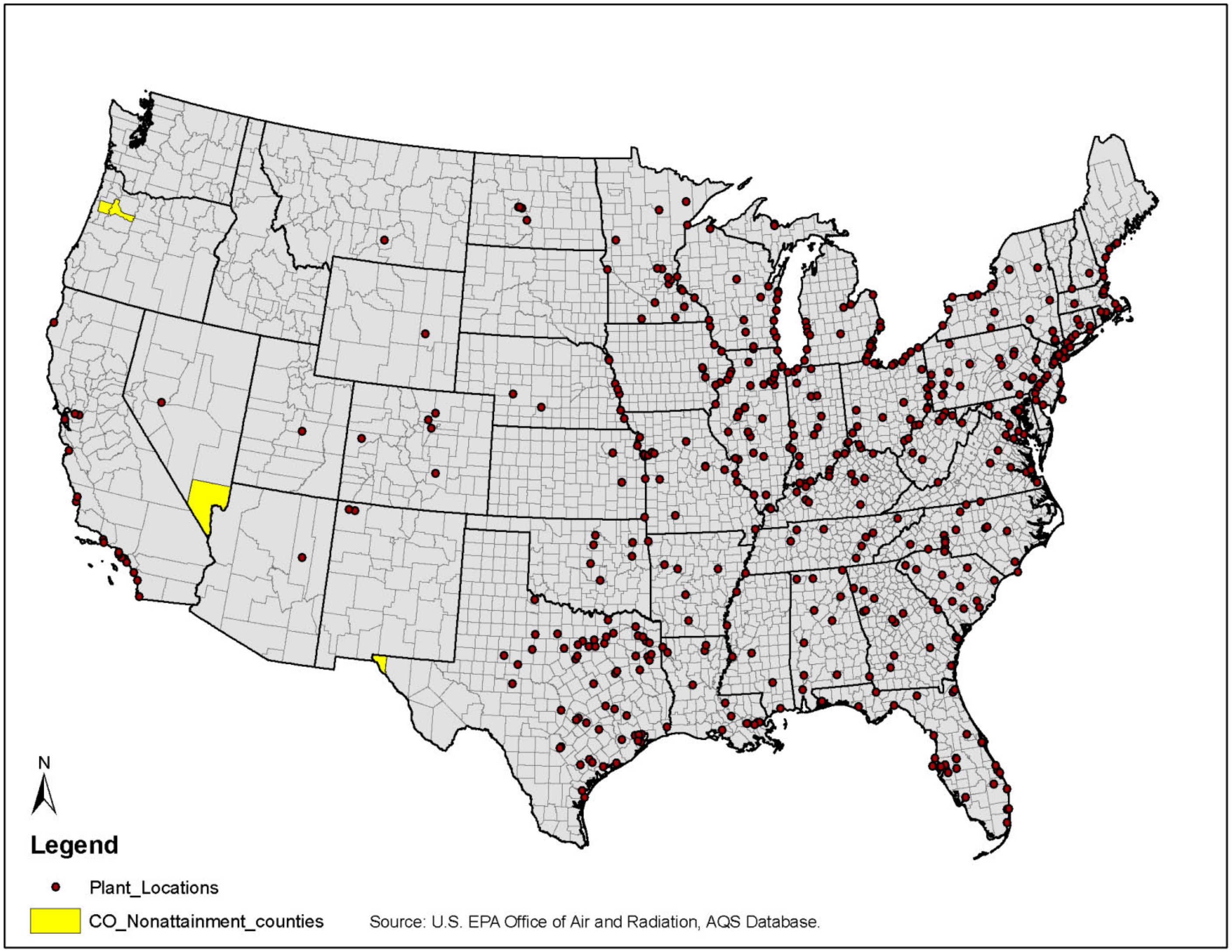
Unit	Total increase in Annual CO_2 (tons)	Total increase in Annual SO_2 (tons)	Total increase in Annual NO_x (tons)	Total increase in Annual Hg (lbs)	Total increase in Annual PM2.5 (tons)	Total increase in Annual PM10 (tons)
143	11,130.96	0.06	13.98		4.38	4.38
144	492,439.33	1,926.14	691.02	18.58	90.54	107.48
145	298,837.98	2,685.20	437.93	23.38	75.71	80.85
146	133,838.18	1,154.35	265.87	4.79	77.87	80.20
147	318,262.91	1,397.99	586.15	14.88	103.57	115.13
148	552,928.93	3,825.75	903.42	22.55	232.81	258.30
149	137,532.97	748.11	317.88			
150	280,145.79	1,444.56	393.03	7.66	57.19	58.05
151	361,319.89	408.45	857.18	5.65	62.47	91.04
152	279,371.93	1,167.42	382.51	9.55	53.17	60.81
153	620,697.97	1,992.54	342.07	32.76	35.43	62.29
154	319,700.75	2,680.25	812.09	18.87	25.49	36.94
155	510,476.19	3,475.57	733.05	19.32	177.96	205.31
156	49,502.38	0.25	13.41		5.89	5.89
157	102,624.92	1.38	251.19		14.25	14.25
158	934,864.48	2,975.95	651.78	56.86	90.00	102.28
159	395,263.14	1,234.25	651.74	16.94	88.53	113.80
160	2,957.39	0.01	3.52		-	-
161	17,817.23	0.09	29.71		1.08	1.08
162	236,556.23	463.21	166.69	10.06	11.99	12.28
163	627,946.34	2,861.15	507.50	77.30	105.22	171.57
164	650,275.69	3,959.99	1,270.78	45.12	101.06	108.63
165	743,242.36	1,985.06	178.47	20.97		
166	606,115.85	627.29	975.98	9.47	94.78	129.49
167	154,739.88	1,181.66	356.45			
TOTAL	19,053,703.14	217,882.36	27,916.17	918.43	3,782.68	4,646.25

10A.2 GIS Analyses of Expected Pollutants from Potentially Affected Facilities

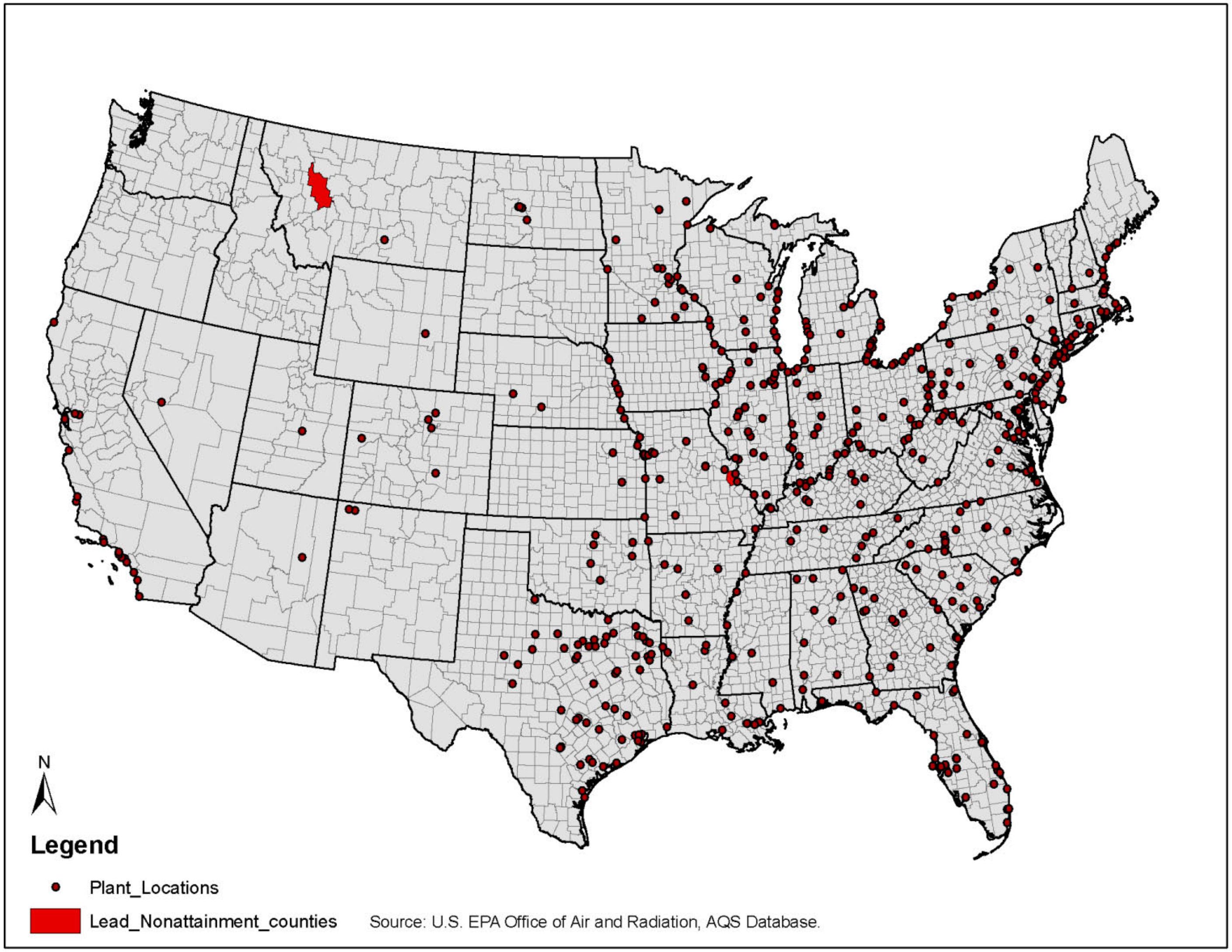
EPA created maps with the locations of all Phase II facilities (excluding manufacturers) overlaid with maps of non-attainment areas for the various criteria air pollutants:

- Carbon monoxide (CO)
- Lead (Pb)
- Particulate matter (PM2.5)
- Particulate matter (PM10)
- Ozone
- Sulphur dioxide (SO_2)

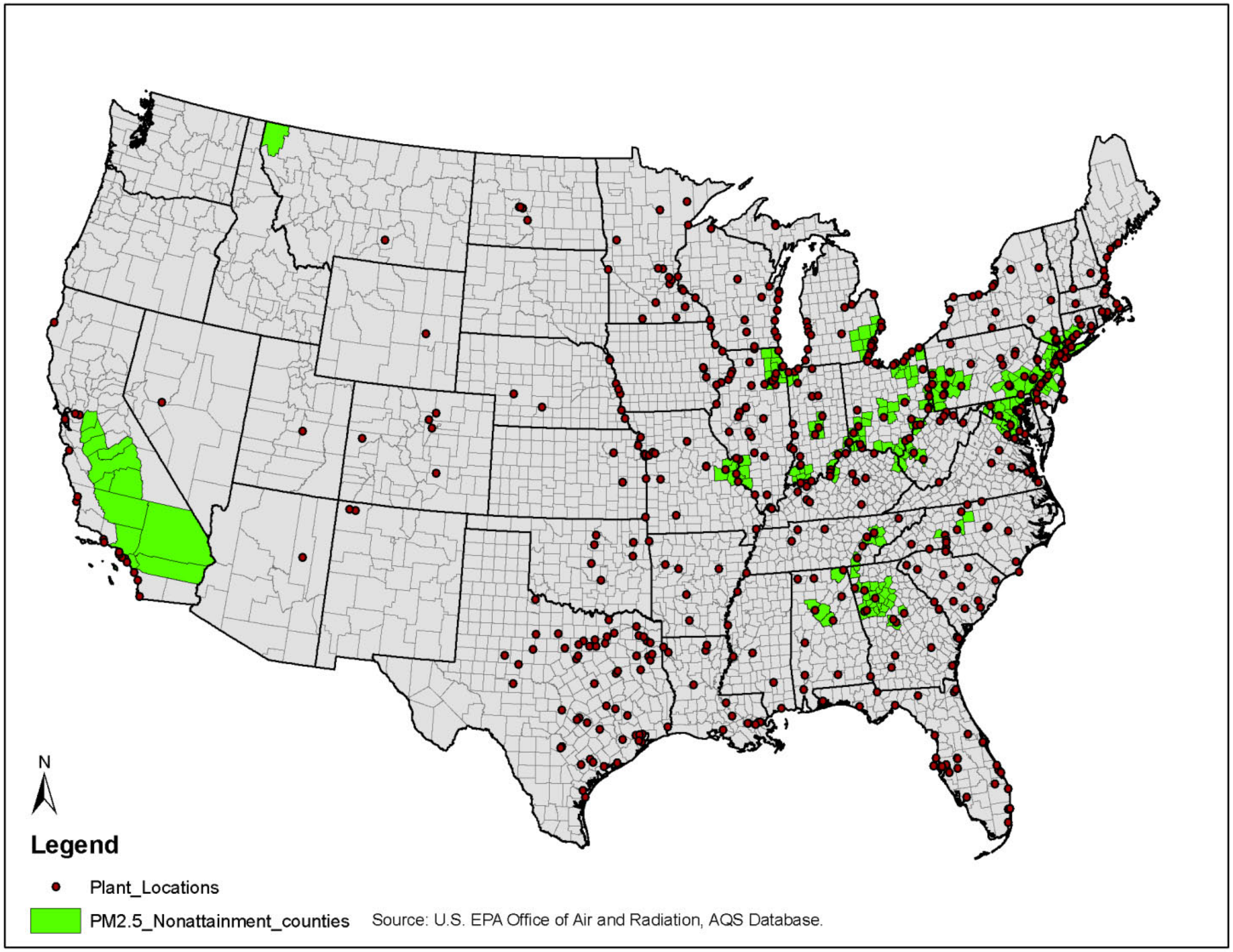
CO_2 Nonattainment Areas



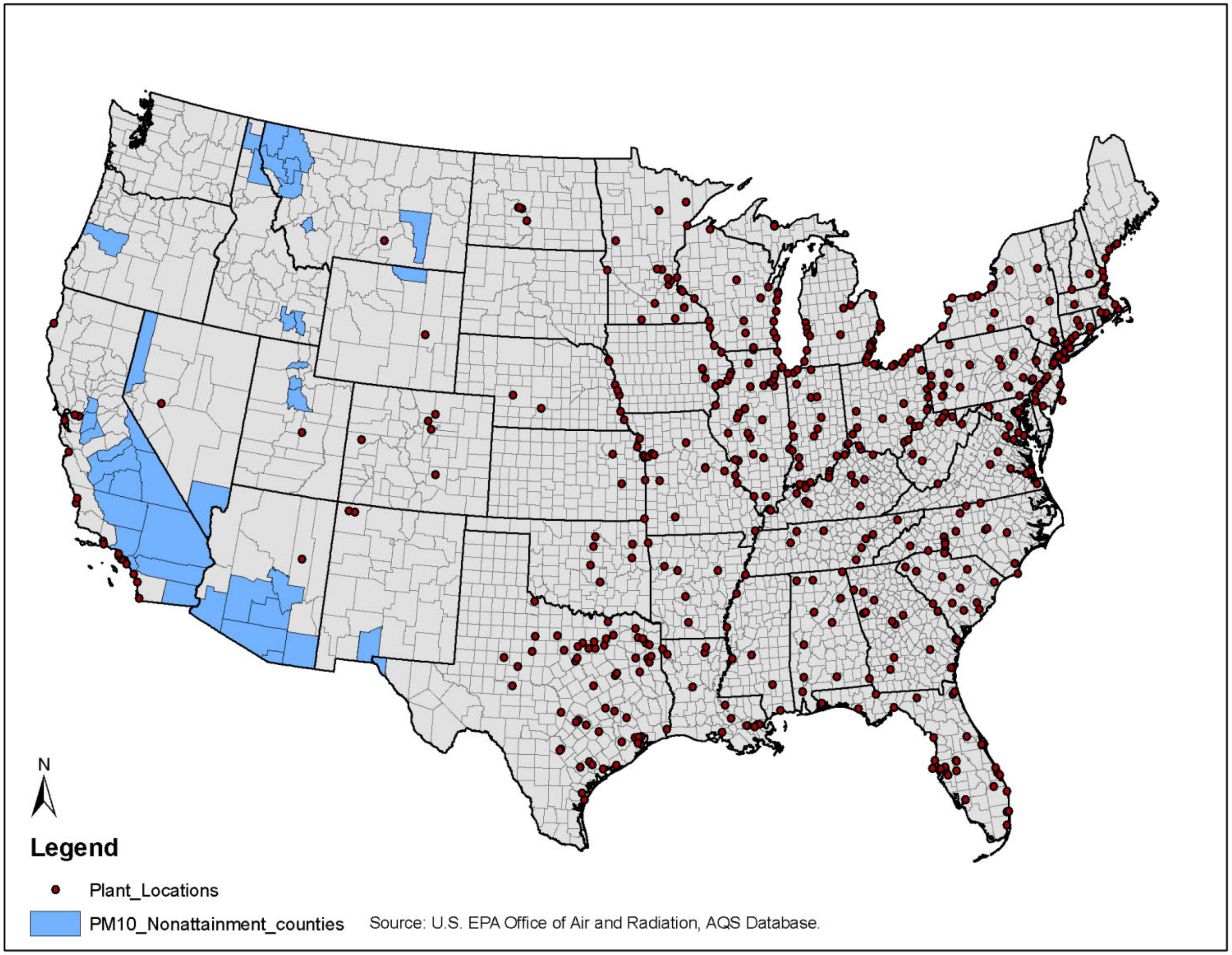
Pb Nonattainment Areas



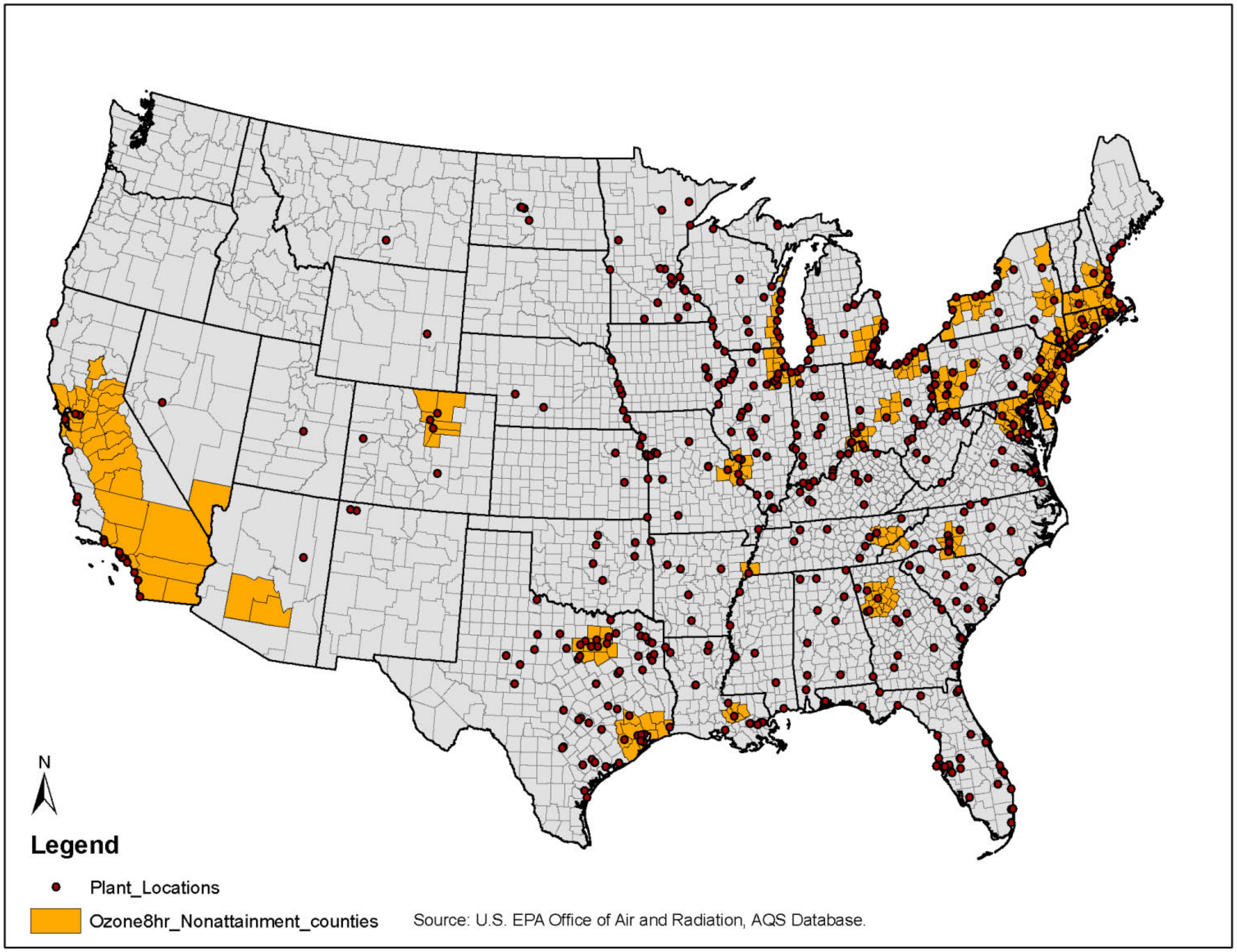
PM2.5 Nonattainment Areas



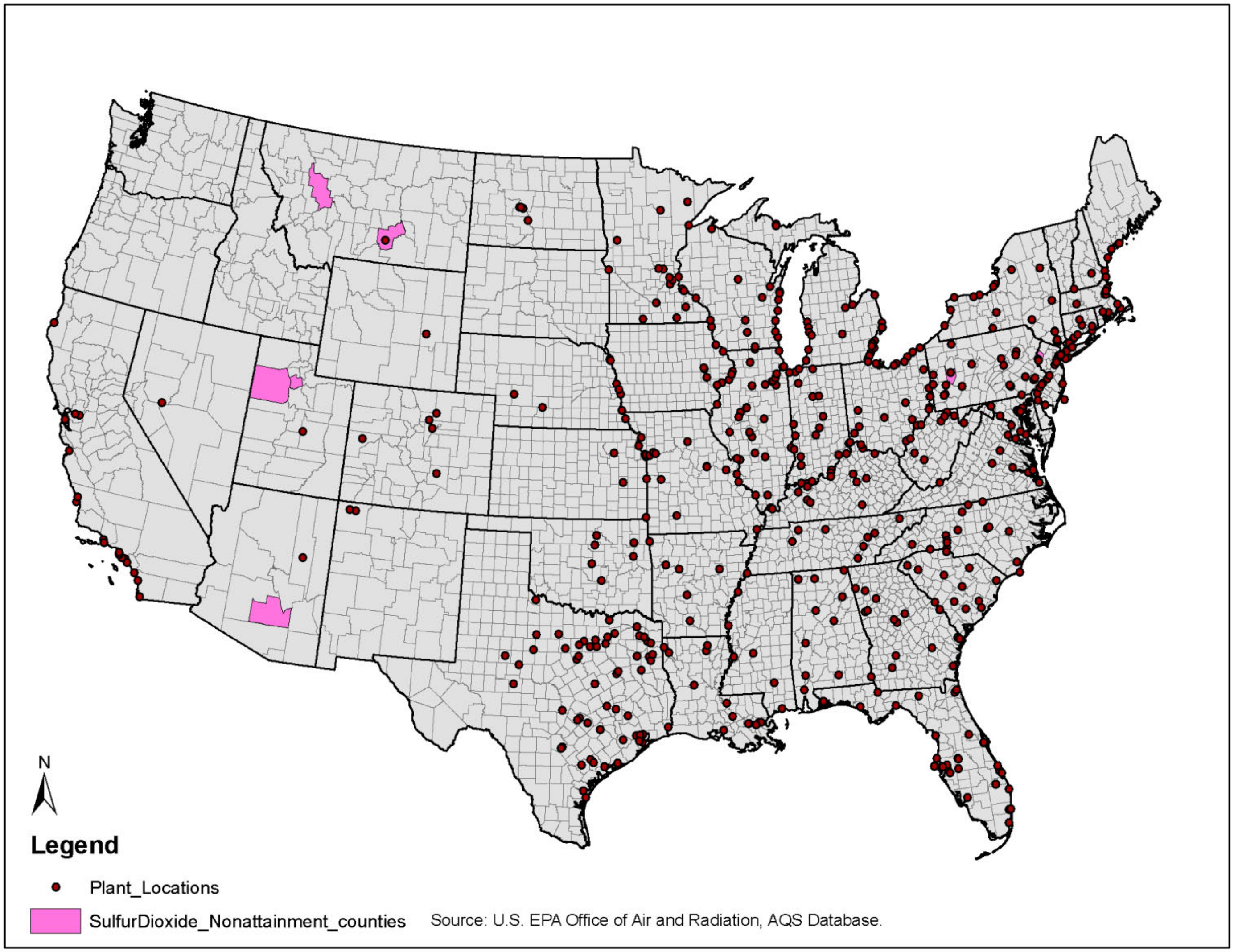
PM10 Nonattainment Areas



Ozone Nonattainment Areas



SO_2 Nonattainment Areas



Chapter 11: Impingement Mortality Limitations and Entrainment Data

11.0 Introduction

This section describes the data selection and statistical methodology used by EPA in calculating the proposed impingement mortality limitations and evaluating the entrainment data for a potential design standard. As described in this section, the proposed limitations account for variation in technology performance. Chapter 6 describes the technologies in further detail.

Section 11.1 provides an overview of the available impingement and entrainment data and EPA's selection criteria. Section 11.2 describes the data and locations used as the basis for the impingement mortality limitations, statistical methodology used to calculate the limitations, and compliance monitoring. Section 11.3 describes the entrainment data and evaluations.

11.1 Overview of Data Selection

In its evaluations of impingement and entrainment, EPA considered data from research studies, technology evaluations, and facility 316(b) demonstrations that spanned the past 40 years. While many of the documents had been collected during the Phase II rulemaking, EPA reviewed documents that were published up to 2008. The primary objective of the document review was to identify relevant information about the performance of different technologies in minimizing impingement and entrainment of aquatic organisms.

This chapter uses the term "study" to refer to the collection of performance data at a single facility (or location) under a given set of testing conditions. For example, different studies may correspond to different screen mesh sizes or approach velocities that were tested at the same facility. A document can report performance data for one or more studies at one or more facilities. EPA focused on studies that provided specific performance metrics such as percent mortality. It also obtained information about the facilities themselves, including operating conditions, species of organisms, and time periods when the studies were conducted. EPA extracted the information into a master database (see DCN 10-5400 for a version in Excel format). Appendix A lists the 178 documents that EPA reviewed, notes those data that were selected for the calculations described in this section, and describes the reasons for excluding certain documents or studies from consideration. Appendix B provides results from a summary and statistical analysis of impingement and entrainment data extracted from these documents.

11.1.1 Data Acceptance Criteria

For different types of analyses for the proposal, EPA specified criteria that were relevant for the particular analysis. As a consequence, the same data were not used consistently throughout EPA's analyses. EPA considers this approach to be reasonable because it results in the best selection of data that correspond to the objective of each analysis. In determining whether data were acceptable for the impingement and entrainment analyses described in this chapter, EPA used four general criteria. Sections 11.2 and 11.3 describe additional criteria specific to impingement and entrainment. The four general criteria are:

1. The data must provide information about one of the candidate technologies shown in Exhibit 11-1. (Chapter 6 provides EPA's review of candidate technologies for impingement and entrainment.)

2. The data must be a quantitative measure that relates to either impingement mortality or entrainment of some life form of aquatic organisms within cooling water intake structures under the given technology. This criterion requires documents to report either or both:

   - Impingement mortality as an absolute number or a percentage of impinged fish that were killed.
   - Entrainment as the numbers of organisms or density per unit volume of water. In addition, the study must have number of organisms (or density) for paired samples: 1) one sample collected from water that had not yet passed through the technology; and 2) another sample collected from water that has passed through the technology. In this manner, EPA could evaluate the percent change in entrainment associated with the technology.

3. The data must reflect technology performance that is representative of conditions that may exist under actual facility operations. As a consequence of this criterion, EPA:

   - Included data from studies conducted on existing structures at facilities;
   - Included data from field tests conducted near intake locations (e.g., from a test barge). Before full-scale installation, facilities often test the suitability of technologies in conditions that they consider to mimic (or represent) typical facility conditions.
   - Excluded data from tests performed under controlled laboratory conditions. These studies are described in the memo "316b: Laboratory Test Data Related to Entrainment" (Battelle, 2008). In contrast to the facility and field studies that generally are designed to represent normal conditions and operations, the laboratory studies generally studied how impingement and entrainment were affected by varying different components of the technology. In such studies, the laboratories sometimes operate the technologies with the intention of increasing impingement or entrainment occurrences. As a consequence, data from these studies are not representative of the performance expected at the facilities.

4. When data were used in deriving proposed limitations (e.g., for impingement mortality), the reported values must be actual measurements, rather than estimates. For entrainment, both actual and estimated data values were deemed acceptable for the evaluations.

Exhibit 11-1. Candidate Technologies Reviewed in the Documents

BTA technology	Alternate terms
Impingement technologies	
Cylindrical wedgewire (coarse)	Fixed screens—coarse mesh
Fine mesh cylindrical wedgewire	Fixed screens—fine mesh
Ristroph (modified) traveling screen with fish return	Traveling screen—coarse mesh
Offshore intake with velocity cap	Offshore location with velocity cap
Barrier net	Barriers
Fine mesh traveling screen with fish return	Traveling screen—fine mesh
Closed-cycle cooling system	Reduced intake flows—cooling tower
Entrainment technologies	
Fine mesh cylindrical wedgewire	Fixed screens—fine mesh
Fine mesh Ristroph (modified) traveling screen with fish return	Traveling screen—fine mesh
Offshore intake with velocity cap	Offshore location with velocity cap
Fine mesh traveling screen with fish return	Traveling screen—fine mesh
Aquatic filter barrier	Barriers
Closed-cycle cooling system	Reduced intake flows—cooling tower

Many documents did not have performance data that met these four general criteria, and therefore, were eliminated early in the review process. Of those performance data that were entered into the database, the data appear to fall within two primary classifications:

- Data that originate from simple observational studies. These studies provide impingement/entrainment data at one or more points in time, when the given technology is in operation. Depending on how a particular document reports study outcomes, these data may represent counts or percentages, such as percent mortality, percent survival (or other positive outcome, such as retention or diversion), percent biomass, or percent injury. Mortality and/or survival data were reported most often, while injury data were reported rarely.
- Paired data sets that correspond to either "before/after implementation" or "treatment/control," which allow for comparisons to be made to some baseline condition when evaluating technology performance at a given location. The paired data sets result in either counts or percentages of organisms being reported under both conditions (e.g., treatment and control, before implementation and after implementation).

11.1.2 Future Data Reviews

For the final rule, if EPA receives new data, EPA may revise the calculated limits.

11.2 Proposed Impingement Mortality Limitations

EPA is proposing numerical limitations that will restrict mortality of fish resulting from impingement. This section describes impingement mortality data, the selection of facilities used as a basis of the proposed limitations, the calculations, and compliance monitoring.

11.2.1 Impingement Mortality Percentage Data

After applying the general acceptance criteria described in Section 11.1, EPA extracted impingement mortality data where they were available in the 178 documents which EPA reviewed (Appendix A) and used these data to characterize impingement mortality percentages. The extracted impingement data were reported in several different ways:

- Percentage of impinged fish that were killed. EPA used these values as reported.
- Percentage of impinged fish that survived. To obtain percent mortality, EPA subtracted this percentage from 100 percent.
- Total number of impinged fish, along with numbers of impinged fish that either survived or were killed. EPA summed each of these measures across all reported species, life stages, etc., and calculated the impingement mortality percentage as:

$$\textit{impingement mortality percentage} = \frac{\textit{total number killed}}{\textit{total number impinged}} \times 100$$

- Impingement survival counts and numbers of impinged fish. EPA first calculated the total of all reported species, life stages, etc., and then calculated an impingement mortality percentage as:

$$\textit{impingement mortality percentage} = \left[1 - \frac{\textit{total number survived}}{\textit{total number impinged}}\right] \times 100$$

As a result of applying other criteria described below, studies with the first two data types were excluded for reasons other than the type of data that they reported. Consequently, the proposed limitations were based upon studies that reported the last two of the four data types. For the final rule, EPA would consider data from any of the four data types.

11.2.2 Additional Criteria Used to Select Data and Facilities as the Basis for Impingement Mortality Limitations

After extracting the impingement data, EPA applied several additional criteria beyond those described in Section 11.1 to select data as the basis of the proposed limitations. The additional criteria are:

- The facility must have employed the selected BTA technology basis for impingement: modified traveling screens. As described in Chapter 6, this technology includes, at a minimum, modified traveling screens with either Ristroph or post-Fletcher features including a dedicated fish handling and return. At least six facilities were excluded, in part, as a result of this criterion.

- The study must have measured total mortality from the time of impingement to no later than 48 hours following impingement. As a consequence of this criterion, EPA excluded:
  - Studies that reported only instantaneous mortality ("zero holding times"). Such counts may be understated because they only measure immediate deaths and not those organisms that were mortally harmed as a result of impingement. They also might reflect already injured, nearly dead, or already dead fish ("naturally moribund") that were impinged by the screen.
  - Data associated with mortality that occurred in excess of 48 hours following impingement. Such counts may be overstated because these longer holding times may cause mortality for reasons not directly reflective of technology performance, such as conditions that do not adequately reflect the organisms' natural habitats.
- The study must have evaluated all species that are typical for that location. Because certain species may be of particular concern, some studies focus on the performance of the technology for them rather than all species likely to impinge on the screens. As a consequence of this criterion, EPA excluded data from two studies performed at the Salem Generating Station on the Delaware River. The 1995 study only monitored weakfish (Ronafalvy et al., 2000) and the 1997-8 study focused primarily on weakfish (EPRI, 2007). According to plant personnel, weakfish is not predominant at that location, and thus, EPA has excluded the data.

As a consequence of these additional criteria (i.e., beyond Section 11.2.2), Exhibit 11-2 identifies the facilities whose data were excluded from the basis of the impingement mortality limitations. Appendix A contains additional detail on why impingement data from certain documents were excluded from consideration.

Exhibit 11-2. List of Excluded Facilities with Impingement Data

Facility Name	Reasons for Excluding Impingement Studies from Facility
Barney Davis	Holding Time = 0, Did not have modified Traveling Screen technology
Big Bend	Holding Time = 0; Did not have modified Traveling Screen technology
Bowline Point	Holding Time = 0; Did not have modified Traveling Screen technology
Brayton Point	Holding Time = 0; Did not have modified Traveling Screen technology
Brunswick	Holding Time = 0; Did not have modified Traveling Screen technology
Danskammer Point	Holding Time > 48h; Holding Time = 0
Indian Point	Holding Time = 0; Holding Time > 48 hours
JEA Northside	Holding Time = 0
Mystic	Holding Time > 48h
Potomac River	Did not have modified Traveling Screen technology
Prairie Island	Holding Time = 0
Salem	Species not representative of location
Somerset	Holding Time > 48h; Holding Time = Zero
Surry	Holding Time = 0

After excluding the facility data identified in Exhibit 11-2, EPA evaluated the remaining data. Three facilities met all of the criteria, and thus, they form the basis for the proposed limitations. These facilities are:

1. Arthur Kill Station on Staten Island along the eastern bank of the Arthur Kill tidal strait (CEC, 1996);
2. Dunkirk Steam Station on Lake Erie (Beak Consultants, Inc., 2000a); and
3. Huntley Steam Station on the Niagara River (Beak Consultants, Inc., 2000b).

Exhibit 11-3 provides a summary of the characteristics and technologies for these three facilities. Listing 1 of Appendix C lists their data. All of the mortality data were measured at a latent period of 24 hours.

Exhibit 11-3. Characteristics of Facilities Used As Basis for Impingement Mortality Limitations

Facility Name	State	Water Body Type	Predominant Species [1]	Study Period	Generating Units/ CWISs	Design Intake Flow [2]	Technology
Arthur Kill	NY	Estuary	alewife, Atlantic herring, Atlantic silverside, bay anchovy, blueback herring, weakfish, crabs	February 1994 through July 1995	Unit 20	87.0 MGD	1/8 x 1/2-in mesh -modified traveling screen.
					Unit 30	85.0 MGD	1/4 x 1/2-in mesh modified traveling screen.
Dunkirk	NY	Great Lakes	alewife, shiners, rainbow smelt, white bass, white perch, yellow perch	Each season from December 1998 to November 1999.	Screenhouse #1, including Units 1 and 2	92.2 MGD	1/8 x 1/2 inch. Prototype modified traveling screen
Huntley	NY	Fresh-water River	alewife, gizzard shad, rainbow smelt, emerald shiner	January and October 1999	Units 67 and 68	82.8 MGD	1/8 x 1/2 inch. Prototype modified traveling screen

[1] Data for other species may also be available within each study.
[2] Derivation of DIF provided in DCN 10-6610.

EPRI (2007) describes the sampling events at the three facilities:

- Arthur Kill (pages 2-40 and 2-41): "During the study, the station was operated on a seasonal schedule from June through September, with a reserve shutdown period occurring from October through May. . . . Collections were made on a biweekly to monthly basis from February 1994 through July 1995. The majority of sampling occurred during the hours of 7 p.m. and 5 a.m., with screens operating at a rotation speed of 6.1 m/min (20 ft/min). Fish and crabs were collected by diverting the screenwash water of the individual screens into a collection tank. Fish and crabs were separated into compatible groups and placed into holding tanks for 24-hour mortality evaluation. At the end of the holding period, fish and crabs were categorized by species and condition and counted."

- Dunkirk (page 2-16): "The shoreline CWIS at the Dunkirk Steam Station includes a skimmer wall and two screenhouses. Fish collected for this evaluation were taken off a prototype Ristroph dual-flow traveling screen in Screenhouse #1. The screen is 11 ft wide and 29 ft deep and is comprised of "smooth tex" stainless steel mesh (1/8 by ½ in.) and a fish collection bucket. The screen was run continuously during sampling. Water from the dual fish/debris return trough was diverted for 2 hours for each sample. Fish were directed to a collection table and then were transferred in water to holding tanks where they were held for the 24-hr latent mortality study. Observations of fish condition were made at 2, 4, 8, and 24 hrs after collection."
- Huntley (page 2-21): "Eight-hour samples were collected on five nights from January 21-25, 1999, and October 24-29, 1999. During sampling, the modified traveling screens were rotated continuously at 8 ft/min. All fish from Screens #5 and #6 were diverted into a collection table. Sampling was conducted continuously for up to 2 hours but was shortened when large numbers of fish were impinged. Sampling was interrupted to move fish when necessary. Fish were removed from the collection table using a brailing device that maintained a minimum of 4 in. of water and minimized handling stress. Fish were held in large fiberglass or galvanized steel tanks (ranging in size from 20 to 240 gallons) and supplied with a continuous supply of water pumped from the forebay. Flow into the tanks was continuous and provided a moderate circular current. Water in the holding tanks was exchanged three to five times per hour. No more than 5 g of fish per liter of water were held in any of the tanks. Fish were separated by size and predator and prey species were separated. The initial condition of all fish was assessed prior to being placed into the holding tanks. . . . Only live fish were transferred to the holding tanks and held for 24 hours to determine latent mortality."

11.2.3 Calculation of Limitations

EPA applied statistical methods to develop the proposed limitations. Statistical methods are appropriate for dealing with impingement data because the mortality rates, even in well-operated systems, are subject to a certain amount of random fluctuation or uncertainty. Statistics is the science of dealing with uncertainty in a logical and consistent manner. Statistical methods, therefore, provide a logical and consistent framework for analyzing a set of impingement data and determining values from the data that form a reasonable basis for the limitations. In modeling the distribution of impingement mortality percentage data, EPA selected the beta family of statistical distributions as the basis for its limitations, because the distributions are continuous and bounded by 0 and 1. This is equivalent to the range of impingement mortality percentages between 0 and 100. Appendix D describes this model and alternatives that EPA may consider in developing the final rule. The following sections provide an overview of the limitations, the monthly average limitation, the annual average limitation, and EPA's evaluation of them.

11.2.3.1 Monthly Average Limitation

The proposed monthly average limitation is based upon the 95th percentile of the beta distribution modeled on the eight impingement mortality percentages presented in Exhibit 11-4. The use of the 95th percentile represents a need to draw a line at a definite point in the statistical distributions (a "100th percentile" would not work because it would represent mortality of all organisms) and a policy judgment about where the line is drawn to insure that operators work hard to implement practices that represent the appropriate level of control. In essence, in developing the monthly average limitation proposed for this rule, EPA has taken into account the reasonable anticipated variability in impingement mortality that may occur at a well-operated facility. The use of percentiles in the development of monthly average limitations for the protection of the nation's waters is a long standing practice that has been upheld by the courts in numerous cases. The use of the 95th percentile also is consistent with the convention used for other monthly average limitations (e.g., for pollutant discharges).

The data in Exhibit 11-4 meet EPA's criteria described earlier in the chapter. The data cover a range of conditions such as seasons, locations, and water bodies. Because the sampling dates were available, EPA classified data from Dunkirk and Huntley into series of sampling events that reflected the monitoring frequencies that EPA expects facilities to use in complying with the monthly average limitation. For the Arthur Kill facility, the individual sampling event information was not available to EPA, and thus, EPA considered the data at each unit as if they were from a single sampling event. EPA then modeled the impingement mortality percentages across the eight events using the beta distribution. The 95th percentile was estimated to be 30 percent impingement mortality.

Exhibit 11-4. Facilities and Data Used As Basis for Monthly Average Limitation on Impingement Mortality

Facility Name	Sampling Period	Total Number of Impinged Fish	Total Number of Impinged Fish that Died	Percent Impingement Mortality
Arthur Kill	Unit 20, 1994-1995	7,130	1,366	19.2
	Unit 30, 1994-1995	3,408	235	6.9
Dunkirk	12/20/98 to 01/09/99	6,775	261	3.9
	04/20/99 to 04/28/99	3,562	435	12.2
	08/16/99 to 09/04/99	1,220	182	14.9
	11/02/99 to 11/11/99	8,928	243	2.7
Huntley	01/21/99 to 01/25/99	6,120	561	9.2
	10/24/99 to 10/29/99	3,258	1,025	31.5

11.2.3.2 Annual Average Limitation

For the proposed annual average limitation, EPA used the statistical expected value (average) of the beta distribution of the monthly averages presented in Exhibit 11-4. As a result of applying the statistical methodology, EPA determined that the annual average limitation was 12 percent impingement mortality. In contrast to the monthly average limitation which provides an allowance for variability, EPA does not believe that any upward adjustment of the annual average limitation is necessary because compliance is only determined over a long period of time, that is, during the course of an entire year during which the facility will have opportunities to modify the technology when necessary to achieve compliance with the annual average limitation.

11.2.3.3 Statistical Evaluation of Proposed Limitations

As an important step in evaluating the statistical methodology, EPA compared the proposed limitations to the data used to derive them. In other rulemakings, commenters have asserted that this comparison step implies that EPA expects occasional exceedances[1] of the limitations. For example, commenters sometimes assert that EPA's use of the 95th percentile implies that the EPA expects that about 5 percent of the data, or one month in 20, should fail to meet the monthly average limitation. Such assertions are incorrect. EPA promulgates limitations that facilities are capable of complying with at all times by properly operating and maintaining their technologies. Instead, EPA performs this comparison to ensure that the statistical model is appropriate and that it used appropriate distributional assumptions for the data used to develop the limitations (i.e., whether the curves EPA used provide a reasonable "fit" to the actual data). As a result of this comparison for the proposed limitations, EPA determined that the distributional assumptions appear to be appropriate for these data, as explained below:

- For the monthly average limitation based upon the data in the last column of Exhibit 11-4, all but one value was less than the proposed limitation of 30 percent. Observing one value in eight that is greater than the limitation is approximately what is expected from the 95th percentile basis of the statistical methodology. This impingement mortality of 31.5 percent is marginally greater than the proposed limitation of 30 percent.
- For the annual average limitation, EPA combined the information from the eight sampling events in Exhibit 11-4 into the four values shown in Exhibit 11-5 to better mimic the annual average calculated from monthly averages, as would be required for compliance reporting. Because Arthur Kill had data for two different units with slightly different screen specifications, EPA continued to consider the data from each unit separately. Based upon the data in the last column of Exhibit 11-5, two of the four values are less than the proposed limitation of 12 percent, which is consistent with the expected value basis of the limitation. To be consistent with the statistical methodology, EPA would expect about half of the data to be greater than the limitation, and this is what was observed.

[1] Exceedances are values greater than the limitations.

Exhibit 11-5. Annual Averages of Impingement Mortality Used to Evaluate Proposed Annual Average Limitation

Facility Name	Total Number of Impinged Fish	Total Number of Impinged Fish that Died	Percent Impingement Mortality
Arthur Kill, Unit 20	7,130	1,366	19.2
Arthur Kill, Unit 30	3,408	235	6.9
Dunkirk	20,485	1,121	5.5
Huntley	9,378	1,586	16.9

11.2.3.4 Biological and Engineering Reviews of Proposed Limitations

In conjunction with the statistical methods, EPA performed engineering and biological reviews which are yet another important step in verifying that the proposed limitations are reasonable based upon the design and expected operation of the technologies and the site conditions. As part of those reviews, EPA examines the range of performance by the data sets used to calculate the proposed limitations. Some data sets demonstrate the best technology available. Other data sets may demonstrate the same technology, but not the best demonstrated design and operating conditions for that technology. For the facilities corresponding to these datasets, EPA evaluates the degree to which the facility can upgrade its design, operating, and maintenance conditions to meet the proposed limitations. If such upgrades are not possible, then the proposed limitations are modified to reflect the lowest levels of impingement mortality that the technologies can reasonably be expected to achieve.

- For the monthly average limitation, only one impingement mortality value in Exhibit 11-4 has a value greater than the proposed limitation of 31 percent. This larger value occurred in October 1999 at the Huntley facility. With a mortality percentage of 31.5 percent, it is barely greater than the proposed percentage limitation of 30 percent. In its engineering review of Huntley's technologies, EPA determined that Huntley's prototype screen has a slightly smaller mesh size (1/8 inch by 1/2 inch) than the technologies subject to the proposed limitation. Smaller screens allow fewer organisms to pass through, retaining more of the smaller and generally more fragile life-stages, and therefore often demonstrate increased mortality. The proposed regulation specifies impinged organisms are those retained by a 3/8-inch mesh; thus the additional organisms would be excluded from limitation compliance monitoring. Because of the technology differences, EPA considered whether Huntley's data should be excluded as the basis of the proposed limitations. As a conservative measure, EPA retained the data. The Agency reasons that if Huntley can generally achieve the limitations with the smaller mesh size, then other facilities can achieve the relevant limitations by adoption of the model technologies which include the larger mesh size.
- For the annual average limitation, two of the four reported mortality percentages in Exhibit 11-5 have values greater than the annual average limitation of 12. The mortality percentages were 16.9 percent from Huntley and 19.2 percent from Arthur Kill's Unit 20. As discussed for the monthly average limitation, Huntley

has a finer mesh size than the proposed technology, and the data were retained in the dataset as a conservative approach (i.e., excluding the data would have resulted in a proposed limitation with a lower mortality rate). At Arthur Kill's Unit 20, the mortality is partially associated with the relatively large numbers of bay anchovy (59 percent of 836). Because bay anchovy are feeder fish and highly prevalent, permit authorities are unlikely to designate them as a species of concern subject to the proposed limitations. After excluding the bay anchovy counts from the calculations, the impingement mortality percentage drops to 14 percent which is only slightly greater than the 12 percent proposed as the annual average limitation. Because Unit 20's screen size of 1/8-inch is smaller than the model technology, EPA concluded that this marginal increase in mortality was a result of the smaller screen size. As it had for Huntley, EPA considered excluding the data because the smaller screen would demonstrate higher impingement mortality than the proposed model technology. For the proposed limitations, EPA has retained the Huntley and Arthur Kill data as a conservative approach in developing the proposed limitations, and will reevaluate its data selection for the final rule.

In conclusion, as a result of the combined statistical modeling and engineering/biological reviews used in developing the proposed limitations, facilities are expected to be capable of designing and operating in a manner that will ensure compliance with the limitations. Facilities are not expected to operate their treatment systems so as to violate the limitations at some pre-set rate merely because probability models are used to develop limitations.

11.2.4 Monitoring For Compliance

To demonstrate compliance with the limitations, EPA is proposing that the permit authority specify the monitoring frequency. The monitoring should be conducted in conditions that are representative of typical operations at the facility and fish behavior (e.g., if the fish tend to appear primarily during night-time, then EPA expects that the facility would monitor during this period).

- For each weekly monitoring event, the facility must determine the percentage of organisms that die from the onset of impingement to some later time period as specified by the permit authority (e.g., 24 to 48 hours following impingement).
  - To determine compliance with the proposed monthly average limitation for a given month, the facility would calculate and report the arithmetic average of the impingement mortalities observed during each of the events during that month. For example, if the facility conducted four sampling events in December, it would calculate the monthly average from the four weekly values. If this monthly average is less than or equal to the monthly average limitation of 30 percent, then the facility would be in compliance for that month.
  - To determine whether compliance with the annual average limit has been achieved, the facility would calculate and report its annual average as the arithmetic average of the monthly averages for the year. If this annual

average was less than the annual average limitation of 12 percent, then the facility would be in compliance.

11.3 Evaluation of the Entrainment Data

This section describes EPA's evaluation of the performance data related to entrainment. Section 11.3.1 provides the calculation used to produce the percent reduction values. Section 11.3.2 describes the initial selection and evaluation of all available entrainment data. In any situation where data originate from numerous sources, variation in study procedures is typical because they are independently designed and executed by different organizations with different objectives and protocols. Section 11.3.3 evaluates the variation in the sampling locations associated with the percent reductions. Section 11.3.4 evaluates the variation in the screen size and slot velocities associated with the percent reductions. Section 11.3.5 describes EPA's consideration of numerical limitations on the percent reduction of entrainment. (The 2004 Final Phase II Rule contains numerical entrainment performance standards.)

11.3.1 Entrainment Percent Reduction Data

Entrainment is a measure of the organisms (generally juveniles, eggs, and larvae) that are drawn past the intake structure and into the plant. In the studies EPA evaluated, facilities sometimes measure entrainment in a canal or forebay, sometimes just prior to the condensers, and sometimes after passing through the plant. Measurements of entrainment usually compare organism densities "in front of" the technology and "behind" the technology. In contrast to impingement mortality, "in front of" may in fact be a measure of what is in the source water at that point in time.

Entrainment is typically characterized in the studies by measuring organism densities both in front of and behind the technology. For studies that reported entrainment data in this manner, EPA calculated the total densities for all species at each location (i.e., "front" and "behind"). EPA then calculated percent reduction as follows:

$$\textit{percent reduction} = \frac{\textit{front} - \textit{behind}}{\textit{front}} \times 100$$

Note that percent reduction does not rely on the units of density in which "front" and "behind" measures are expressed.

11.3.2 Initial Selection and Evaluation of Entrainment Data

After examining the 178 documents in Appendix A, EPA selected entrainment data that met the general data acceptance criteria described in Section 11.1.1. This section describes EPA's evaluation of entrainment data for fine mesh traveling screens and wedgewire screens. Exhibit 11-6 describes the facilities, locations, study conditions, and species associated with these entrainment data. The data originated from the following nine locations that represent seven states:

- Big Bend (FL) Power Station (Mote Marine Laboratory, 1987).

- Brunswick (NC) Steam Electric Plant (CP&L, 1985a and 1985b).
- Chalk Point (MD) intake canal within the Patuxent estuary (Weisberg et al., 1984)
- Chesapeake Bay (VA) (EPRI, 2006).
- Logan Generating Plant (NJ) and the Delaware River (Ehrler and Raifsnider, 2000)
- Oyster Creek (NJ) intake canal (EPRI, 2007).
- Portage River (OH) (EPRI, 2007).
- Sakkonet River (RI) within Narragansett Bay (EPRI, 2007).
- St. Johns River (FL) (Dames and Moore, 1979).

As noted in Exhibit 11-6, these data demonstrated performance of fine mesh traveling screens and wedgewire screens of varying mesh sizes, were collected from 1979 to 2005, and measured many different species in different life stages.

When EPA examined the percent reduction of total organisms for each test location and condition as shown in Exhibit 11-7, it found a range from -24.7 percent to 95.8 percent.[2] Negative values indicate an increase in organisms behind the technology compared to in front of the technology, or what is naturally occurring in the waterbody. Such results are not appropriate for measuring the effectiveness of the technologies to protect organisms from entering the plant. After EPA excluded the negative values, the range was 10.1 percent to 95.8 percent. As described in the following sections, EPA examined sampling locations, screen characteristics and life stages.

[2] In its evaluations, EPA generally used the data presented in report summaries without verifying their calculations. For example, the St. Johns Study presents summaries that include estimated values (Dames and Moore, 1979, p. 40).

Exhibit 11-6. Characteristics of Facilities with Entrainment Data and the Technology Basis

Facility Location	State	Test Condition	Tech-nology	Water-body	Date(s) of Sampling	Screen Mesh Size (mm)	Slot Velocity (m/s)	Species Reported in Studies
Big Bend Power Plant	FL	Plant/Test	Traveling Screens	Estuary	3/18/1987, 3/31/1987, 4/16/1987, 5/12/1987	0.5	not specified	• Sciaenidae spp. (eggs) • Bay anchovy (eggs, larvae) • Silver perch (larvae) • Spotted seatrout (larvae) • Stone crab (zoea) • Penaeus spp. (juvenile) • Bienniidae spp. (larvae) • Gobiidae spp. (larvae) • Gobiesox strumosus (larvae)
Brunswick Steam Electric Plant	NC	Plant/Test	Traveling Screens	Estuary	Nov. 1984 to Jan. 1985	1	not specified	• Anchoa spp. • Spot • Croaker • Gobionellus spp. • Others (at lower numbers)
Chalk Point intake canal	MD	Test Barge	Wedgewire	Estuary	Aug. 1982	1	not specified	• Bay anchovy (eggs, larvae) • Naked goby (larvae)
						2		
					July 1983	1	0.20	
						2	0.095, 0.19, 0.20, 0.40	
						3	0.20	
Chesapeake Bay	VA	EPRI Test Barge	Wedgewire	Estuary	June 2005	0.5	0.15, 0.3	• Bay anchovy eggs "All larvae" which included: • Bay anchovy • Naked goby • Northern pipefish • Skilletfish • Striped blenny
						1	0.15, 0.3	
Logan Gen. Plant	NJ	Plant/Test	Wedgewire	Fresh-water River	May and June 1995	1	0.15	Larval fishes
Oyster Creek intake canal	NJ	Test Barge	Wedgewire	Estuary	1/3/1979	1	0.152	Opossum shrimp (age category unspecified).
						2	0.152	
Portage River	OH	EPRI Test Barge	Wedgewire	Fresh-water River	May and June 2004	0.5	0.15, 0.30	Eggs (no species given). Larvae for: • Carp • Freshwater drum • Shad spp. • Temperate bass
						1	0.15, 0.30	
Sakkonet River	RI	EPRI Test Barge	Wedgewire	Estuary	April and May 2004	0.5	0.15, 0.30	Eggs (no species given). "All larvae" which includedof: • Grubby • Sand lance • Winter flounder
						1	0.15, 0.30	
St. Johns River	FL	Test Barge	Wedgewire	Estuary	March to September 1979	1	0.13	Numbers of "potentially entrainable" larvae and juveniles for the following: • Strongylura marina • Lucania parva • Menidia beryllina • Lepomis spp. • Gobisoma bosci • Microgobius gulosus
						2	0.12	

Exhibit 11-7. Total Organisms: Percent Reduction of Entrainment by Slot Width and Slot Velocity

Test Location	Screen Slot Width (mm)	Slot Velocity (m/s)	"Front" Samples: Total Density of all Organisms	"Behind" Samples: Total Density of all Organisms	Density Units of "Front" and "Behind" Samples	Percent Reduction of Total Organisms
Big Bend Station	0.5	not specified	51,793.1	2,174.1	#/100m^3	95.8
Brunswick Steam Electric Plant	1	not specified	543	99	#/1000m^3	81.8
Chalk Point intake canal (1982)	1	not specified	374.2	50.6	#/1000m^3	86.5
	2		374.2	141.1	#/1000m^3	62.3
Chalk Point intake canal (1983)	1	0.20	825.2	655.8	#/1000m^3	20.5
	2	0.20	825.2	641.2	#/1000m^3	22.3
		0.095	825.2	404.4	#/1000m^3	51.0
		0.19	825.2	314.8	#/1000m^3	61.9
		0.40	825.2	311.8	#/1000m^3	62.2
	3	0.20	3,166.2	2,399	#/1000m^3	24.2
Chesapeake Bay	0.5	0.15	1,145.4	175.8	#/100m^3	84.7
		0.30	590.7	443	#/100m^3	25.0
	1	0.15	845	728	#/100m^3	13.8
		0.30	378	406.8	#/100m^3	-7.6
Logan Gen. Plant	1	0.15	637	41	#	93.6
Oyster Creek intake canal	1	0.152	39.3	25.1	#/m^3	36.1
	2	0.152	39.3	49	#/m^3	-24.7
Portage River	0.5	0.15	199.6	121.3	#/100m^3	39.2
		0.30	302.8	128	#/100m^3	57.7
	1	0.15	719.5	517.7	#/100m^3	28.0
		0.30	704.8	633.5	#/100m^3	10.1
Sakkonet River	0.5	0.15	95.6	15.6	#/100m^3	83.7
		0.30	75.4	14.5	#/100m^3	80.8
	1	0.15	85.5	72.8	#/100m^3	14.9
		0.30	86.2	75.3	#/100m^3	12.6
St. Johns River	1	0.13	38,692,597	13,152,507	#	66.0
	2	0.12	38,692,597	14,530,529	#	62.4

11.3.3 "In Front" and "Behind" Sampling Locations

As part of its evaluation of the entrainment data, EPA considered whether variations in sampling locations affected the percent reductions and reviewed the studies for any conclusions about locations by the authors.

In EPA's entrainment database, studies that did not collect "in front" and "behind" samples simultaneously (i.e., at the same point in time) typically did so within a short time period (i.e., within a few hours), so that only a minor deviation in time occurred between the paired samples used to calculate percent reduction. In all studies, plankton nets were used to collect the samples at the given sample locations.

The Logan and Big Bend studies were the only studies whose "in front" samples did not represent water that passed through an intake. The Logan study deviated considerably from the others, as its "in front" samples were collected at various depths within the source water body at some distance away from the intakes. Thus, its "in front" samples represented general ambient densities of the source water body. The Big Bend study actually collected its "in front" samples from directly in front of a screened intake and was the only study listed in Exhibit 11-6 to do so.

The following is a summary of the "in front" and "behind" sampling locations in the studies listed in Exhibit 11-6. Exhibit 11-8 also summarizes the information.

- The Big Bend study was the only study that took samples simultaneously in front and behind of a common screened intake.
- In the Logan study, "front" samples were taken from river transects (inner shallow, outer shallow, deep sampling) at some distance from the plant intakes.
- In the 1982 and 1983 Chalk Point studies, "front" and "behind" samples were collected from the discharge point of a common intake; the samples were classified as "front" or "behind" based on whether or not the wedgewire screen covered the intake at the time of sampling. The St. Johns River study used a similar approach, but collected fish from a holding tank in which intake water was discharged, rather than at the intake's discharge point to the water body. Thus, "front" and "behind" samples in these studies were collected at different points in time.
- The Chesapeake Bay, Portage River, and Sakkonet River studies were performed by EPRI and used the same test barge and sampling approaches. Thus, the "front" and "behind" sample collection approaches were identical across these studies. These samples were collected from distinct intakes, with each screen of a specific mesh size being assigned to a specific intake. One intake was covered with a 9.5 mm mesh screen (primarily for preventing trash intake) and was used for collecting the "front" sample. The other intakes were covered with fine-mesh screens and were the source of the "behind" samples.
- The Oyster Creek study collected "front" samples from an unscreened intake and "behind" samples from the pump discharge pipes. While detailed information was not available on the sampling approach, EPA assumes it was similar to those used in the EPRI studies, because they all used test barges.
- The Brunswick study used different sampling approaches in different months. In November and January, the "front" and "behind" samples were collected in consecutive 24-hour time periods. The document did not state whether the two sampling events used the same intake or different intakes. In December, the "front" and "behind" samples were collected simultaneously from within different discharge weirs, similar to the Chesapeake Bay, Portage River, and Sakkonet River studies.

In the EPRI studies, the intake velocities for the control intake (for collecting the "front" samples) were designed to approximate the intake velocities associated with the wedgewire screens (for collecting the "behind" samples). Other studies did not indicate that the velocities for the control intake were maintained in this manner. Because the data did not clearly establish a pattern related to sampling location (e.g., at the same location in the Chesapeake Bay, reductions ranged from -7.6 to 13.8 percent for the same screen mesh size), EPA concluded that factors other than sampling location (e.g., velocity) might better explain the ranges of percent reductions seen in Exhibit 11-7.

Exhibit 11-8. Collection Locations for "Front" and "Behind" Entrainment Samples

Study	"Front" Sample Location	"Behind" Sample Location
Big Bend	In front of both sides of Screen 3A (i.e., two sample locations). Entrainment density consisted of the average of the sample densities from the two locations.	From an intake screenwell located behind Screen 3A, where water was pumped and channeled.
Brunswick	In the discharge weir of an intake covered by a 9.4 mm mesh screen. (For two of three sampling periods, a common intake was used between the control and fine mesh screen tests, with the control test occurring first, while for the third sampling period, the tests were done simultaneously with separate intakes.)	In the discharge weir of an intake covered by a 1.0 mm mesh screen. (For two of three sampling periods, a common intake was used between the control and fine mesh screen tests, with the fine mesh test occurring last, while for the third sampling period, the tests were done simultaneously with separate intakes.)
Chalk Point	At the discharge point associated with one of two intakes. Samples were classified as "front" samples if the intake was not covered by a wedgewire screen with mesh size 3 mm or smaller.	At the discharge point associated with one of two intakes. Samples were classified as "behind" samples if the intake was screened with either a 1, 2, or 3 mm wedgewire screen.
Chesapeake Bay	At the stern of the barge where water was discharged after being withdrawn through a 9.5 mm screened intake (at the bow) and passed through a fish pump. Intake was located midway between the two intakes capped with the 0.5 mm and 1 mm wedgewire screens.	At the stern of the barge where water was discharged after being withdrawn through either a 0.5 mm or 1 mm screened intake (at the bow) and passed through a fish pump. Two separate intakes were used – one for each screen size – but only one intake was used at a time as they shared a pump and sampling location.
Logan Generating Plant	Three different river transects: inner shallow, outer (channel) shallow, and deep sampling. Number of entrained organisms was taken to be the average of the numbers from the deep channel and shallow samples.	Within a water filled plastic tank in which water was discharged after flowing through the wedgewire screen intake (located at the plant's wet well) and passing through the centrifugal pump.
Oyster Creek	From an unscreened intake	From the pump discharge pipes.
Portage River	Same test barge and sampling locations as Chesapeake Bay	Same test barge and sampling locations as Chesapeake Bay
Sakkonet River	Same test barge and sampling locations as Chesapeake Bay	Same test barge and sampling locations as Chesapeake Bay
St. Johns River*	Within a collection tank in which water was discharged after being withdrawn through a 9.5 mm screen and passed through a trash pump. The tank was one of the two tanks used by either the 1 mm or 2 mm wedgewire screens, and sampling occurred when the wedgewire screens were not in operation.	Within a collection tank in which water was discharged after being withdrawn through either 1 mm or 2 mm screens and passed through a trash pump. Two separate screen/pump/tank assemblies were used – one for each screen size.

* Study document is missing pages that described sampling methodology.

11.3.4 Evaluation of Screen Characteristics in Reducing Entrainment

EPA considered whether screen characteristics, such as mesh size and slot velocity, affected the percent reductions. It first reviewed the studies for any conclusions about slot size and velocity by the authors. It then applied statistical techniques to evaluate the effect of slot mesh size and slot velocity on values of the entrainment data.

11.3.4.1 Literature Review of Slot Size and Velocity Effects on Entrainment

For all studies identified in Exhibit 11-6 except Logan, the available documentation included results of statistical analyses to identify the presence of significant reductions in entrainment that are associated with changes in slot size and/or slot velocity. This section briefly describes their evaluations and conclusions.

Most of these studies noted greater incidences of significant reductions at smaller slot sizes. For example, the Portage and Sakkonet River studies noted that a smaller slot width resulted in a significant reduction in larval and egg densities. At a 1.0 mm mesh size, no significant reduction in egg entrainment was noted in these two studies, nor was a significant reduction noted in larval entrainment within the Sakkonet River study at this mesh size. However, a significant reduction was noted at a 0.5-mm size in each case. These findings held for each slot velocity considered in these studies. Certain species of larvae did not see a significant reduction in entrainment at one or both of these slot sizes, but this may have been partially the result of limited numbers of these species found in the samples. However, these two studies (plus the Chesapeake Bay study) did note that, for each slot width and velocity, greater reductions in entrainment densities occurred with increased larval lengths.

The Chesapeake Bay study noted that both slot widths (0.5 and 1.0 mm) led to significant reductions in entrainment for eggs and most larval species, with the smaller width yielding greater reductions.

The St. Johns River study failed to see a significant reduction in entrainment densities (counts of organisms) between 1 mm and 2 mm slot widths. This result was noted for all species and life stages. In the latter part of the study which extended from March to September, the study authors report that entrainment was actually higher through the 1 mm screen compared to the 2-mm screen for certain species. They hypothesize that this may have been due to “fouling and partial plugging” of the 1-mm screen noted in August, which resulted in higher slot velocities. The authors note that significant variation in entrainment could occur from one day to another due to meteorological factors such as wind speed and river surface (waves). So it is uncertain whether any observed increases in data collected late in the study was due to biofouling or other factors. Furthermore, the study conclusions were based partly on estimated data for those days in which entrainment samples were not collected. As noted by the authors, counts for some species may have been overestimated on a particular day if the estimates were based on counts from other days when abundance was high or meteorological factors promoted high entrainment.

The Chalk Point study noted that the general effect of screen slot size on reducing the numbers of entrained organisms was small, but measurable. While no effect could be discerned for small organisms (<5 mm in length), approximately a 25 percent difference in exclusion efficiency between 1-mm and 3-mm screens was noted for organisms of intermediate size, while this percentage difference increased to approximately 80 percent for larger organisms. Thus, organism size was an important factor in determining screen effectiveness at small mesh sizes.

The Chalk Point studies reported entrainment results for two species: bay anchovy and naked goby. Slot velocity had a significant effect in entrainment counts for naked goby only. The study authors hypothesize that this was due to naked gobies inhabiting areas close to the screens, while bay anchovies and other open water species are not as influenced by screen slot velocities. For naked gobies, higher velocities were associated with greater rates of entrainment. For larger gobies, increased rates were observed only at the highest velocity (0.40 m/s), while increased rates were observed at velocities as low as 0.095 m/s for smaller gobies.

In the EPRI studies (i.e., Chesapeake Bay, Portage, and Sakkonet), slot velocity had only minor effects on entrainment densities (at a constant mesh size of 2 mm). The Portage River study noted that entrainment reduction was not significantly affected by either velocity setting. The Chesapeake Bay study noted that the slot velocity effect varied by species, but the 0.15 m/s setting was generally more effective (by up to 30 percent) in leading to entrainment reductions of both eggs and larvae than the 0.30 m/s setting. In fact, this study observed a significantly greater reduction at 0.15 m/s compared to 0.30 m/s for eggs and some species of larvae.

While the Big Bend study had some unique characteristics (e.g., use of traveling screens, location of "front" samples), the study was not designed to evaluate impacts of slot velocity on entrainment reduction, and therefore, made no such conclusions. The study reported effective performance relative at a 0.5 mm mesh size, based on observing percent reductions. Eggs had a somewhat higher level of effectiveness compared to larvae, but both life stages achieved more than 80 percent reduction. While "behind" samples often had considerably lower densities than "front" samples, the study noted that occasional large densities of certain specifies within "behind" samples likely reflected schools of organisms that spawned and inhabited behind the screens.

While the Brunswick study also performed statistical analyses to investigate effects of such factors as test period and night versus day on entrainment numbers, it did not evaluate effects of slot mesh size or velocity (as only one fine mesh size was considered, and slot velocity was not specified). The study did note that there was no significant difference in entrainment densities of Gobionellus spp. between 1.0 mm and 9.4 mm screens according to an analysis of variance (CP&L, 1985b) and implied that this difference was significant for other species.

11.3.4.2 EPA's Evaluation of Slot Size and Velocity Effects on Entrainment

After reviewing the statistical analyses in the studies, EPA performed three types of statistical analyses to evaluate the effect of slot mesh size and slot velocity on percent reduction data from the studies identified in Exhibit 11-6. The three types of statistical analyses are: analysis of variance, generalized linear models, and graphical analyses. Each is described below.

Analysis of Variance (ANOVA)

Analysis of variance models express the value of the dependent variable (i.e., the variable on which statistical inference is to be made) as a mathematical function of predictor variables, known as the ANOVA model. As the ANOVA model is fitted to the data, statistical hypothesis tests are performed to determine whether different values of one or more predictor variables significantly affect the value of the dependent variable.

EPA fit an ANOVA model with effects of slot mesh size and slot velocity to the percent reduction in entrainment data. EPA fit this model to three different sets of percent reduction data: to the percent reduction in total organisms, eggs only, and larvae only. (EPA considered "larva" to be anything not specifically identified as eggs.) Appendix E describes the analyses and results. In summary, from these analyses, EPA noted the following:

- On average, the effect of screen size was nearly significant for percent reduction in total organisms (p-value = 0.055) and on average percent reduction in eggs (p-value = 0.053). Screen size did not appear to have a significant effect on average percent reduction of larvae (p-value = 0.169). However, in all three cases, the highest predicted mean in percent reduction occurred when the screen width was 0.5 mm. In each case, the largest differences occurred between 0.5-mm and 1.0-mm mesh sizes.
- Slot velocity did not have a significant effect on average percent reduction in any of the three cases (p-value = 0.183 for total organisms, p-value = 0.154 for eggs, and p-value = 0.874 for larvae). When treating slot velocity as a categorical variable rather than a continuous variable (similar to screen size), EPA still did not observe a significant slot velocity effect, and the predicted means did not follow any noticeable pattern.

Generalized Linear Models

Generalized linear models (GLMs) are statistical methods that explain the relationship between a response variable and a set of predictors. Unlike ANOVA methods, GLMs can be used to make inferences about the model when the data follow a distribution other than the normal distribution. GLMs model a transformation of the mean (called the link function) as a linear combination of the factors under investigation. For the entrainment data, we considered two types of GLMs: Poisson regression and logistic regression. Appendix F describes the analyses and the results. In summary from these analyses, EPA reached the following conclusions:

- Both screen width and slot velocity variables were highly significant at explaining the number of eggs entrained.
- Screen width was not significant at explaining the number of non-eggs entrained or the number of total organisms entrained. Slot velocity also was not significant at explaining the number of non-eggs entrained or the number of total organisms entrained.

<u>Graphical Analysis</u>

In addition to the ANOVA, EPA examined a series of plots for patterns in mesh sizes and slot velocities. The plots are provided in Exhibits 11-9 through 11-12 and 11-14 through 11-15. They display percent reductions for total organisms, eggs, and larvae (non-eggs). Here are EPA's conclusions:

- Total Organisms: Exhibits 11-9 and 11-10 show a wide range of percent reductions of total organisms at any screen size and slot velocity. (Exhibit 11-7 provides the percent reduction values plotted in the figures.)
- Eggs: Exhibits 11-11 and 11-12 show that:
    - 0.5-mm screens generally reduce over 80 percent of the entrainment of eggs. The one exception is associated with a slot velocity of 0.3 meters per second (m/s). As shown in Exhibit 11-13 which presents percent reduction of eggs, this value is 19 percent from the Chesapeake Bay Study. EPRI (2006) notes that "At the salinity closest to that observed at our test site (15 ppt) the mean diameters of the major and minor axes were estimated to be 0.97 and 0.90 mms, respectively." (page 4-30) At the slower slot velocity of 0.15 m/s, Chesapeake study reports 87 percent reduction. EPA concludes that the higher slot velocity forced more eggs through the 0.5-mm screen, and thus, the lower velocity is more protective.
    - 1-mm screens are generally reducing relatively little entrainment. Most values are below 20 percent. The one exception, 96 percent, has a slot velocity of 0.15 m/s and was observed during the Portage River study.
- Larvae: Exhibits 11-14 and 11-15 have similar patterns to those for total organisms. There are wide ranges of percent reductions at any screen size and velocity. Exhibit 11-16 provides the percent reductions for each study condition.

Exhibit 11-9. Percent Reduction of Total Organisms Entrained by Slot Velocity and Screen Size, with Screen Size on the Horizontal Axis

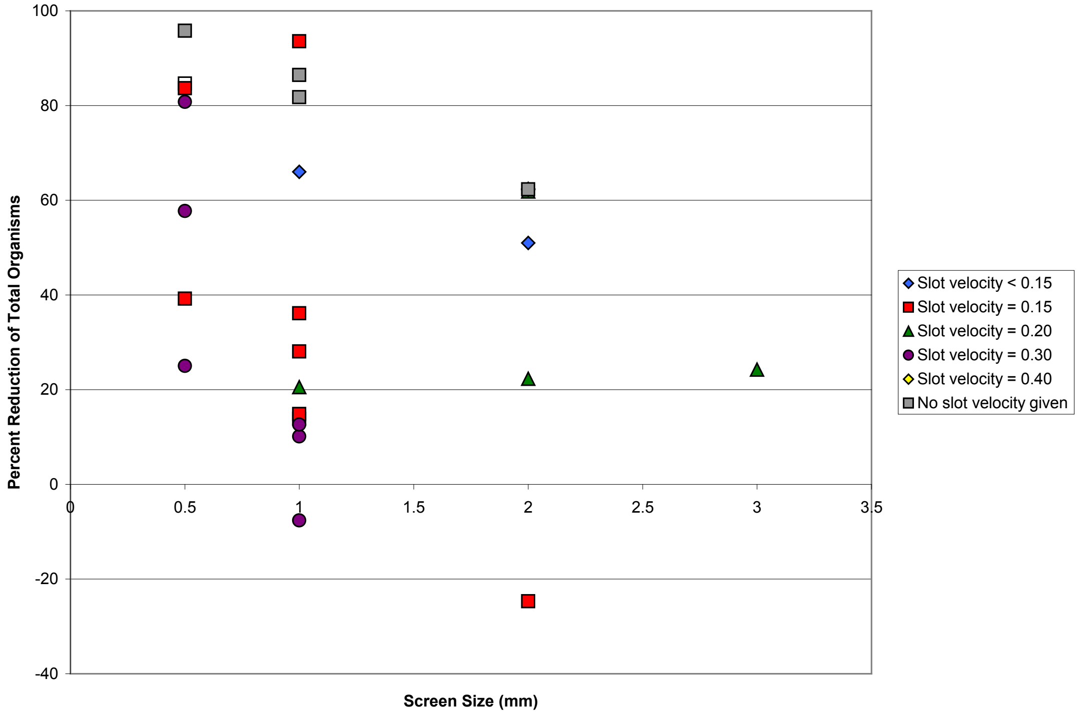


Exhibit 11-10. Percent Reduction of <u>Total Organisms</u> Entrained by Slot Velocity and Screen Size, with Slot Velocity on the Horizontal Axis

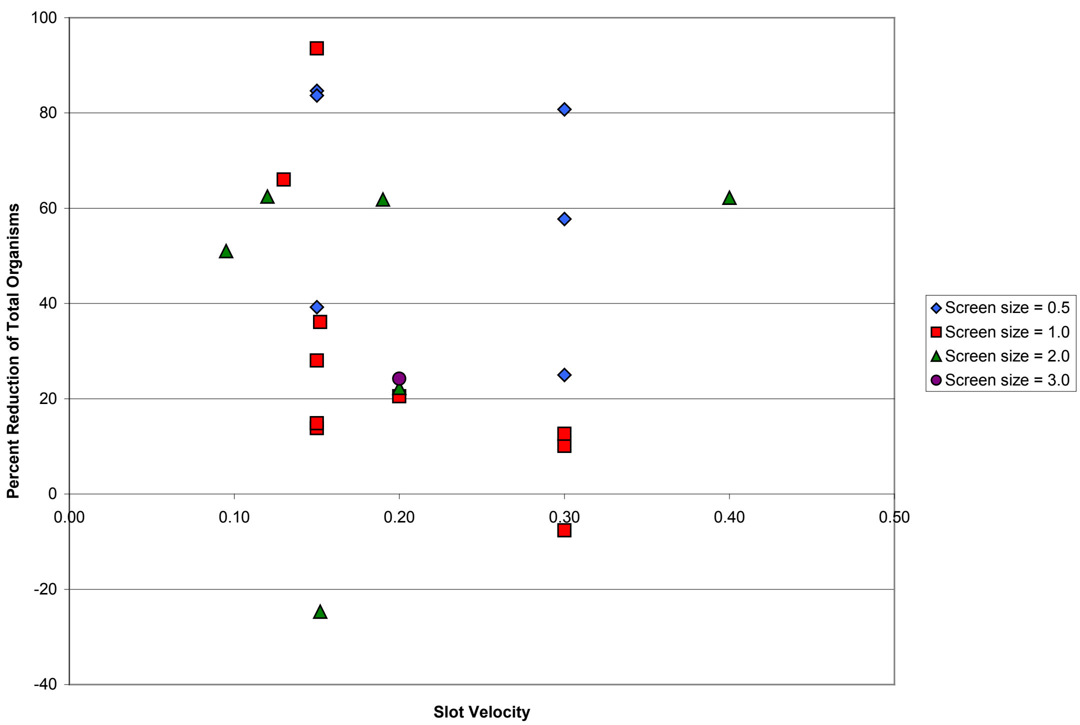


Exhibit 11-11. Percent Reduction of Eggs Entrained by Slot Velocity and Screen Size, with Screen Size on the Horizontal Axis

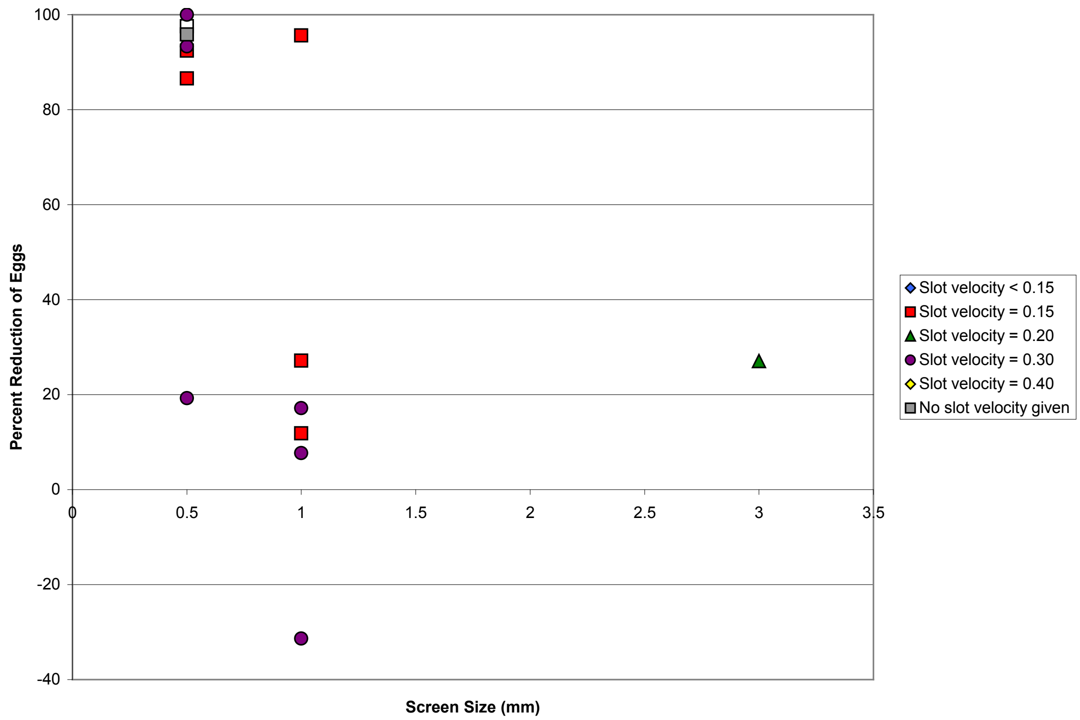


Exhibit 11-12. Percent Reduction of Eggs Entrained by Slot Velocity and Screen Size, with Slot Velocity on the Horizontal Axis

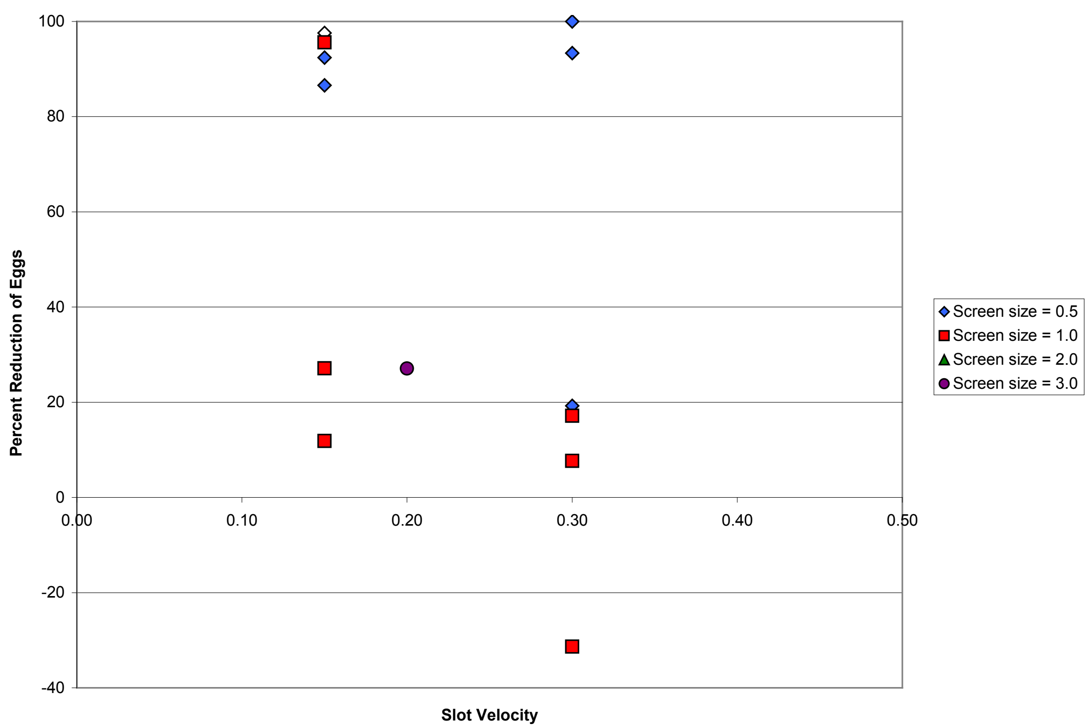


Exhibit 11-13. Eggs: Percent Reduction of Entrainment

Test Location	Screen Slot Width (mm)	Slot Velocity (m/s)	"Front" Samples: Total Density of Eggs	"Behind" Samples: Total Density of Eggs	Density Units of "Front" and "Behind" Samples	Percent Reduction of Eggs
Big Bend Station	0.5	not specified	51,455	2,133	#/100m^3	95.9
Chalk Point intake canal (1983)	3	0.20	2,341	1,707	#/1000m^3	27.1
Chesapeake Bay	0.5	0.15	998.8	134.1	#/100m^3	86.6
	0.5	0.30	503.1	406.2	#/100m^3	19.3
	1	0.15	774	682.3	#/100m^3	11.8
	1	0.30	271.7	356.9	#/100m^3	-31.4
Portage River	0.5	0.15	45.1	1.1	#/100m^3	97.6
	0.5	0.30	42	2.8	#/100m^3	93.3
	1	0.15	102.9	4.5	#/100m^3	95.6
	1	0.30	117.2	97.1	#/100m^3	17.2
Sakkonet River	0.5	0.15	14.5	1.1	#/100m^3	92.4
	0.5	0.30	22.8	0	#/100m^3	100.0
	1	0.15	42	30.6	#/100m^3	27.1
	1	0.30	42.9	39.6	#/100m^3	7.7

Exhibit 11-14. Percent Reduction of Larvae Entrained by Slot Velocity and Screen Size, with Screen Size on the Horizontal Axis

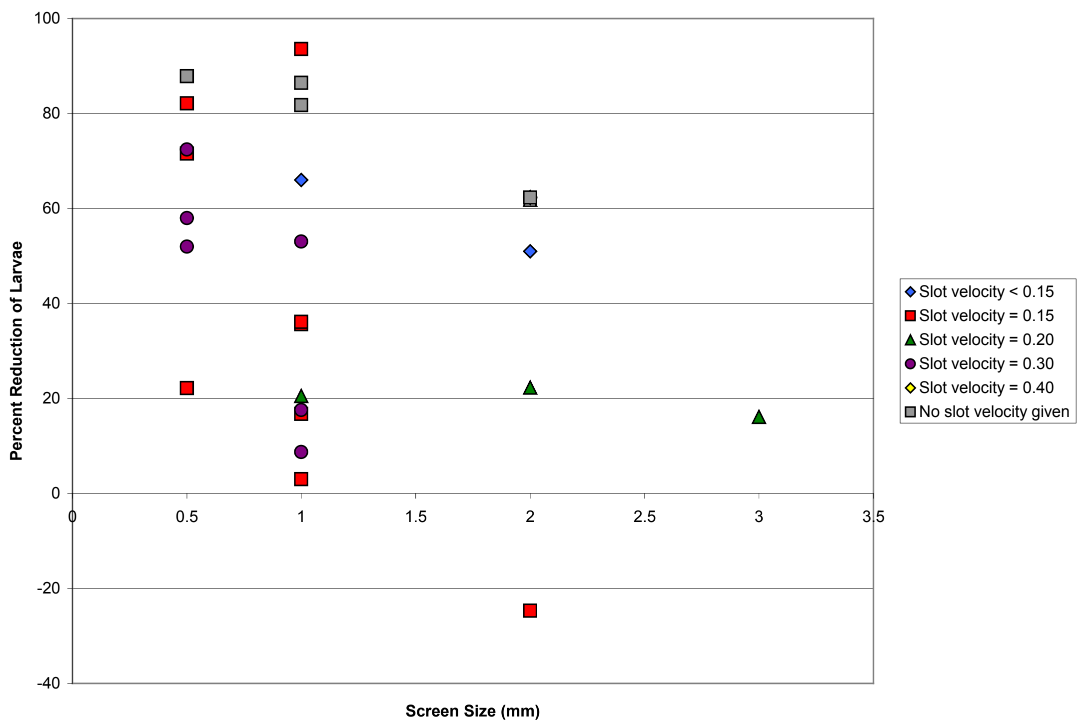


Exhibit 11-15. Percent Reduction of Larvae Entrained by Slot Velocity and Screen Size, with Slot Velocity on the Horizontal Axis

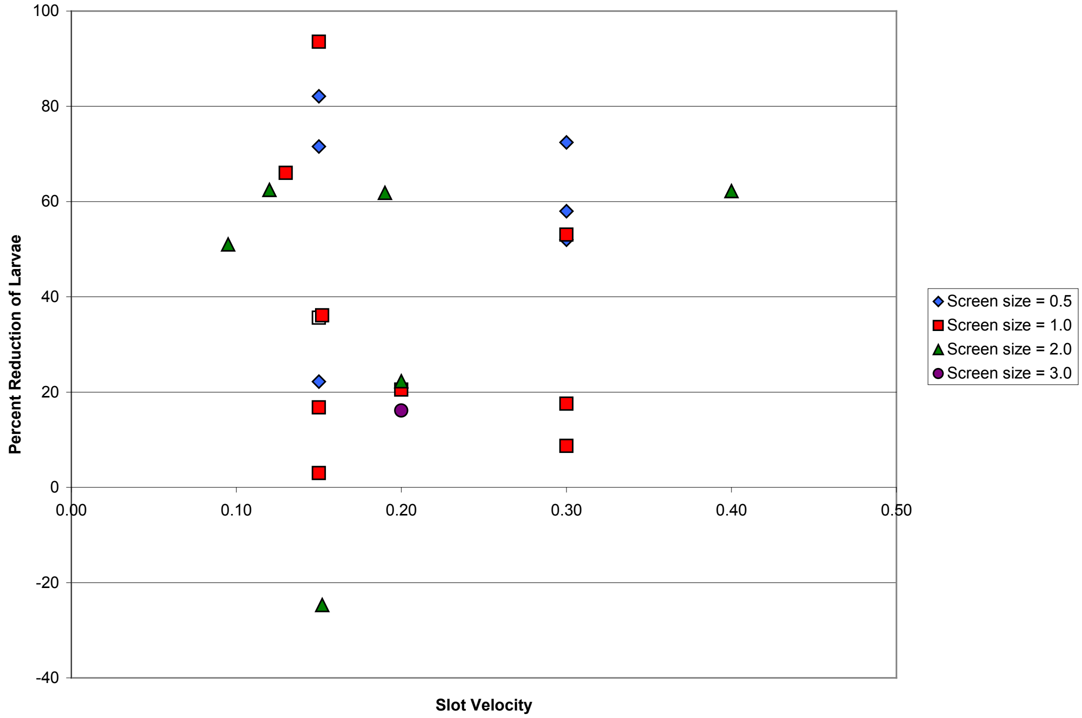


Exhibit 11-16. Larvae: Percent Reduction of Entrainment

Test Location	Screen Slot Width (mm)	Slot Velocity (m/s)	"Front" Samples: Total Density of Larvae	"Behind" Samples: Total Density of Larvae	Density Units of "Front" and "Behind" Samples	Percent Reduction of Larvae
Big Bend Station	0.5	not specified	338.1	41.1	#/100m^3	87.8
Brunswick Steam Electric Plant	1	not specified	543	99	#/1000m^3	81.8
Chalk Point intake canal (1982)	1	not specified	374.2	50.6	#/1000m^3	86.5
	2		374.2	141.1	#/1000m^3	62.3
Chalk Point intake canal (1983)	1	0.20	825.2	655.8	#/1000m^3	20.5
	2	0.20	825.2	641.2	#/1000m^3	22.3
		0.095	825.2	404.4	#/1000m^3	51.0
		0.19	825.2	314.8	#/1000m^3	61.9
		0.40	825.2	311.8	#/1000m^3	62.2
	3	0.20	825.2	692	#/1000m^3	16.1
Chesapeake Bay	0.5	0.15	146.6	41.7	#/100m^3	71.6
		0.30	87.6	36.8	#/100m^3	58.0
	1	0.15	71	45.7	#/100m^3	35.6
		0.30	106.3	49.9	#/100m^3	53.1
Logan Gen. Plant	1	0.15	637	41	#	93.6
Oyster Creek intake canal	1	0.152	39.3	25.1	#/m^3	36.1
	2	0.152	39.3	49	#/m^3	-24.7
Portage River	0.5	0.15	154.5	120.2	#/100m^3	22.2
		0.30	260.8	125.2	#/100m^3	52.0
	1	0.15	616.6	513.2	#/100m^3	16.8
		0.30	587.6	536.4	#/100m^3	8.7
Sakkonet River	0.5	0.15	81.1	14.5	#/100m^3	82.1
		0.30	52.6	14.5	#/100m^3	72.4
	1	0.15	43.5	42.2	#/100m^3	3.0
		0.30	43.3	35.7	#/100m^3	17.6
St. Johns River	1	0.13	38692597	13152507	#	66.0
	2	0.12	38692597	14530529	#	62.4

11.3.5 Consideration of Entrainment Limitation

In its consideration of potential entrainment limitations, EPA summarized the data as shown in Exhibit 11-17 to distinguish between different life stages, slot sizes, and velocities. EPA then focused on data representing the entrainment of eggs, because, of all life stages, eggs are the least able to avoid being entrained (in other words eggs have no avoidance capability), and because eggs pose the smallest life-stage that any screens-based technology must be able to protect. To develop a limitation that would be protective of eggs, EPA evaluated the performance of circular wedgewire screens with mesh sizes of 0.5-mm screens and a slot velocity of 0.5 feet per second. Many eggs are larger than 0.5-mm screens, and thus, a mesh size of 0.5 mm would reduce the likelihood of entrainment. In addition, the relatively low velocity of 0.5 feet per second means that organisms larger than 0.5 mm are less likely to be squeezed or forced through the mesh. EPA found, on average, the screen size and velocity specifications resulted in 92 percent reduction of eggs. However, as explained in Chapter 6, EPA has concerns about the technical availability of requiring 0.5-mm fine mesh screens for this industry. As a consequence, EPA considered developing limitations based upon a larger mesh size, such as 1 or 2 mm, but concluded that eggs, because of their small size, would generally pass through the larger mesh sizes. After reviewing the documents listed in Appendix A, EPA further notes that none of the studies evaluated egg entrainment reduction by 2-mm fine mesh screens. As explained in the preamble, EPA has not proposed entrainment limitations.

Exhibit 11-17. List of Percent Reduction in Entrainment Data by Study, Screen Size, and Slot Velocity, and Summary Statistics

Organisms	Screen Size (mm)[c]	Slot Velocity (m/s)	Study (Test Location): Big Bend	Brunswick	Chalk Point 1982	Chalk Point 1983	Chesapeake Bay	Logan Plant	Oyster Creek	Portage River	Sakonet River	St. Johns River	Summary Statistics: Min[a]	Min[b]	Max	Average[b]	Median[b]
Total	0.5	0.15					84.7			39.2	83.7		39.2	39.2	84.7	69.2	83.7
		0.30					25.0			57.7	80.8		25.0	25.0	80.8	54.5	57.7
		NS	95.8										95.8	95.8	95.8	95.8	95.8
		All											25.0	25.0	95.8	66.7	80.8
	1.0	≤ 0.15					13.8	93.6	36.1	28.0	14.9	66.0	13.8	13.8	93.6	42.1	32.1
		> 0.15				20.5	-7.6			10.1	12.6		-7.6	10.1	20.5	14.4	12.6
		NS		81.8	86.5								81.8	81.8	86.5	84.2	84.2
		All											-7.6	10.1	93.6	42.2	28.0
	2.0	≤ 0.15				51.0			-24.7			62.4	-24.7	51.0	62.4	56.7	56.7
		> 0.15				61.9, 22.3, 62.2							22.3	22.3	62.2	48.8	61.9
		NS			62.3								62.3	62.3	62.3	62.3	62.3
		All											-24.7	22.3	62.4	53.7	62.1
Eggs Only	0.5	0.15					86.6			97.6	92.4		86.6	86.6	97.6	92.2	92.4
		0.30					19.3			93.3	100.0		19.3	19.3	100	70.9	93.3
		NS	95.9										95.9	95.9	95.9	95.9	95.9
		All											19.3	19.3	100	83.6	93.3
	1.0	≤ 0.15					11.8			95.6	27.1		11.8	11.8	95.6	44.8	27.1
		> 0.15					-31.4			17.2	7.7		-31.4	7.7	17.2	12.5	12.5
		All											-31.4	7.7	95.6	31.9	17.2
Larvae (non-eggs) Only	0.5	0.15					71.6			22.2	82.1		22.2	22.2	82.1	58.6	71.6
		0.30					58.0			52.0	72.4		52.0	52.0	72.4	60.8	58.0
		NS	87.8										87.8	87.8	87.8	87.8	87.8
		All											22.2	22.2	87.8	63.7	71.6
	1.0	≤ 0.15					35.6	93.6	36.1	16.8	3.0	66.0	3.0	3.0	93.6	41.9	35.9
		> 0.15				20.5	53.1			8.7	17.6		8.7	8.7	53.1	25.0	19.1
		NS		81.8	86.5								81.8	81.8	86.5	84.2	84.2
		All											3.0	3.0	93.6	43.3	35.9
	2.0	≤ 0.15				51.0			-24.7			62.4	-24.7	51.0	62.4	56.7	56.7
		> 0.15				61.9, 22.3, 62.2							22.3	22.3	62.2	48.8	61.9
		NS			62.3								62.3	62.3	62.3	62.3	62.3
		All											-24.7	22.3	62.4	53.7	62.1

[a] Includes negative values

[b] Excludes negative values

[c] Does not include data on the 3.0 mm mesh size from the 1983 Chalk Point study.

NS = not specified

11.4 References

Battelle. 2008. "316b: Laboratory Test Data Related to Entrainment." Prepared under EPA Contract No. EP-C-05-030. October 17, 2008.

Beak Consultants, Inc. 2000a. *Post-Impingement Fish Survival at Dunkirk Steam Station. Winter, Spring, Summer and Fall 1998-1999*. Prepared for NRG Dunkirk Power, LLC. 26 January 2000. (DCN 5-4327)

Beak Consultants, Inc. 2000b. *Post-Impingement Fish Survival at Huntley Steam Station. Winter and Fall 1999*. Prepared for Niagara Mohawk Power Corp. 10 April 2000. (DCN 5-4325)

CEC. 1996. *Arthur Kill Generating Station Diagnostic Study and Post-Impingement Viability Substudy Report*. Prepared by Consolidated Edison Company of New York, Inc. 31 January 1996. (DCN 5-4326)

CP&L. 1985a. *Brunswick Steam Electric Plant, Cape Fear Studies: Interpretive Report.* Carolina Power & Light Company. August 1985.

CP&L. 1985b. *Brunswick Steam Electric Plant, 1984 Biological Monitoring Report.* Biology Unit, Environmental Services Section, Carolina Power & Light Company. August 1985.

Dames and Moore. 1979. *Seminole Plant Units No. 1 and No. 2: 316b Study and Report.* Prepared for Seminole Electric Cooperative, Inc. November 1979.

Electric Power Research Institute (EPRI). 2006. *Field Evaluation of Wedgewire Screens for Protecting Early Life Stages of Fish at Cooling Water Intake Structures: Chesapeake Bay Studies.* Palo Alto, CA: Electric Power Research Institute. 1012542.

Electric Power Research Institute. 2007. *Fish Protection at Cooling Water Intake Structures: A Technical Reference Manual*. Palo Alto, CA: Electric Power Research Institute. 1014934.

Electric Power Research Institute. 2008. *Laboratory Evaluation of Fine-Mesh Traveling Water Screens for Protecting Early Life Stages of Fish at Cooling Water Intakes.* Palo Alto, CA: Electric Power Research Institute, Inc. 1014021.

Ehrler, C, and Raifsnider, C. 2000. Evaluation of the effectiveness of intake wedgewire screens. *Environmental Science & Policy.* 3:S361-S368. (DCN 5-4335)

Mote Marine Laboratory. 1987. *Fine Mesh Screen (FMS) Optimization Study: A Technical Report.* Prepared for Environmental Planning, Tampa (FL) Electric Company. 2 July 1987. (DCN 5-4371)

Ronafalvy, J.P., et al. 2000. "Circulating water traveling screen modifications to improve impinged fish survival and debris handling at Salem Generating Station." *Environmental Science & Policy,* 3, pages S377-S382. (DCN 5-4333).

Weisberg, S.B., Burton, W.H., Ross, E.A., and Jacobs, F. 1984. *The Effects of Screen Slot Size, Screen Diameter, and Through-Slot Velocity on Entrainment of Estuarine Ichthyoplankton Through Wedge-Wire Screens.* Prepared by Martin Marietta Environmental Systems for the Maryland Department of Natural Resources. August 1984. (DCN 5-4008)

Appendix A to Chapter 11: Studies

The tables in this appendix provide information about the studies and data evaluated for Chapter 11.

- Exhibit 11A-1 identifies the documents and whether they:
  - Included impingement/entrainment data (i.e., counts and/or percentages);
  - Were used to develop the proposed limitations (for impingement mortality) or the entrainment design approaches, and reasons for using or not using the data in the evaluations; and
  - Are included in the performance database (DCN 10-5400).
- Exhibit 11A-2 identifies the subset of documents and facilities with impingement mortality data.
- Exhibit 11A-3 identifies the subset of documents and facilities with entrainment density data ("front" and "behind").
- Exhibit 11A-4 identifies the subset of documents and facilities with entrainment mortality data (counts and/or percentages).

Exhibit 11A-1: List of Documents Reviewed for Data on Impingement and Entrainment For Use in Preparing Proposed Limitations on Impingement Mortality and BTA Design Standards for Entrainment

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
4	DCN 5-4053	CCI Environmental Services	Zooplankton Entrainment Survival at the Anclote Power Plant Near Tarpon Springs, Florida	1994			No impingement data	Yes*	No	Focused on mortality resulting from entrainment through system and dilution pumps, rather than measuring entrainment reduction. Technology was alternate reduced intake flow, and not fine-mesh screens.
5	DCN 1-3019-BE	US EPA Region IV	In the Matter of Florida Power Corporation, Crystal River Power Plant, Units 1, 2 and 3, Citrus County Florida, NPDES Permit No. FL0000159, Findings and Determinations, per 33 USC 1326	1988	Yes	No	Brief mention of total annual impingement of two shrimp and crab species is given in tons. No impingement mortality data reported. Limited information available on technology, which is not modified traveling screens.			No entrainment data.
8	DCN 4-4002B	EPRI	Fish Protection at Cooling Water Intakes: Status Report	1999	Yes	No	Summary report containing data from various studies and facilities. Some acceptable impingement mortality data found in this report were obtained from their original source or from a later update (2007) of this report instead.			No entrainment data.
16	DCN 5-4397	Lawler Matusky & Skelly Engineers	Intake Research Facilities Manual	1985			No impingement data. (Report contains only detailed descriptions of intake testing facilities.)			No entrainment data.
17 150	DCN 5-4313	AWH Turnpenny, R Wood, and KP Thatcher	Fish Deterrent Field Trials at Hinkley Point Power Station, Somerset, 1993-1994	1994	Yes*	No	Study of fish diversion using non-BTA technology (sound generating system)			No entrainment data.
18	DCN 5-4414	Ecological Analysts Inc.	Potrero Power Plant CWIS 316(b) Demonstration	1980	Yes*	No	Used course mesh traveling screens, but not modified features to make it BTA.	Yes*	No	Only reported estimated entrainment abundance and survival, and not reduction in density, at a single sample point. Used coarse mesh rather than fine mesh screens.

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
38	DCN 5-4391	JB Hutchinson and JA Matousek	Evaluation of a Barrier Net Used to Mitigate Fish Impingement at a Hudson River Power Plant Intake	1988	Yes*	No	Did not use modified traveling screen technology. Did not record mortality data within 48 hours of impingement.			No entrainment data.
39	DCN 5-4389	J Homa, M Stafford-Glase, and ME Connors; Ichthyological Associates, Inc.	An Evaluation of the Effectiveness of the Strobe Light Deterrent System at Milliken Station on Cayuga Lake, Tompkins County, New York	1994			No impingement data.	Yes	No	Used strobe light deterrent system rather than fine mesh screen technology. Sampling done at a single collection point.
40	DCN 5-4417	Lawler, matusky, & Skelly Engineers LLP	Lovett Generating Station Gunderboom System Evaluation Program	1998			No impingement data.	Yes*	No	Used Gunderboom system rather than fine mesh screen technology.
41	DCN 5-4322	Lawler, Matusky, & Skelly Engineers LLP	Lovett Generating Station Gunderboom Deployment Program, 2000	2001			No impingement data.	Yes*	No	Used Gunderboom system rather than fine mesh screen technology.
42	DCN 5-4388	Stone and Webster Engineering Corporation	Evaluation of the Eicher Screen at Elwha Dam: Spring 1990 Test Results	1991			No impingement data. Data represent fish diversion associated with a prototype installation operated under highly controlled conditions.			Data represent fish diversion associated with a prototype installation operated under highly controlled conditions. Screens classified as coarse mesh.
43	DCN 5-4394	Roberto Pagano and Wade H.B. Smith - Mitre Corporation	Recent Developments in Techniques to Protect Aquatic Organisms at the Water Intakes of Steam-Electric Power Plants	1977	Yes*	No	Impingement data from Surry and Barney Davis Power Stations represent fish bucket screens and double-exit traveling screens, respectively but the data only represent mortality immediately following impingement.			No entrainment data
44	DCN 5-4327	Beak Consultants Incorporated	Post-Impingement Fish Survival at Dunkirk Steam Station 1998-1999	2000	Yes*	Yes	Mortality data were reported at 24-hour post-impingement for Ristroph-type dual flow traveling screens.			No entrainment data
45	DCN 5-4419	Tennessee Valley Authority	A State-of-the-Art Report on Intake Technologies	1976	Yes	No	Data represent laboratory studies and do not represent traveling screens with BTA features.	Yes	No	Percentage entrainment data are reported for various mesh sizes, but entrainment reduction is not reported.

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
46	DCN 4-4002V-R12	Lawler, Matusky & Skelly Engineers	Intake Technologies: Research Status	1989	Yes*	No	Summary report of impingement mortality data from various facilities. Typically, only immediate impingement mortality is provided, or technologies were not traveling screens with BTA features.			No entrainment data
47	DCN 10-5435	Stone and Webster Environmental Technology and Services	Evaluation of the Modular Inclined Screen at the Green Island Hydroelectric Project: 1995 Test Results	1996			No impingement data.	Yes*	No	Controlled study performed in a test facility near the power plant. Fish were injected into the test facility, and numbers diverted from the screens and collected at bypass were reported rather than entrainment.
48	DCN 5-4314	AWH Turnpenny, JM Fleming, KP Thatcher & R Wood (Fawley Aquatic Research Laboratories, Ltd.)	Trials of an Acoustic Fish Deterrent System at Hartlepool Power Station	1995	Yes	No	Study measured how fish impingement rate (rather than mortality) is reduced when a non-BTA technology (acoustic deterrent system) is in place.			No entrainment data
49	DCN 5-4396	David E. Bailey, Jules J. Loos, Elgin S. Perry	Studies of Cooling Water Intake Structure Effects at Potomac Electric Power Company Generating Stations	Unk.	Yes*	No	Impingement counts, but not mortality, are reported for several facilities. Technologies were not fully documented (but were not traveling screens with BTA features).	Yes*	No	Entrainment data expressed as percent loss or biomass, and not percent reduction in density. Technologies were not fully documented (but were not fine-mesh screens).
50	DCN 10-5438	Drs. P.A. Henderson and R.M. Seaby	Technical Evaluation of USEPA's Proposed Cooling Water Intake Regulations for New Facilities	2000	Yes	No	Only estimated annual fish impingement reported to assess impact of pumping rate on impingement at various plants. Technologies not fully documented.	Yes	No	Only entrainment counts were reported for various plants, and not "before/after" measurements. Technologies not fully documented.
51	DCN 5-4325	Beak Consultants, Inc.	Post-Impingement Fish Survival at Huntley Steam Station (Winter and Fall, 1999)	2000	Yes*	Yes	Mortality data were reported at 24-hour post-impingement for Ristroph-type dual flow traveling screens.			No entrainment data
52	DCN 5-4371	Mote Marine Laboratory	Fine Mesh Screen (FMS) Optimization Study	1987			No impingement data.	Yes*	Yes	Entrainment density data were reported from front and behind screen 3A for representative important species.

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
53	DCN 5-4378	John S. Stevens, Jr., and Milton S. Love	Chapter 10: San Onofre Units 2 and 3 316(b) Demonstration, The Effectiveness of the Fish Return System	Unk.	Yes	No	Impingement mortality measured at 96 hours. Technology involved louvers and angled screens.			No entrainment data
54 209	DCN 5-4326	Consolidated Edison Company of New York	Arthur Kill Generating Station Diagnostic Study and Post-Impingement Viability Substudy Report	2000	Yes*	Yes	Mortality data utilized were collected at 24-hour post-impingement at Screens No. 24 and 31 which featured Ristroph-type dual flow traveling screens. Limited mortality data reported in a chapter comparing performance at Arthur Kill and Indian Point plants were not used.	Yes	No	While fine-mesh screens were evaluated, samples were measured downstream and used to estimate entrainment (with no paired "front" sample results to compare with).
55	DCN 2-013L-R1	American Electric Power Service Corporation	Cardinal Plant Demonstration Document	1981	Yes	No	Impingement data consist solely of impinged fish, with no mortality information. Traveling screens were not modified.	Yes	No	Entrainment data consist solely of numbers of fish that passed through coarse-mesh screens.
56 66	DCN 5-4006 DCN 6-2074	TG Ringger, Baltimore Gas & Electric	Investigations of Impingement of Aquatic Organisms at the Calvert Cliffs Nuclear Power Plant, 1975-1995	2000	Yes*	No	Annual impingement counts and mortality are estimated. Traveling screens were not modified.			No entrainment data
57	DCN 2-017A-R7	EPRI	Review of Entrainment Survival Studies: 1970-2000	2000			No impingement data.	Yes	No	Summary report consisting solely of entrainment survival data summaries from several plants, with no data reported on reduction in entrainment or on the specified technologies used.
58 97	DCN 5-4337	Delta Fish Facilities Technical Coordination Committee	Preliminary Design Criteria for the Peripheral Canal Intake Fish Facilities	1981			No impingement data.			No entrainment data
59	DCN 5-4354	E.S. Fritz	Cooling Water Intake Screening Devices Used to Reduce Entrainment and Impingement	1980			No impingement data.			No entrainment data
60	DCN 10-5448	Latvaitis et al. Edited by Loren Jensen	Third National Workshop on Entrainment and Impingement - - Impingement Studies at Quad-Cities Station, Mississippi River	1976	Yes*	No	Losses of standing crop to impingement are reported rather than impingement mortality. Data are estimated. Traveling screens were not modified.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
61	DCN 5-4343	Department of Fish and Game and the Department of Water Resources	Memorandum Report on the Peripheral Canal Fish Return Facilities	1971			No impingement data.			No entrainment data
62	DCN 10-5448	Thomas & Miller. Edited by Loren Jensen	Third National Workshop on Entrainment and Impingement --Impingement Studies at Oyster Creek Generating Station, Forked River, New Jersey, from Sept. to Dec. 1975	1976	Yes*	No	Traveling screens were not modified. Reported impingement mortality data appear to represent only immediate mortality, although report notes delayed mortality was examined.			No entrainment data
63	DCN 5-4381	Ronald Raschke - US EPA	Finding of Fact for Biological and Environmental 316 Demonstration Studies	1983	Yes	No	Only total annual impingement counts were reported for selected species, and not impingement mortality. No information given to verify use of BTA.	Yes	No	Only total annual entrainment counts were reported for selected species, with no “front” data to allow for percent reduction to be calculated. Technology likely not fine-mesh screens.
64	DCN 5-4334	James B. McLaren	Fish Survival on Fine Mesh Travelling Screens	2000	Yes*	No	Impingement mortality data reported only at 0 and 96 hours post-impingement.			No entrainment data
65	DCN 10-5453	Richard Horwitz	Lecture Notes on Coastal and Estuarine Studies - Ecological Studies in the Middle Reach of the Chesapeake Bay - Impingement Studies	1987	Yes*	No	Traveling screens were not modified with BTA features. Only immediate mortality following impingement appears to be reported in most cases.			No entrainment data
69	DCN 5-4346	Q.E. Ross; D.J. Dunning; J.K. Meneszees; M.J.Kenn Jr.; G.Tiller	Reducing Impingement of Alewives with High Energy Frequency Sound at a Power Plant Intake in Lake Ontario	1996	Yes	No	Study used non-BTA technology (sound generating system)			No entrainment data
70	DCN 5-4347	Q.E. Ross; D.J. Dunning; J.K. Meneszees; M.J.Kenn Jr.; G.Tiller	Response of Alewives to High Frequency Sound at a Power Plant Intake on lake Ontario	1993	Yes	No	Study used non-BTA technology (sound generating system)			No entrainment data. (Although densities of fish near the intakes were collected, the densities were associated with the sound deterrent system either on or off).
71	DCN 5-4374	N.J. Thurber and D.J Jude, Great Lakes and Marine Waters Center, University of Michigan	Impingement Losses at the DC Cook Nuclear Power Plant During 1975-1982 With a Discussion of Factors Responsible and Possible Impact on Local Populations	1985	Yes	No	Estimated annual impingement totals without noting mortality. Used non-BTA technology (traveling screens with no modification). Data are of questionable quality.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
73	DCN 5-4301	A.W.H. Turnpenny	Fish Return at Cooling Water Intakes	1992	Yes*	No	Only ranges of impingement mortality are presented for one facility, for each of five levels of fish resistance/sensitivity. Minimal information was available to assess BTA use. One study measured only 96 hour survival rate.			No entrainment data
74	DCN 5-4330	Rob Brown	The potential of strobe lighting as a cost-effective means for reducing impingement and entrainment	2000			No impingement data. Study used non-BTA technology (strobe lighting system)			No entrainment data
75	DCN 5-4302	A.W.H. Turnpenny	Exclusion of Salmonid Fish From Water Intakes	1988			No impingement data.			No entrainment data
76	DCN 5-4303	A.W.H. Turnpenny	Bubble Curtain Fish Exclusion Trials at Heyshaam 2 Power Station	1993	Yes*	No	Data correspond to “fish catch on screens.” Study assessed non-BTA technology (bubble curtain, with no information on screens used).			No entrainment data
77	DCN 5-4304	A. Turnpenny, J. Nedwell	Fish Behaving Badly	2002			No impingement data.			No entrainment data
78	DCN 5-4300	A.W.H. Turnpenny, C.J.L. Taylor	An Assessment of the Effect of the Sizewell Power Stations on Fish Populations	2000	Yes*	No	Impingement data expressed as “losses to the fishery” as biomass rather than mortality. Facilities do not appear to have used BTA.			No entrainment data
79	DCN 5-4357	Fish and Wildlife Service - US Department of the Interior	Impacts of Power Plant Intake Velocities on Fish	1977			No impingement data.			No entrainment data
80	DCN 5-4307	H.H. Reading	Retention of Juvenile White Sturgeon, Acipenser Transmontanus, by Perforated Plate and Wedgewire Screen Materials	1982			Laboratory study that did not collect impingement mortality data.			No entrainment data
81	DCN 10-5465	D.T. Michaud, E.P. Taft	Recent Evaluations of Physical and Behavioral Barriers for Reducing Fish Entrainment at Hydroelectric Plants in the Upper Midwest	2000			No impingement data.	Yes*	No	Study evaluated different technologies (e.g., barrier net, sound, strobe lights, air bubble devices) other than use of fine mesh screens.

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
82	DCN 10-5466	E.R. Guilfoos, R.W. Williams, T.E. Rourke, P.B. Latvaitis, J.A. Gulvas, R.H. Reider	Six Years of Monitoring the Effectiveness of a Barrier Net at the Ludington Pumped Storage Plants on Lake Michigan (Waterpower 95)	1995			No impingement data.			No entrainment data with regard to fine-mesh screens (instead, the percentage of fish prohibited from entering a barrier net enclosure was measured).
84	DCN 5-4335	C. Ehrler, C. Raifsnider	Evaluation of the Effectiveness of Intake Wedgewire Screens	2000			No impingement data.	Yes*	Yes	Entrainment data represent samples collected "behind" 1 mm screens, while "front" sample data were taken as the average # fish from samples collected from deep channel and shallow stations.
85	DCN 5-4333	John P. Ronafalvy, R. Roy Cheesman, William M. Matejek	Circulating water traveling screen modifications to improve impinged fish survival and debris handling at Salem Generating Station	2000	Yes*	No	Impingement data for only one species (weakfish) were available.			No entrainment data
86	DCN 6-5068	Lawler, Matusky, and Skelly	Lovett Generating Station Gunderboom Evaluation Program	1996	Yes	No	No mortality data. No information on type of traveling screens used (focus is on Gunderboom evaluation).	Yes	No	Estimated entrainment counts are provided only with and without Gunderboom in place.
94	DCN 5-4344	KeySpan Corporation	Screenwash return water modification study, Glennwood and Port Jefferson Power Stations	2002	Yes	No	Only monthly totals reported. No information given on type of technology. No mortality data.			No entrainment data
95	DCN 5-4332	Andrew E. Jahn, Kevin T. Herbinson	Designing a light-meditated behavioral barrier to fish impingement and a monitoring program to test its effectiveness at a coastal power station	2000			No impingement data. Study used non-BTA technology (light used as stimulus for attracting fish to bypass).			No entrainment data
96	DCN 5-4331	David R. Sager, Charles H. Hocutt, Jay R. Stauffer Jr.	Avoidance behavior of Morone americana, Leiostomus xanthurus and Brevooritia tyrannus to strobe light as a method of impingement mitigation	2000			No impingement data. Laboratory study that used non-BTA technology (strobe light and bubble curtain deterrents).			No entrainment data
98	DCN 5-4338	Delta Fish Facilities Technical Coordinating Committee	Justification for Abandonment of Further Consideration of the Louver Fish Screen for an Intake Facility for the Peripheral Canal	1981			No impingement data			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
99	DCN 5-4339	Delta Fish Facilities Technical Coordinating Committee	Horizontal Traveling Fish Screen Status	1980	Yes	No	Laboratory study. No mortality data or information given on whether traveling screens were modified.			No entrainment data
100	DCN 5-4340	Delta Fish Facilities Technical Coordinating Committee	Justification for Abandonment of Further Consideration of the Filtration Concept for an Intake Facility for the Peripheral Canal	1979			No impingement data			No entrainment data
101	DCN 5-4341	Delta Fish Facilities Technical Coordinating Committee	Justification for Eliminating from Further Consideration the Horizontal Rotary Drum Screen for the Peripheral Canal	1979			No impingement data			No entrainment data
102	DCN 5-4342	Delta Fish Facilities Technical Coordinating Committee	Justification for Proceeding with an "Off-River" Intake Concept for the Peripheral Canal	1979			No impingement data			No entrainment data
103	DCN 5-4360	CD Goodyear, Great Lakes Fishery Laboratory	Evaluation of 316(b) Demonstration: Detroit Edison's Monroe Power Plant	1978	Yes*	No	No mortality data. No indication that traveling screens were modified. Data appear to be estimates.	Yes	No	Coarse mesh screens used. No "front" data.
104	DCN 5-4362	LW Barnthouse et al, Oak Ridge National Laboratory	The Impact of Entrainment and Impingement on Fish Populations in the Hudson River Estuary (Volume II)	1982	Yes	No	Estimated monthly data provided. For three plants with impingement mortality data, holding times exceed 48 hours.			No entrainment data
105	DCN 5-4376	JH Balletto and HW Brown, American Electrip Power	Kammer Plant Demonstration Document for PL 92-500 Section 316(b)	1980	Yes	No	Only estimated total impingement counts were reported, with no mortality data. Traveling screens were not modified to include BTA features.	Yes	No	Only estimated total entrainment counts were reported from a single sampling point. Coarse mesh screens used.

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data: Pre-sent?	Impingement Data: Used?	Impingement Data: Reasons for Use/Non-Use	Entrainment Data: Pre-sent?	Entrainment Data: Used?	Entrainment Data: Reasons for Use/Non-Use
106	DCN 6-5037	Stone & Webster Engineering	Biological and Engineering Evaluation of a Fine-Mesh Screen Intake for Big Bend Station Unit 4	1980	Yes*	No	Interim report of data originating from a controlled study involving a prototype. While technology involved dual flow traveling screens with baskets and mortality data were reported at 0 and 48 hours post-impingement, the technology is not BTA. It is also not clear whether the 48-hour data correspond to the same organisms as evaluated at 0 hours.			No entrainment data
107	DCN 6-5046O	John Young, William Dey, Steven Jinks, Nancy Decker, Martin Daley, John Carnright	Evaluation of Variable Pumping Rates as a Means to Reduce Entrainment Mortalities	2003			No impingement data	Yes	No	Data for only one species reported. Coarse mesh screens used. No “front” data.
108	DCN 5-4409	Consumers Power Company	1991 Annual Report Describing Performance of Deterrent Net System at JR Whiting	1992	Yes*	No	No mortality data. Technology is not modified traveling screens.			No entrainment data
109	DCN 5-4418	Tennessee Valley Authority, Division of Water Resources	A Biological Evaluation of Fish Handling Components of a Water Intake Screen Designed to Protect Larval Fish	1979			No impingement data			No entrainment data
110	DCN 5-4305	New York Power Authority	Conditional Entrainment Mortality Rates for Seven Taxa of Fish at Water Intakes on the Hudson River	1998			No impingement data	Yes	No	Estimated mortality data only. No information reported on technology.
111	DCN 5-4411	Southern Energy California	Best Technology Available 1999 Technical Report for the Pittsburg and Contra Costa Power Plants	2000			No impingement data			No entrainment data
112	DCN 5-4336	California Departments of Fish and Game and Water Resources	A Fish Protection Facility for the Proposed Peripheral Canal	1981			No impingement data			No entrainment data
113	DCN 4-1326	American Electric Power	Philip Sporn Plant Demonstration Project for PL 92-500 Section 316(b)	1980	Yes	No	No mortality data. Technology is not modified traveling screens.	Yes	No	No fine mesh screens considered. No “front” data.
114	DCN 5-4306	Bay-Delta Fishery Project	Roaring River Slough Fish Screen Evaluation, 1984	1984			No impingement data	Yes	No	No information on screen size given.

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data: Pre-sent?	Impingement Data: Used?	Impingement Data: Reasons for Use/Non-Use	Entrainment Data: Pre-sent?	Entrainment Data: Used?	Entrainment Data: Reasons for Use/Non-Use
115	DCN 5-4008	Stephen B. Weisburg, William H. Burton, Eric A. Ross, Fred Jacobs	The Effects of Screen Slot Size, Screen Diameter, and Through-Slot Velocity on Entrainment of Estuarine Ichthyoplankton through Wedgewire Screens	1984			No impingement data	Yes*	Yes	Entrainment density data reported for samples collected from “behind” screens of various mesh sizes (1-3 mm) and from samples collected from an open port (“front”).
116	DCN 10-5491	HDR/LMS	Salem NJPDES Permit Renewal Application February 2006	2006			No impingement data			No entrainment data
118	DCN 10-5492	Edward Taft, Thomas Horst, and John Dowling - Stone and Webster Engineering Corporation	Biological Evaluation of a Fine-Mesh Traveling Screen for Protecting Organisms	1981	Yes*	No	Data originate from a controlled study involving a prototype. While technology involved dual flow traveling screens with baskets and mortality data were reported at 0 and 48 hours post-impingement, it is not clear whether the 48-hour data correspond to the same organisms as evaluated at 0 hours.			No entrainment data
119	DCN 10-5493	E. P. Taft - Stone and Webster Environmental Services	Evaluation of Strobe Lights for Fish Diversion at the York Haven Hydroelectric project	1992			No impingement data. (Technology focuses on avoidance/deterrence involving strobe lights, sound.)			No entrainment data
122 123	DCN 5-4404	Versar, Inc.	Evaluation of the 316 Status of Delaware Facilities with Cooling Water Discharges	1990			No impingement data			No entrainment data
124	DCN 6-5050	U.S. NRC, Office of Standards Development	U.S. Nuclear Regulatory Commission Regulatory Guide	1975			No impingement data			No entrainment data
125	DCN 4-1516	NJ DEP; Prepared by ESSA Technologies	Review of Portions of NJPDES Renewal Application for the PSE&G salem Generating Station	2000	Yes*	No	Non-BTA technology used (sound deterrent)			No entrainment data
126	DCN 6-5046E	David Baily, Jules Loos, Ann Wearmouth, Pat Langley, Elgin Perry	Effectiveness, Operation and Maintenance, and Costs of a Barrier Net System for Impingement Reduction at the Chalk Point Generating Station	2003	Yes*	No	No mortality data. Focus is on evaluating barrier net effectiveness.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
127	DCN 6-5046F	Steven M. Jinks, Nancy Decker, William Dey, John Young, Douglas Dixon	A Review of Impingement Survival Studies at Steam-Electric Power Stations	Unk.	Yes	No	Summary report. While some data are provided for Ristroph screens, holding time is either uncertain or 96 hours post-impingement.			No entrainment data
128	DCN 6-5043	David Bruzek, Selvakumaran Mahadevan, Mote Marine Laboratory	Fine Mesh Screen Survivability Study Big Bend Unit 4 Tampa Bay Electric Company	1986	Yes	No	Non-BTA technology (traveling screens not specified)			No entrainment data
129	DCN 6-5046D	Mark F. Strickland, James E. Mudge	Selection and Design of Wedge Wire Screens and a Fixed-Panel Aquatic Filter Barrier System to Reduce Impingement and Entrainment at a Cooling Water Intake Structure on the Hudson River	2003			No impingement data			No entrainment data
130	DCN 5-4361	J. Boreman, L.W. Barnthouse, D.S. Vaughan, C.P. Goodyear, S.W. Christensen, K.D. Kumar, B.L. Kirk, W. Van Winkle	The Impact of Entrainment and Impingement on Fish Populations in the Hudson River Estuary for Six Fish Populations Inhabiting the Hudson River Estuary	1982			No impingement data	Yes*	No	Focus is on entrainment mortality as estimated for several facilities. Technologies do not include fine-mesh screens.
131	DCN 5-4384	Dr. Y.G. Mussalli et al (Stone & Webster), M.P.McNamera et al (NUSCO)	Feasibility Study of Cooling Water System Alternatives to Reduce Winter Flounder Larval Entrainment at Millstone Units 1, 2, and 3	1993			No impingement data	Yes	No	Estimated counts only. Coarse mesh screens used. No "front" data. Data given for one species (winter flounder).
132	DCN 5-4358	Douglas Hjorth, Fred Winchell, John Downing, Don Cochran, Rose Perry (Stone & Webster)	Preliminary Assessment of Fish Entrainment at Hydropower Projects - A Report on Studies and Protective Measures	1995			No impingement data	Yes	No	Report on construction of a database containing data from multiple facilities. Entrainment rates are given (per unit time) at a high level. No information on technologies used was given and were not expected to include fine-mesh screens.
133	DCN 5-4386	Lawler Matusky & Skeller Engineers	Field Testing of Behavioral Barriers for Fish Exclusion at Cooling-Water Intake Systems	1988	Yes	No	No mortality data. Technology is non-BTA (various behavioral barriers).			No entrainment data
134	DCN 5-4399	Tenera Environmental Services	Moss Landing Power Plant Modernization Project 316(b) Resource Assessment	2000	Yes	No	Mortality considered only for 4 minutes holding time. Data given for one species (striped bass).	Yes	No	Coarse mesh screens used.

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
135	DCN 5-4400	Tenera Environmental Services	Diablo Canyon Power Plant 316(b) Demonstration Report	2000			While impingement is noted in the report, no impingement data are summarized in tables. Traveling screens were not modified.	Yes	No	Coarse mesh screens used.
136	DCN 5-4317	Lawler, Matusky & Skelly Engineers	Intake Debris Screen Postimpingement Survival Evaluation Study: Roseton Generating Station 1990 (Portion of Chapter 3 and selected tables from Chapter 5)	1991	Yes*	No	While impingement mortality was reported up to 48 hours post-impingement for dual-flow traveling screens with screen baskets, there is limited information to confirm that the fish return system is BTA.			No entrainment data
137	DCN 6-5016	Marine Resource Advisory Council	Effects of Power Plants on Hudson River Fish	2000			No impingement data			No entrainment data
138	DCN 6-5046H	Isabel C. Johnson and Steve Moser	Fish Return System Efficacy and Impingement Monitoring Studies for JEA's Northside Generating System	Unk.	Yes*	No	Impingement mortality data were reported either immediate (0 hr.) or "long term" (at least 72 hours) post-impingement.			No entrainment data
139	DCN 6-5046P	J R Nedwell, AWH Turnpenny, and D Lambert	Objective Design of Acoustic Fish Deterrent Systems	2003			No impingement data			No entrainment data
140	DCN 6-5046Q	E. P. Taft, Thomas C. Cook, Jonathan L. Black, Nathaniel Olkien	Fish Protection Technologies for Existing Cooling Water Intake Structures and their Costs	2003			No impingement data			No entrainment data
141	DCN 5-4363	R. H. Gray, T. L. Page, E. G. Wolf, M. J. Schneider (Batelle)	A Study of Fish Impingement and Screen Passage at Hanford Generation Project - A Progress Report	1975	Yes*	No	No impingement mortality data reported. Traveling screens are not modified.	Yes	No	Some limited "passage to behind screens" entrainment data were reported with impingement data, but no "front" data. Screens are coarse mesh.
142	DCN 5-4366	Thomas J. Edwards, William H. Hunt, Larry E. Miller, James J. Sevic	An Evaluation of the Impingement of Fishes at Four Duke Power Company Steam Generating Facilities	1976	Yes	No	No impingement mortality data reported. Traveling screens are not modified.			No entrainment data
143	DCN 5-4369	Stone & Webster Engineering Corporation	Final Report: Biological Evaluation of a Modified Traveling Screen Mystic Station - Unit No. 7	1981	Yes*	No	While some impingement mortality data were reported for modified traveling screens at 0 and 24 hours post-impingement, information was not sufficient to determine cumulative mortality by 24 hours. Some question on whether technology is BTA.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
144	DCN 5-4370	United Engineers & Constructors	Edgar Energy Park Clean Water Act Sections 316(a) & 316(b) Demonstration	1990			No impingement data	Yes	No	Estimated entrainment counts are based on samples taken from the water body. No "front" sample data were reported. Coarse mesh screens used.
145	DCN 5-4372	Florida Power & Light Company	Assessment of the Impacts of the St Lucie Nuclear Generating Plant on Sea Turtle Species Found in the Inshore Waters of Florida	1995			No impingement data. (Only turtle species were considered.)			No entrainment data
146	DCN 6-5057	American Society of Civil Engineers	Design of Water Intake Structures for Fish Protection	1982	Yes*	No	Impingement mortality data were accompanied by only limited information on technology used.			No entrainment data
147	DCN 5-4308	Ronald J. Decoto	1974 Evaluation of the Glenn-Colusa Irrigation District Fish Screen	1978			No impingement data (bypass data were reported instead).			No entrainment data
148	DCN 5-4309	Brian D. Quevlog	An Inventory of Selected Fish Screens in California	1981			No impingement data			No entrainment data
149	DCN 5-4310	Randall L. Brown, Dan B. Odenweller	A Fish Protection Facility for the Prposed Peripheral Canal	1981			No impingement data			No entrainment data
151	DCN 5-4315	AWH Turnpenny, PA Henderson	Design and Testing Specification for a Deterrent Bubble Barrier for Heysham Power Stations 1 & 2	1992			No impingement data			No entrainment data
152	DCN 5-4316	A W H Turnpenny, K P Thatcher, R Wood, P H Loeffelman	Experiments on the Use of Sound as a Fish Deterrent	1993			No impingement data			No entrainment data
153	DCN 10-5523	Tom M. Pankratz	Screening Equipment Handbook	1995			No impingement data			No entrainment data
154	DCN 10-5524	Stone & Webster Engineering Corporation	Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application	1986			No impingement data.			No entrainment data
155	DCN 10-5525	Malcolm E. Brown	Progress Report on Profile Wire Intake Screen Testing Forked River, New Jersey	1979			No impingement data.			No entrainment data
156	DCN 10-5526	Lawrence W. Smith, David E. Ferguson	Cleaning and Clogging Tests of Passive Screens in the Sacramento River, California	1979			No impingement data.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
157	DCN 10-5527	T. E. Crumlish	Extended Abstract - Engineering Aspects of Screen Testing on the St. Johns River, Palatka, Fla.	1979			No impingement data.			No entrainment data
158	DCN 10-5528	W. S. Lifton	Extended Abstract - Biological Aspects of the Screen Testing of the St Johns River, Palatka, Fla.	1979			No impingement data.			No entrainment data
159	DCN 10-5529	Brian N. Hanson	Studies of Three Cylindrical Profile-wire Screens Mounted Parallel to Flow Direction	1979			No impingement data	Yes	No	Laboratory study.
160	DCN 10-5530	James M. Wiersema, Dorothy Hogg, and Lowell J. Eck	Biofouling Studies in Gaslveston Bay - Biological Aspects - Abstract	1979			No impingement data.			No entrainment data
162	DCN 10-5531	R. W. Crippen	Impacts of Three Types of Power Generating Discharge Systems on Entrained Plankton	1977			No impingement data.			No entrainment data (only plankton considered in a controlled study).
163	DCN 10-5532	Lawrence R. King, Jay B. Hutchison Jr., Thomas G. Huggins	Impingement Survival Studies on White Perch, Striped Bass, and Atlantic Tomcod at Three Hudson River Power Plants	1977	Yes*	No	Only immediate and >48 hour post-impingement mortality reported.			No entrainment data
164	DCN 10-5533	Thomas R. Thathom, David L. Thomas, Gerald J. Miller	Survival of Fishes and Macroinvertibrates Impinged at Oyster Creek Generatiing Station	1977	Yes*	No	Traveling screens are not modified.			No entrainment data
165	DCN 10-5534	T. L. Page, D. A. Neitzel, R. H. Gray	Comparative Fish Impingement at Two Adjacent Water Intakes on the Mid-Columbia River	1977	Yes	No	Traveling screens are not modified.			No entrainment data
166	DCN 10-5535	Yusuf G. Mussalli, Edward P. Taft, Peter Hoffman	Engineering Implications of New Fish Screening Concepts	1977			No impingement data.			No entrainment data
167	DCN 10-5536	Brian N. Hanson, Wiliam H. Bason, Barry E. Beitz, Kevin E. Charles	A Practical Intake Screen which Substantially Reduces the Entrainment and Impingementof Early Life Stages of Fish	1977	Yes	No	Laboratory study	Yes*	No	Laboratory study

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
168	DCN 5-4379	L.S. Murray and T.S. Jinnette	Survival of Dominant Estuarine Organisms Impinged on Fine-Mesh Traveling Screens at the Barney M. Davis Power Station	1977	Yes*	No	While impingement mortality was documented for Passavant center-flow traveling screens that feature screening baskets for retaining screened material, only immediate mortality was observed (for up to 10-15 minutes post-impingement).			No entrainment data
169 206-A	DCN 5-4379	D.A. Tomljanovich, J.H. Heuer, and C.W. Voigtlander	Investigations on the Protection of Fish Larvae at Water Intakes Using Fine-Mesh Screening	1977	Yes*	No	While percent impingement mortality was documented, this is a laboratory study that did not involve evaluation of modified traveling screens.	Yes	No	Laboratory study. "Retained" data are reported, implying that entrainment data may be combined with impingement data.
170	DCN 5-4379	J.H. Heuer and D.A. Tomljanovich	A Study on the Protection of Fish Larvae at Water Intakes Using Wedge-Wire Screens	1987			Laboratory study. "Bypassed" data are reported rather than impingement data.			Laboratory study. "Bypassed" (avoidance) data are reported rather than entrainment data.
171	DCN 5-4379	B.N. Hanson, W.H. Bason, B.E. Beitz, and K.E. Charles	Practicality of Profile-Wire Screen in Reducing Entrainment and Impingement	1977	Yes*	No	Laboratory study.	Yes	No	Laboratory study
173	DCN 5-4350	EA Science and Technology	Results of entrainment and impingement monitoring studies at the Westchester RESCO facility, Peekskill, New York	1987	Yes	No	Only percentages of impinged data represented by certain species, and total fish impinged, were reported. No impingement mortality reported.	Yes	No	Only percentages of entrained data represented by certain species, and total fish entrained, were reported. No "front" data reported.
174	DCN 7-4561	Acres International Corporation	Report on fish entrainment study: November 1993 to November 1994, Glens Falls	1995			No impingement data	Yes	No	Use of behavioral systems with no clear information given on screen mesh size. Data originate from a controlled study and report entrainment mortality.
175	DCN 7-4530	Dames and Moore	Seminole Plant Units 1&2 316b Study Report	1979	Yes	No	Technology involved fixed screens rather than traveling screens. No impingement mortality data reported.	Yes*	Yes	Estimated numbers of entrainable fish reported behind 1 and 2 mm mesh screens, and through open pipe ("front").
176	DCN 10-5544	Alliant Energy	Final Environmental Impact Statement: Ottumwa Generating Station	1978			No impingement data.			No entrainment data
177	DCN 10-5545	B.D. Giese and K.N. Mueller	Section III Prairie Island Nuclear Generating Plant Environmental Monitoring Report - 2002 Annual Report	2002	Yes	No	No impingement mortality data. Traveling screens are not modified.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
178	DCN 10-5546	Tennessee Valley Authority	Biological Effects of Intake Browns Ferry Nuclear Vol 1 Summary of the Evaluation of the Browns Ferry Nuclear Plant Intake Structure	1978			No impingement data.			No entrainment data
179 180	DCN 10-5547	Tennessee Valley Authority	316(a) and 316(b) Demonstration Cumberland Steam Plant - Volume 5	1977			No impingement data	Yes*	No	Coarse mesh size screens used.
181	DCN 10-5548	Tennessee Valley Authority	316(a) and 316)b) Demonstration: John Sevier Steam Plant	1977			No impingement data	Yes	No	No information on screen mesh size.
182	DCN 8-4501	Normandeau Associates, Inc.	Impingement and Entrainment at the Cooling Water Intake Structure of the Delaware City Refinery, April 1998-March 2000	2000	Yes	No	No impingement mortality data. Traveling screens are not modified.	Yes	No	Coarse mesh size screens. No “front” density data reported.
183	DCN 10-5550	Industrial Bio-Test Laboratories, Inc.	A Baseline/Predictive Environmental Investigation of Lake Wylie	1974			No impingement data.			No entrainment data that corresponds to organism densities. No information on screen mesh size.
184	DCN 8-4513	Carolina Power & Light Company	Brunswick Steam Electric Plant Cape Fear Studies Interpretive Report	1985	Yes	No	Impingement mortality measured at 0 and 96 hours post-impingement only. Traveling screen technology not modified.	Yes*	Yes	Densities of organisms entrained through 1 mm screens (“behind”) and 9.5 mm screens (“front”).
185	DCN 7-4507	Wisconsin Electric Power Company	Oak Creek Power Plant Final Report Intake Monitoring Studies	1976	Yes	No	No impingement mortality data. Traveling screens are not modified.	Yes	No	Coarse mesh size screens. Only total entrainment estimates reported.
186	DCN 7-4508	Wisconsin Electric Power Company	Port Washington Power Plant Final Report Intake Monitoring Studies	1976	Yes	No	No impingement mortality data. Traveling screens are not modified.	Yes	No	Coarse mesh size screens. Only total entrainment estimates reported.
187	DCN 10-5554	Delmarva Power & Light Company	Vienna Power Station Prediction of Aquatic Impacts of the Proposed Cooling Water Intake A Section 316(b) Demonstration	1982			No impingement data.	Yes*	No	While “front” and “behind” sample data are available for fine-mesh screens, intersample contamination between screened and unscreened samples prevented their use.
188	DCN 7-4512	Applied Biology, Inc.	Impingement Monitoring Program South Carolina Public Service Authority Winyah Plant Final Report	1977	Yes	No	No impingement mortality data. Traveling screens are not modified.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
189	DCN 7-4513	Geo-Marine, Inc.	316b Demonstration Report for the Arkansas Eastman Plant on the White River	1981			No impingement count or mortality data reported. Limited information is given on technology used.	Yes	No	No information given on mesh size of traveling screens (expected to be coarse mesh). “Behind” entrainment data collected only.
190	DCN 10-5557	Equitable Environmental Health, Inc.	Meramec Power Plant Entrainment and Impingement Effects on Biological Populations of the Mississippi River	1976	Yes	No	No impingement mortality data. Traveling screens are not modified.	Yes	No	Coarse mesh size only. Entrainment data did not include eggs or larvae.
191	DCN 10-6806	EPRI	Field evaluation of wedgewire screens for protecting early life stages at cooling water intake structures: Chesapeake Bay studies	2006			No impingement data	Yes*	Yes	Source of “front” and “behind” entrainment density data from test barge in the Chesapeake Bay, which were used in determining the proposed entrainment design standard.
192	DCN 10-6801	EPRI	Laboratory evaluation of modified Ristroph traveling screens for protecting fish at cooling water intakes	2006	Yes*	No	Laboratory study			No entrainment data
193 201	DCN 10-6813	EPRI	Fish Protection at Cooling Water Intake Structures: A Technical Reference Manual	2007	Yes*	Yes	This is a summary report of data from multiple studies. Chapter 2 contains impingement data, some of which originate from other reviewed reports. Data appear from Dunkirk and Huntley that were utilized in the impingement mortality limitations. Impingement mortality data from other sources were not used due to non-BTA technology or corresponding to 0 or >48 hours post-impingement.	Yes*	Yes	This is a summary report of data from multiple studies. Chapter 5 contains entrainment data from wedgewire screens. This report was the source of “front” and “behind” entrainment density data from test barge studies in the Portage and Sakkonet Rivers and from Oyster Creek, which were used in determining the proposed entrainment design standard. Other entrainment data were not used due to not reporting results for both “front” and “behind” samples.
194	DCN 10-6804	EPRI	Design considerations and specifications for fish barrier net deployment at cooling water intake structures	2006			No impingement data.			No entrainment data
195	DCN 10-6802	EPRI	Laboratory evaluation of fine-mesh traveling water screens for protecting early life stages of fish at cooling water intakes	2008	Yes*	No	Laboratory study			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
196	DCN 10-6814	EPRI	Latent impingement mortality assessment of the Geiger Multi-Disc screening system at Potomac River Generating Station	2007	Yes*	No	Technology not classified as BTA. Concern about data quality (influence of weather events).			No entrainment data
197	DCN 10-6970	EPRI	The role of temperature and nutritional status in impingement of clupeid fish species	2008			No impingement data.			No entrainment data
198	DCN 10-6971	EPRI	Cooling Water Intake Structure Area-of-Influence Evaluations for Ohio River Ecological Research Program Facilities	2007			No impingement data.			No entrainment data
199	DCN 4-1682	Robert W. Davis, John A. Matousek, Michael J. Skelly, and Milton R. Anderson	Biological Evaluation of Brayton Point Station Unit 4, Angled Screen Intake	1988	Yes	No	Although impingement mortality is reported at 48 hours post-impingement and the technology is referred to as “modified intake screens,” fish are removed from screens using spraywash into a fish trough.			No entrainment data
200	DCN 10-5567	Applied Science Associates	Ichthyoplankton Monitoring Study Deployment of a Gunderboom System at Lovett Generating Station Unit 3, 1998	1999			No impingement data.	Yes	No	Used Gunderboom system rather than fine mesh screen technology. (Same data found in other Gunderboom reports.)
202	DCN 10-5568	S.L. Blanton, D.A. Neitzel, and C.S. Abernethy	Washington Phase II Fish Diversion Screen Evaluations in the Yakima River Basin, 1997	1998			No impingement data. Non-BTA screen technology used to promote fish diversion.			No entrainment data
203	DCN 10-5569	W. Bengeyfield	Evaluation of a Temporary Screen to Divert Fish at Puntledge Generating Station	1992			No impingement data. Evaluation of temporary barrier net.			No entrainment data
204	DCN 10-5570	M.D. Bowen, S.M. Siegfried, C.R. Liston, A.J. Hess and C.A. Karp	Fish Collections and Secondary Louver Efficiency at the Tracy Fish Collection Facility	1998			No impingement data.			No entrainment data
205	DCN 10-5571	D.L.Breitburg and T.A.Thoman	Calvert Cliffs Nuclear Power Plant Finfish Survival Study	1986	Yes*	No	Assessed technologies included dual-speed, Beauderey, and control traveling screens. Impingement mortality data appear to represent only immediate post-impingement.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data Pre-sent?	Impingement Data Used?	Impingement Data Reasons for Use/Non-Use	Entrainment Data Pre-sent?	Entrainment Data Used?	Entrainment Data Reasons for Use/Non-Use
206	DCN 10-5572	V. Brueggemeyer, D.Cowdrick, K. Durrell, S. Mahadevan and D. Bruzek	Full-scale Operational Demonstration of Fine Mesh Screens at Power Plant Intakes	1998	Yes*	No	Mortality data are reported only immediately following impingement. Technology does not appear to be BTA.			No entrainment data (focus was on engineering evaluations of screening efficiencies)
207	DCN 10-5573	Beak Consultants Incorporated	Dunkirk Station Biological Studies	1988	Yes*	No	Impingement mortality data correspond to Beauderey traveling screens with no fish return system, and reported only at 0 and 96 hours post-impingement.	Yes	No	Densities of organisms that would pass through 3.2 mm mesh size screens were estimated from samples collected upstream of the screens. No densities representing the "front" of intake were reported.
208	DCN 10-5574	Carolina Power and Light Company	Brunswick Steam Electric Plant: 1984 Biological Monitoring Report	1985	Yes*	No	Traveling screen technology not modified.	Yes	Yes	Densities of organisms entrained through 1 mm screens ("behind") and 9.5 mm screens ("front").
210	DCN 7-4504	NALCO Environmental Sciences	Dean H Mitchell Station 316(b) Demonstration	1976	Yes	No	Impingement mortality not reported. Traveling screen technology not modified.	Yes	No	Coarse mesh screens used. Only "behind" sample data reported.
211	DCN 9-4664	Wapora Inc	Studies of screen impingement and egg and fry entrainment at the Joppa Illinois Electric Generating Station	1976	Yes	No	Impingement mortality not reported. Traveling screen technology not modified.	Yes	No	No information given on screen mesh size.
212	DCN 10-5577	Hugh Barwick	Fish Impingement at Oconee Nuclear Station	1990	Yes	No	Impingement mortality not reported. Modified traveling screens not used.			No entrainment data
213	DCN 10-5578	J. P. Buchanan, D.L. Dycus, H.R. Gwinner, and J.M. Roberts, Jr.	Aquatic Environmental Conditions in Chickamauga Reservoir During Operation of Sequoyah Nuclear Plant, Sixth Annual Report	1987			No impingement data.			No entrainment data
214	DCN 10-5579	Stone and Webster Engineering Corporation, Boston, MA	Studies to Alleviate Potential Fish Entrapment Problems (Volume 1 of 2)	1977			No impingement data associated with field studies.			No entrainment data
215	DCN 7-4511	Wapora	316 (a) and (b) Studies on the Grand River	1977	Yes	No	No impingement mortality data reported. No information given on technology used at the specified plants.	Yes	No	Fish counts obtained only from samples collected in front of the intakes and estimated to be entrained. No information given on technology used at the specified plants.

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data: Pre-sent?	Impingement Data: Used?	Impingement Data: Reasons for Use/Non-Use	Entrainment Data: Pre-sent?	Entrainment Data: Used?	Entrainment Data: Reasons for Use/Non-Use
216	DCN 7-0009	Tetra Tech	Small facility ichthyoplankton entrainment sampling for the development of the 316(b) Phase III Rule for cooling water intake structures	2004			No impingement data.	Yes	No	Entrainment densities reported for several sites at the nearfield ("front") and within the intake prior to the intake pumps ("behind") , but no information is given on technology (e.g., screen size).
217	DCN 7-4520	Western Illinois Power Cooperative	Fish impingement studies at Pearl Station--February 1977-January 1978	1978	Yes	No	Impingement mortality was not assessed. No information given on the technology used.			No entrainment data
218	DCN 7-4505	Foster Wheeler Environmental Corporation	Comanche Peak Steam Electric Station Units 1 and 2 316 (b) Demonstration	1995	Yes	No	Traveling screens are not modified. No impingement mortality results reported.	Yes	No	Coarse mesh screens were utilized. While "front" samples appeared to have been collected, their data were not summarized.
219	DCN 7-4516	Carolina Power and Light	HB Robinson Steam Electric Plant 316 Demonstration Study	1976	Yes	No	Traveling screens are not modified. No impingement mortality results reported.	Yes	No	Coarse mesh screens were utilized. No "front" samples reported.
220	DCN 7-4557	EA Science	Bayway Refinery impingement and entrainment study for 316(b) of the Clean Water Act	1995	Yes	No	Traveling screens are not modified. No impingement mortality results reported.	Yes	No	Coarse mesh screens were utilized. No "front" samples reported.
221	DCN 10-5586	Alden Rsearch Laboratory and Stone & Webster Engineering Corporation	Laboratory Evaluation of Fish Protective Devices at Intakes	1981			No impingement data. Several technologies were evaluated under laboratory conditions, including fish diversion and bypass, and behavioral barriers, but not modified traveling screens. For angled screens, mortality associated with diversion was reported only at 96 hours.			No entrainment data
200-A	DCN 10-5587	Stone & Webster Engineering Corporation	Alternative Intake Designs for Reducing Fish Losses, Mystic Station - Unit 7	1979	Yes	No	While this report documents the findings of several studies assessing impingement mortality associated with modified traveling screens, mortality was assessed either at impingement (or within 15 minutes of impingement) or >48 hours post-impingement in each case.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
201-A	DCN 10-5588	Donald E. Clark and Douglas P. Cramer	Evaluation of the Downstream Migrant Bypass System - T.W. Sullivan Plant, Willamette Falls	1993			No impingement data – mortality data (>48 hour holding time) were associated with negotiating a downstream migrant bypass system rather than screen impingement.			No entrainment data
202-A	DCN 10-5589	D.P. Cramer	Evaluation of a Louver Guidance System and Eicher Screen for Fish Protection at the T.W. Sullivan Plant in Oregon	1997			No impingement data – 48-hour mortality data were associated with negotiating a downstream migrant bypass system rather than screen impingement.			No entrainment data
203-A	DCN 10-5590	P.M Cumbie and J.B. Banks	Protection of Aquatic Life in Design and Operation of the Cope Station Water Intake and Discharge Structures	1997			No impingement data.			No entrainment data
204-A	DCN 10-5591	Stone & Webster Environmental Services	Proposal for Services to Perform 1992 Blueback Herring Environmetnal Studies at the Little Falls Hydroelectric Project, Little Falls, New York	1991			No impingement data.			No entrainment data
205-A	DCN 10-5592	Texas Instruments Incorporated	Initial and Extended Survival of Fish Collected from a Fine Mesh Continuously Operating Traveling Screen at the Indain Point Generating Station	1978	Yes	No	While percent impingement mortality associated with Ristroph traveling screens are reported, more information is needed to determine cumulative mortality at a certain point (e.g., 36 hours) post-impingement.			No entrainment data
207-A	DCN 10-5593	Larry E. Week, Victor C. Bird, and R. Eugene Geary	Effects of Passing Juvenile Steelhead, Chinook Salmon, and Coho Salmon Through an Archimedes' Screw Pump	1989			No impingement data. This report documents the outcome of controlled experiments of screw pump pass-through.			No entrainment data
208-A	DCN 10-5594	Michael Wert	Hydraulic Model Evaluation of the Eicher Passive Pressure Screen Fish Bypass System	1988	Yes	No	Laboratory study of Eicher screens rather than modified traveling screens. Impingement mortality evaluated at 72 hours post-impingement only.			No entrainment data
209-A	DCN 10-5595	Fred Winchell, Ned Taft, Tom Cook and Charles Sullivan	Research Update on the Eicher Screen at Elwha Dam	1993			"Passage survival" after 96 hours was reported rather than screen impingement survival or mortality.			No entrainment data

Exhibit 11A-1: (Continued)

ID	DCN	Authors	Title	Date[a]	Impingement Data			Entrainment Data		
					Pre-sent?	Used?	Reasons for Use/Non-Use	Pre-sent?	Used?	Reasons for Use/Non-Use
210-A	DCN 10-5596	Thomas Plante, Michael Feldhausen, Dennis Olsen and David Michaud	Maintenance Requirements of a Fish Barrier Net System	1997			No impingement data. Focus was on assessing the functionality and performance (biofouling) of a prototype barrier net system.			No entrainment data
	DCN 6-5004B	EPRI	Laboratory Evaluation of Wedgewire Screens for Protecting Early Life Stages of Fish at Cooling Water Intakes	2003	Yes	No	Laboratory study. No impingement mortality data reported.	Yes	No	Laboratory study

* Some of the impingement or entrainment data reported in this document (counts and/or mortality percentages) were entered in EPA's performance study database and were summarized within a meta-analysis.

[a] Unknown (not specified).

Exhibit 11A-2: List of Documents and Facilities with Impingement Mortality Data (counts and/or percentages) in EPA's Performance Study Database

Document ID	Facility Name	# Hours Following Impingement Associated with Entered Mortality Data
17	Hinkley Point Power Station	0
18	Moss Landing	0, 96
38	Bowline Point Generating Station	0
43	Barney Davis Power Station	0
43	Surry Power Station	0
44	Dunkirk Steam Station	0, 24
46	Brayton Point Generating Station Unit 4	0, 48
46	Calvert Cliffs Nuclear Generating Station	0
46	Dunkirk Steam Station	0
46	Indian Point Generating Station	0
49	Chalk Point Generating Station	0
51	Huntley Steam Station	0, 24
54	Arthur Kill Generating Station	24
60	Quad Cities Generating Station	0
62	Oyster Creek Nuclear Generating Station	0
64	Somerset Generating Station	0, 96
65	Calvert Cliffs Nuclear Generating Station	0
66	Calvert Cliffs Nuclear Generating Station	0
73	Le Blayais	0
76	Heysham Power Station	0
78	Sizewell A and B	0
78	Various Coastal Stations in the U.K.	0
85	Salem Generating Station	48
103	Monroe Power Plant	0
106	Big Bend Power Station	0
108	JR Whiting	0
118	Big Bend Power Station	0, 48, 96
125	Salem Generating Station	0
126	Chalk Point Generating Station	0
136	Roseton Generating Station	0
138	JEA Northside Generating System	0
138	Roseton Generating Station	0
141	Hanford Generating Project	0
143	Mystic Generating Station	0, 24, 96
146	No facility specified	0
163	Bowline Point Generating Station	0, 96
163	Roseton Generating Station	0
164	Oyster Creek Nuclear Generating Station	0
168	Barney Davis Power Station	0
169	TVA laboratory	0, 12, 24, 48
171	Test laboratory	0
192	Test laboratory	0, 48
193	Arthur Kill Generating Station	24
193	Bowline Point Generating Station	0, 96
193	Brayton Point Generating Station Unit 4	0, 48

Exhibit 11A-2: (Continued)

Document ID	Facility Name	# Hours Following Impingement Associated with Entered Mortality Data
193	Brunswick Steam Electric Plant	0
193	Danskammer Point Generating Station	0, 84
193	Dunkirk Steam Station	0
193	Indian Point Generating Station	0, 96
193	Mystic Generating Station	0, 96
193	Oswego Steam Station	0
193	Oyster Creek Nuclear Generating Station	0
193	Prairie Island Nuclear Generating Station	0
193	Salem Generating Station	0, 18
195	Test laboratory	0
196	Potomac River	48
205	Calvert Cliffs Nuclear Generating Station	0
206	Big Bend Power Station	0
207	Dunkirk Steam Station	0, 8, 24
208	Brunswick Steam Electric Plant	0

Note: Documents are identified by their ID number in Exhibit 11A-1.

Exhibit 11A-3: List of Documents and Facilities with Entrainment Density Data (“front” and “behind”) in EPA’s Performance Study Database

Document ID	Facility Name
52	Big Bend Power Station
84	Logan Generating Plant
115	Test barge (Chalk Point)
175	Test barge (St. John's River)
180	Cumberland Steam Plant
184	Brunswick Steam Electric Plant
187	Vienna Power Station
191	Test barge (Chesapeake Bay)
193	Test barge (Oyster Creek)
193	Test barge (Portage River)
193	Test barge (Sakkonet River)

Note: Documents are identified by their ID number in Exhibit 11A-1.

Exhibit 11A-4: List of Documents and Facilities with Entrainment Mortality Data (counts and/or percentages) in EPA's Performance Study Database

Document ID	Facility Name	# Hours Following Entrainment Associated with Entered Mortality Data
4	Anclote Power Plant	0
18	Potrero Power Plant	0, 96
40	Lovett Generating Station	0
41	Lovett Generating Station	0
47	Green Island Hydroelectric Project	0, 24, 48
49	Chalk Point Generating Station	0
49	Dickerson	0
49	Morgantown	0
49	Potomac River	0
81	Pine Hydroelectric Project	0
130	Bowline Point Generating Station	0, 24
130	Danskammer Point Generating Station	0, 24
130	Indian Point Generating Station	0, 24
130	Lovett Generating Station	0, 24
130	Multiple test facilities	24
130	Roseton Generating Station	0, 24
167	Delmarva Ecological Laboratory	0
193	Tracy Fish Collecting Facility	0

Note: Documents are identified by their ID number in Exhibit 11A-1.

Appendix B to Chapter 11: Summaries and Analyses of Data from Published Documents to Assess the Performance of Technologies to Reduce the Impact of Impingement or Entrainment on Aquatic Life Under Section 316(b) of the Clean Water Act

11B.0 Introduction

This appendix provides initial summaries and analyses of data obtained from 66 technical reports and publications which document the performance of selected technologies utilized by facilities such as power plants to reduce the adverse environmental impact associated with operating cooling water intake structures. Of particular interest was the impact of impingement and entrainment on the viability of fish life within different age categories. EPA reviewed documents containing data on impingement and entrainment and placed data into a “performance study database” that reported percentages of fish killed, injured, or survived (or experienced some other positive outcome, such as diversion). A focus was placed on percentage data as they were most likely to be directly comparable among different documents and studies and thus could be combined for statistical analysis. When counts of fish accompanied these percentages within the documents, or if counts were reported from which percentages could be calculated, then EPA also entered these counts into the database.

This appendix presents a series of summaries of the performance data entered within EPA’s performance study database. These summaries are presented by technology category, type of measure (e.g., percent mortality, mortality counts, percentage change from baseline in mortality counts or percentage), and data classification (e.g., impingement, entrainment). For a given study, data values are entered for various species and time points. Therefore, the number of values entering into a particular data summary depends on the number of documents with relevant data and the number of species and time points for which data are reported within these documents. For percentage and count measures, Exhibit 11B-1 presents impingement and entrainment data summaries for those technologies having the most data within the database (i.e., when the number of data points exceeded 20). Key conclusions made from this exhibit include the following:

- Only a small number of studies have available performance data that are expressed as biomass or injury, and the amount of data within these studies is generally limited.
- Most data related to mortality and survival (or other positive outcomes) are associated with impingement on traveling screens. Across species, time points, and studies, percent mortality data were observed to cover the range of 0 to 100 percent among the technology categories, especially for impingement.
- Similar patterns in percent mortality following impingement are seen between fine mesh and coarse mesh traveling screens.

- When percent mortality data were available at different elapsed times following impingement, a general increase in average percent mortality was observed as the amount of time between impingement and observation increased. However, such trends are hard to discern when reviewing these data summaries due to the data being represented by different studies and test conditions.
- Percent mortality following entrainment tended to cover similar ranges among the two technology categories in Exhibit 11B-1 having the most entrainment data.

Exhibit 11B-1. Data Summaries on Performance Measures With the Most Impingement and Entrainment Data Values Within EPA's Performance Study Database

Technology Category	Mortality Obs. Time	N	Mean	Std. Dev.	Min.	Max.	Percentiles 25th	50th	75th	95th
Percent Mortality: Entrainment										
Reduced Intake Flows - Other	0 hr.	177	27.9	23.3	0.0	88.4	7.4	24.9	42.6	76.0
Traveling Screen - Coarse Mesh	0 hr.	115	4.1	9.7	0.1	83.9	0.5	1.3	3.3	20.3
	24 hr.	133	6.3	11.4	0.1	77.8	0.7	2.0	5.7	25.4
Percent Mortality: Impingement										
Barriers	0 hr.	21	71.1	35.7	1.3	98.7	54.9	91.9	97.7	98.7
Fixed Screen - Fine Mesh	0 hr.	38	23.7	27.6	0.0	91.8	0.8	10.5	44.9	81.1
	24 hr.	40	43.0	38.3	0.0	100.0	4.0	32.2	84.9	100.0
Traveling Screen - Coarse Mesh	0 hr.	684	26.4	33.4	0.0	100.0	0.0	9.2	45.4	100.0
	18 hr.	26	31.7	25.4	2.0	82.0	12.0	26.5	42.0	80.0
	24 hr.	233	16.0	28.5	0.0	100.0	0.0	1.4	16.8	100.0
	48 hr.	34	23.9	37.0	0.0	100.0	0.0	0.0	45.7	100.0
	96 hr.	91	52.7	38.3	0.0	100.0	16.7	50.0	100.0	100.0
Traveling Screen - Fine Mesh	0 hr.	373	25.5	32.9	0.0	100.0	0.0	8.0	43.2	98.5
	8 hr.	67	22.4	32.5	0.0	100.0	0.0	4.9	30.3	100.0
	24 hr.	67	28.6	34.9	0.0	100.0	0.0	12.6	50.0	100.0
	48 hr.	82	17.7	30.2	0.0	100.0	1.0	3.9	15.9	96.8
	96 hr.	70	37.4	35.8	0.0	100.0	5.1	26.4	63.6	100.0
Percent Biomass: Impingement										
Traveling Screen - Coarse Mesh	--	48	1.4	2.6	0.0	12.8	0.1	0.3	1.2	7.6
Percent Injury: Impingement										
Traveling Screen - Coarse Mesh	--	20	28.1	15.9	5.0	64.0	12.5	28.5	38.5	57.0
Traveling Screen - Fine Mesh	--	30	7.3	9.9	0.0	34.0	0.4	2.9	9.5	29.8
Mortality Counts: Impingement										
Traveling Screen - Coarse Mesh	0 hr.	478	15596	122127	0	2229859	0	3	50	8985
	24 hr.	130	26	95	0	866	0	0	3	111
	96 hr.	58	26	114	0	848	1	3	10	77
Traveling Screen - Fine Mesh	0 hr.	125	20850	81984	0	521500	4	31	753	113280
Survival Counts: Impingement										
Fixed Screen - Fine Mesh	24 hr.	30	34	68	0	342	1	9	35	134
Traveling Screen - Coarse Mesh	0 hr.	386	388	1329	0	17719	2	17	176	2383
	24 hr.	233	170	582	0	5948	2	8	48	875
	96 hr.	63	120	376	0	2253	1	5	45	420
Traveling Screen - Fine Mesh	0 hr.	158	2344712	12842622	0	110000000	7	29	296	11000000
	8 hr.	67	37	83	0	395	1	6	22	237
	24 hr.	67	30	67	0	365	1	5	20	213

- For percent injury following impingement under traveling screen technologies, coarse mesh screens tended to have higher injury rate than fine mesh screens.
- Mortality and survival counts are highly variable, as these counts are likely to vary considerably across species, seasons of the year, water temperature, etc. For these reasons, counts may not be directly comparable among different studies.

Percent mortality data were statistically analyzed using mixed model analysis of variance techniques, with the goal of estimating average performance measure when possible for selected age categories, seasons of the year, and elapsed times to mortality. This analysis was applied to percent mortality data for the following technologies (as determined by available data):

- Percent mortality following entrainment: fixed screen (fine mesh) and reduced intake flow (other).
- Percent mortality following impingement: traveling screens (both fine and coarse mesh).

Key findings from the statistical modeling analysis were as follows:

- Among early age categories (e.g., larvae, juvenile), the model-based estimates for average percent mortality following entrainment under reduced intake flow technology ranged from 27 to 34 percent. These averages did not differ significantly at the 0.05 level.
- For impinged fish under traveling screens with either fine or coarse mesh, estimated average percent mortality was highest in summer months, with over 50 percent mortality estimated in summer. Under fine mesh, estimated average percent mortality also exceeded 50 percent in spring months. Differences between seasons of the year, age categories, and elapsed time to mortality were statistically significant at the 0.05 level.

11B.1 BACKGROUND AND OBJECTIVES

More than 1,500 industrial facilities in the United States, including steam electric power plants, use large volumes of cooling water from lakes, rivers, estuaries or oceans to cool their plants. Cooling water intake structures cause adverse environmental impact by pulling large numbers of fish and shellfish or their eggs into the facility's cooling system ("entrainment"). As a result, the organisms may be killed or injured by heat, physical stress, or by chemicals used to clean the cooling system. Larger organisms may be killed or injured by becoming trapped against screens at the front of an intake structure ("impingement").

Section 316(b) of the Clean Water Act requires that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact such as mortality of aquatic organisms. To minimize impingement and entrainment, facilities subject to Section 316(b) regulations have implemented a range of different technologies. As part of the permitting process to discharge cooling water, these facilities have collected data to demonstrate that they are using best technology available to minimize impingement and entrainment and issued documents containing the results of these studies. Other organizations have issued publications on the outcome of controlled laboratory studies to identify key factors that impact technology performance and to determine settings for these factors that are associated with improved performance.

In its Section 316(b) rule development effort, the U.S. Environmental Protection Agency (EPA) gathered a series of industry documents and research publications that contain information from studies which evaluated the performance of a range of technologies for minimizing impingement or entrainment. In gathering this information, EPA's objective was to review the methods used to generate data in these studies and to combine relevant data across studies in order to produce reasonably valid statistical estimates of the overall performance of each of the technologies.

This appendix contains statistical summaries of performance data compiled across several reports and publications that EPA has collected, along with the results of statistical analyses performed on these data. The primary objective of this analysis was to characterize the distribution of data across studies and facilities, in order to better assess the performance of different technology categories relative to their ability to minimize impingement and entrainment of aquatic organisms.

11B.2 DOCUMENT REVIEW AND DATA ENTRY

11B.2.1 Document receipt

For assessing performance for various technology categories, EPA considered data from over 170 documents (See Appendix 11A). These documents contain information on the operation and/or performance of various forms and applications of these technologies, typically at a specific facility or in a controlled setting such as a research laboratory. The studies presented in these documents were performed by owners of facilities with cooling water intake structures, organizations that represent utilities and the electric power industry, and other research organizations. In bringing information from these documents together to better assess performance, EPA obtained and reviewed these documents for the presence of relevant data. Within the review process, EPA prepared a Microsoft (MS) Access database which contained information on the following:

- The document (e.g., title, author, funding source, type of document);
- The facility(ies) represented in a document (with location, water body type, etc.); and
- The type (category) of technology implemented at each facility within a document.

11B.2.2 Classifying data by technology category

When performance data for a given facility were obtained from a given document and used in the statistical summaries and analyses, EPA determined the technology category assigned to that data by information specified in its database of facility information ("facility database") which it compiled from other data sources such as a dataset of questionnaire responses. Fourteen possible technology categories were defined:

- Barriers (nets, micronets, Gunderboom, bars, canal diversions)
- Behavioral systems I (louvers, angled screens)
- Behavioral systems II (e.g., acoustic/sound, light, air bubbles)
- Fixed screens (coarse mesh)
- Fixed screens (fine mesh)
- Off-shore location with velocity cap
- Off-shore location (any combination other than velocity cap)
- Porous dikes, perforated pipe, substratum intakes
- Reduced intake flows - cooling towers
- Reduced intake flows - other (variable speed pumps, seasonal flows reductions, reduced plant power output)
- Traveling screens (coarse mesh)
- Traveling screens (fine mesh)
- Velocity limit (additional screens, reduced intake velocity, T-bend)
- Other technologies.

The statistical summaries and analyses presented in this appendix focused on technology categories having the most available data. These included fixed and traveling screens, barriers, and behavioral systems II. While data for other technologies also existed in the performance study database, the number of documents (or distinct studies[1] within these documents) and the amount of data was very limited, if any were encountered at all. EPA's facility database was also the source of information on a facility's name, water body (e.g., river, lake/reservoir, Great Lakes, ocean, estuary), and location (state).

11B.2.3 Data acceptance criteria

While a document may present data that were acceptable for use in meeting the document's original objectives, this does not necessarily imply that these data will meet EPA's objective to combine data across multiple sources to better access performance of the different technology categories. Thus, it was necessary to establish specific criteria for accepting data from the documents for use in the statistical summaries and analyses in this appendix. These acceptance criteria were as follows:

- The data must be associated with technologies for minimizing impingement or entrainment that are currently viable (as recognized by EPA) for use by industries with cooling water intake structures that are (or will be) subject to Section 316(b) regulation.

[1] In our analysis, we use the term "study" to refer to the collection of performance data within a given set of testing conditions. A document can report performance data for one or more studies.

- They must represent a quantitative measure (e.g., counts or percentages) that is related to the impingement or entrainment of some life form of aquatic organisms within cooling water intake structures under the given technology.
- The measure must be reported in one of two ways:
  - On a "per available organism" basis (typically in percentage terms); or
  - Accompanied by the same type of measure taken for the same species under baseline or control conditions (i.e., in the absence of the given technology).

The last criterion was necessary to help ensure that data would be comparable when combined across different studies and documents. Only data meeting these criteria were considered for inclusion within the statistical summaries and analyses in this appendix.

11B.2.4 Document review process

Reviewers of the documents had a variety of scientific backgrounds (e.g., statistics, environmental science, chemistry, biology) and prior experience in extracting data from technical reports and publications for statistical analysis. They were trained on the objectives of the data analysis to be performed and the data acceptance criteria. In performing their reviews, the reviewers completed a pre-defined "roadmap" for each document. These roadmaps noted the presence and location of relevant data within the document and captured key information from the documents that were related to these data. This roadmap is given in Exhibit 11B-2. Statisticians used information recorded in the roadmap to help determine the presence and acceptability of data for the statistical summaries and analyses. The roadmaps also were useful in identifying when documents did not appear to report any relevant quantitative data.

Exhibit 11B-3 lists the 66 documents from which performance study data were extracted and utilized within the summaries and analyses presented in this appendix. Data were entered from these documents that achieved the above acceptance criteria. For a given document, different facilities, technologies, data types, or test conditions are specified as separate rows within this table. See Appendix 11A for other documents that were reviewed and determined not to contain suitable data for this effort.

Exhibit 11B-2. Roadmap Used in Identifying Relevant Performance Data for EPA's Evaluation of Technologies to Reduce Impingement and Entrainment of Aquatic Organisms

Template for Evaluating Studies, Assessing Data Quality, and Extracting Data from Documents
Part 3: Design and Reporting

Title of document:			
Tetra Tech ID:		Template completion ID:	

Abstractor's initials: [ ]
No relevant data in this document (check:) [ ]

Technology (if report addresses multiple technologies): [ ]

Study Information -- Data Collected when Technology is in Place

[ ] *See worksheet for the following report for this informatic*

Here, "data" refers to measures of mortality and/or injury to aquatic organisms. Copy rows as needed to represent different data collection types or locations.

	Tables/Page Numbers(1)			Comments
Data collection period:	[ ]	[ ] Start to (mm/dd/yy)	[ ] End (mm/dd/yy)	[ ]
Frequency of data collection at a single location:	[ ]	[ ] One time point	[ ] Multiple time points *Specify time point information:* [ ]	[ ] [ ]
Is one objective of data collection to collect data over multiple seasons of the year?	[ ]	[ ] No	[ ] Yes *Specify seasons:* [ ]	[ ]
Is one objective of data collection to collect data in both day and night periods?	[ ]	[ ] No	[ ] Yes	[ ]
Are data collected from multiple locations (e.g., multiple intakes or units within a facility)?	[ ]	[ ] No	[ ] Yes (specify details:)	[ ]
Does the report note problems with implementing the technology, or other problems, during data collection?	[ ]	[ ] No	[ ] Yes (specify details:)	[ ]

Study Information -- Availability of Baseline/Control Data for Comparing Efficacy of Technology

[ ] *See worksheet for the following report for this informatic*

The following list represents different types of "control" (or baseline) conditions against which a technology's efficacy could be compared. For those controls used in this study, specify the page number(s) where cited, and tables where detailed control data may be reported separately from data under the given technology. (An alternative technology is NOT a control.) Provide details or explanations in the comment field.

	Tables/Page Numbers(1)	Comments
Historical data (e.g., 30-year running average)		
Conditions when the technology is NOT in place		
Downstream conditions		
Known numbers of fish introduced (controlled studies)		
Baseline/control was used but is undefined		
Other (specify): [ ]		
No baseline/control used		

Study Information -- Methods and Definitions

See worksheet for the following report for this information:

	#	Tables/Page Numbers(1)	Comments, Definitions, Species, Methods, etc.
Method for determining ...			
Definition of "fish" — # species total:			
Definition of priority species	#		
Threatened/endangered species			
Commercial species			
Recreational species			
Other type of priority species			
Definitions of fish age categories			
Definitions of fish size categories			
Definition of other non-fish, non-plant organisms			
# species			

Part 3 (cont.)

TetraTech ID:		Template completion ID:	

Technology (if report addresses multiple technologies):

Types of Available Data Collected to Assess Efficacy

Focus only on non-cost measures related to specified outcome. Copy additional rows as necessary. Ignore results presented in figures.

Include, as attachments, any copies of tables and listings of data or summary statistics referenced below. These data will be entered into the analysis database.

Outcome	Organism Type	Measure Type	Units (if not count or %)	Type of Data Reported (if not count or %)	Conditions	Tables/ Page Numbers/ Appendices(1)	Comments

11B.2.5 Performance study database

For the statistical summary and analysis, EPA prepared a MS Access database containing relevant performance study data from the documents listed in Exhibit 11B-3. Within this database, each document was distinguished by a unique "document ID." A given document could have presented performance data for different test or study conditions, facilities, technology categories, etc. These subsets of data were distinguished within the database by assigning a unique "study ID" to each data subset. Thus, a given document ID was often associated with multiple study IDs within the database.

The performance study database consisted of two primary data tables:

- A table containing specific information on a particular study, such as the document and study IDs, facility name, water body, data classification (e.g., impingement, entrainment), technology category, and other test conditions when specified (e.g., mesh size, velocity, water temperature, conditions when the technology is in place, control conditions). The rows of this table were distinguished by study ID.
- A table containing the reported performance data for a given study. Each row of this table contained one or more performance measures for a particular species along with other factors when they were specified (e.g., age category, dates or seasons of data collection, water temperature, velocity, elapsed time to mortality). Possible performance measures that could be specified in a given row of this table included:
    - Percent mortality
    - Percent survival (or other positive outcome, such as retention or diversion)
    - Percent biomass
    - Percent injury
    - Total counts or biomass of available, impinged, or entrained fish. (This number would enter into the denominator of one of the above percentages.)
    - Three types of counts of impinged or entrained fish that were classified as either 1) dead, 2) survived, or 3) injured. (This count would enter into the numerator of one of the above percentages.)

Exhibit 11B-3. List of Documents Represented in the Performance Study Database

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
4	Zooplankton Entrainment Survival at the Anclote Power Plant Near Tarpon Springs, Florida	CCI Environmental Services	DCN 5-4053	1994	Entrainment	Anclote Power Plant	Estuary	Reduced Intake Flows - Other	58	At condenser unit
									59	At discharge
17	Fish Deterrent Field Trials at Hinkley Point Power Station, Somerset, 1993-1994	AWH Turnpenny, R Wood, and KP Thatcher	DCN 5-4313	1995	Impingement	Hinkley Point Power Station	Estuary	Behavioral Systems II	98	Sound on
									99	Sound off
18	Potrero Power Plant CWIS 316(b) Demonstration	Ecoogical Analysts Inc.	DCN 5-4414	1980	Entrainment	Potrero Power Plant	Other	Traveling Screen - Coarse Mesh	100	At intake (control)
									101	At discharge
					Impingement	Moss Landing	Other	Traveling Screen - Coarse Mesh	102	3-hour intermittent screen operational mode
									103	1-hour intermittent screen operational mode
									104	Continuous operation
38	Evaluation of a Barrier Net Used to Mitigate Fish Impingement at a Hudson River Power Plant Intake	JB Hutchinson and JA Matousek	DCN 5-4391	1988	Impingement	Bowline Point Generating Station	Estuary	Barriers	105	Predeployment (control)
									106	Postdeployment
									189	
40	Lovett Generating Station Gunderboom System Evaluation Program	Lawler, matusky, & Skelly Engineers LLP	DCN 5-4417	1998	Entrainment	Lovett Generating Station	River/ Freshwater	Barriers	107	Outside test area (control)
									108	Inside test area
41	Lovett Generating Station Gunderboom Deployment Program	Lawler, Matusky, & Skelly Engineers LLP	DCN 5-4322	2000	Entrainment	Lovett Generating Station	River/ Freshwater	Barriers	109	Outside test area (control)
									110	Inside test area
42	Evaluation of the Eicher Screen at Elwha Dam: Spring 1990 Test Results	Stone and Webster Engineering Corporation	DCN 5-4388	1991	Diversion (not impinged or entrained)	Elwha Dam	River/ Freshwater	Fixed Screen - Coarse Mesh	4	Controlled Study
									7	Controlled Study
									121	Controlled Study
									122	Controlled Study
									123	Controlled Study
									125	Controlled Study
									126	Controlled Study
									127	Controlled Study
43	Recent Developments in Techniques to Protect Aquatic Organisms at the Water Intakes of Steam-Electric Power Plants	Roberto Pagano and Wade H.B. Smith - Mitre Corporation	DCN 5-4394	1977	Impingement	Barney Davis Power Station	Estuary	Traveling Screen - Fine Mesh	21	
						Surry Power Station	River/Fresh-Salt-Mixed	Traveling Screen - Coarse Mesh	18	

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
43	Recent Developments in Techniques to Protect Aquatic Organisms at the Water Intakes of Steam-Electric Power Plants	Roberto Pagano and Wade H.B. Smith - Mitre Corporation	DCN 5-4394	1977	Impingement	Barney Davis Power Station	Estuary	Traveling Screen - Fine Mesh	21	
						Surry Power Station	River/Fresh-Salt-Mixed	Traveling Screen - Coarse Mesh	18	
44	Post-Impingement Fish Survival at Dunkirk Steam Station	Beak Consultants Incorporated	DCN 5-4327	2000	Impingement	Dunkirk Steam Station	Great Lakes	Traveling Screen - Coarse Mesh	8	
46	Intake Technologies: Research Status	Lawler, Matusky & Skelly Engineers	DCN 4-4002V-R12	1989	Impingement	Brayton Point Generating Station Unit 4	Estuary	Behavioral Systems I	119	Estimated Diversion Bypass
								Traveling Screen - Fine Mesh	83	Angled Screens
						Calvert Cliffs Nuclear Generating Station	Estuary	Traveling Screen - Coarse Mesh	78	Dual Flow Screens
									118	Through Flow Screens
						Dunkirk Steam Station	Great Lakes	Traveling Screen - Fine Mesh	79	Dual Flow Screens
						Indian Point Generating Station	River/ Freshwater	Traveling Screen - Coarse Mesh	82	Ristroph screens
47	Evaluation of the Modular Inclined Screen at the Green Island Hydroelectric Project: 1995 Test Results	Stone and Webster Environmental Technology and Services	DCN 10-5435	1996	Entrainment	Green Island Hydroelectric Project	River/ Freshwater	Fixed Screen - Fine Mesh	2	
49	Studies of Cooling Water Intake Structure Effects at Potomac Electric Power Company Generating Stations	David E. Bailey, Jules J. Loos, Elgin S. Perry	DCN 5-4396	undated	Entrainment	Chalk Point Generating Station	Estuary	Barriers	14	
						Dickerson	River/ Freshwater	Fixed Screen - Coarse Mesh	10	
						Morgantown	Estuary	Fixed Screen - Coarse Mesh	13	
						Potomac River	River/ Freshwater	Fixed Screen - Coarse Mesh	12	
					Impingement	Chalk Point Generating Station	Estuary	Barriers	15	Predeployment (control)
									120	Postdeployment
51	Post-Impingement Fish Survival at Huntley Steam Station (Winter and Fall)	Beak Consultants, Inc.	DCN 5-4325	1996	Impingement	Huntley Steam Station	River/ Freshwater	Traveling Screen - Coarse Mesh	1	
52	Fine Mesh Screen (FMS) Optimization Study	Mote Marine Laboratory	DCN 5-4371	1987	Entrainment	Big Bend Power Station	Ocean	Traveling Screen - Fine Mesh	191	

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
53	Chapter 10: San Onofre Units 2 and 3 316(b) Demonstration, The Effectiveness of the Fish Return System	John S. Stevens, Jr., and Milton S. Love	DCN 5-4378	undated	Diversion (not impinged or entrained)	San Onofre Nuclear Generating Station (SONGS)	Ocean	Behavioral Systems I	65	
54	Arthur Kill Generating Station Diagnostic Study and Post-Impingement Viability Substudy Report	Consolidated Edison Company of New York	DCN 5-4326	2000	Impingement	Arthur Kill Generating Station	Estuary	Traveling Screen - Coarse Mesh	156	Modified Screen No. 24
									157	Modified Screen No. 31
60	Third National Workshop on Entrainment and Impingement -- Impingement Studies at Quad-Cities Station, Mississippi River	Latvaitis et al. Edited by Loren Jensen	DCN 10-5448	1976	Impingement	Quad Cities Generating Station	River/ Freshwater	Traveling Screen - Coarse Mesh	9	
61	Memorandum Report on the Peripheral Canal Fish Return Facilities	Department of Fish and Game and the Department of Water Resources	DCN 5-4343	1971	Other	California Delta Pumping Plant	River/ Freshwater	Other technologies	128	Control
								Traveling Screen - Coarse Mesh	11	Decompression Test
									23	Control
									24	Pressure Gradient Test
62	Third National Workshop on Entrainment and Impingement -- Impingement Studies at Oyster Creek Generating Station, Forked River, New Jersey, from Sept. to Dec. 1975	Thomas & Miller. Edited by Loren Jensen	DCN 10-5448	1976	Impingement	Oyster Creek Nuclear Generating Station	Estuary	Traveling Screen - Coarse Mesh	19	
64	Fish Survival on Fine Mesh Travelling Screens	James B. McLaren	DCN 5-4334	2000	Entrapment	Somerset Generating Station	Great Lakes	Traveling Screen - Fine Mesh	144	
					Impingement	Somerset Generating Station	Great Lakes	Traveling Screen - Fine Mesh	5	
65	Lecture Notes on Coastal and Estuarine Studies - Ecological Studies in the Middle Reach of the Chesapeake Bay - Impingement Studies	Richard Horwitz	DCN 10-5453	1987	Impingement	Calvert Cliffs Nuclear Generating Station	Estuary	Traveling Screen - Coarse Mesh	50	
66	Investigations of Impingement of Aquatic Organisms at the Calvert Cliffs Nnuclear Power Plant, 1975-1995.	T.G. Ringger	DCN 6-2074	1999	Impingement	Calvert Cliffs Nuclear Generating Station	Estuary	Traveling Screen - Coarse Mesh	71	

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
71	Impingement Losses at the DC Cook Nuclear Power Plant During 1975-1982 With a Discussion of Factors Responsible and Possible Impact on Local Populations	N.J. Thurber and D.J Jude, Great Lakes and Marine Waters Center, University of Michigan	DCN 5-4374	1985	Impingement	DC Cook	Great Lakes	Off-shore Location (any combination other than velocity cap)	55	
73	Fish Return at Cooling Water Intakes	A.W.H. Turnpenny	DCN 5-4301	1992	Impingement	Le Blayais	Ocean	Traveling Screen - Fine Mesh	6	
76	Bubble Curtain Fish Exclusion Trials at Heyshaam 2 Power Station	A.W.H. Turnpenny	DCN 5-4303	1993	Impingement	Heysham Power Station		Behavioral Systems II	40	Bubbles off
									41	Bubbles on
78	An Assessment of the Effect of the Sizewell Power Stations on Fish Populations	A.W.H. Turnpenny, C.J.L. Taylor	DCN 5-4300	2000	Impingement	Sizewell A and B	Ocean	Off-shore Location with velocity Cap	42	1981-82 study
									45	1992 study
						Various Coastal Stations in the U.K.	Ocean	Off-shore Location with velocity Cap	46	
81	Recent Evaluations of Physical and Behavioral Barriers for Reducing Fish Entrainment at Hydroelectric Plants in the Upper Midwest	D.T. Michaud, E.P. Taft	DCN 10-5465	1999	Entrainment	Pine Hydroelectric Project	River/ Freshwater	Behavioral Systems II	17	Strobes On
									25	Sound on
									26	Strobe/sound
									27	Control
									28	Strobes On
									29	Sound on
									30	Strobe/sound
									31	Control
									32	Strobes On
									33	Sound on
									34	Strobe/sound
									35	Control
									36	Strobe/air
									37	Sound/air
									38	Air
									39	Control
82	Six Years of Monitoring the Effectiveness of a Barrier Net at the Ludington Pumped Storage Plants on Lake Michigan (Waterpower 95)	E.R. Guilfoos, R.W. Williams, T.E. Rourke, P.B. Latvaitis, J.A. Gulvas, R.H. Reider	DCN 10-5466	1995	Percent effectiveness	Luddington Pumped Storage	Great Lakes	Barriers	145	

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
84	Evaluation of the Effectiveness of Intake Wedgewire Screens	C. Ehrler, C. Raifsnider	DCN 5-4335	2000	Entrainment	Logan Generating Plant	River/ Freshwater	Fixed Screen – Fine Mesh	240	
85	Circulating water traveling screen modifications to improve impinged fish survival and debris handling at Salem Generating Station	John P. Ronafalvy, R. Roy Cheesman, William M. Matejek	DCN 5-4333	2000	Impingement	Salem Generating Station	Estuary	Traveling Screen – Coarse Mesh	146	Original Screen
									147	Modified Screen
103	Evaluation of 316(b) Demonstration: Detroit Edison's Monroe Power Plant	CD Goodyear, Great Lakes Fishery Laboratory	DCN 5-4360	1978	Impingement	Monroe Power Plant	Great Lakes	Traveling Screen – Fine Mesh	188	
106	Biological and Engineering Evaluation of a Fine-Mesh Screen Intake for Big Bend Station Unit 4	Stone & Webster Engineering	DCN 6-5037	1980	Impingement	Big Bend Power Station	Estuary	Traveling Screen – Fine Mesh	16	
108	1991 Annual Report Describing Performance of Deterrent Net System at JR Whiting	Consumers Power Company	DCN 5-4409	1992	Impingement	JR Whiting	Great Lakes	Barriers	148	Control
									149	Test
115	The Effects of Screen Slot Size, Screen Diameter, and Through-Slot Velocity on Entrainment of Estuarine Ichthyoplankton through Wedgewire Screens	Stephen B. Weisburg, William H. Burton, Eric A. Ross, Fred Jacobs	DCN 5-4008	1984	Entrainment	Test barge (Chalk Point)	Estuary	Fixed Screen – Fine Mesh	206	8/82 study, 1 mm slot width
									207	8/82 study, 2 mm slot width
									208	7/83 study, 1 mm slot width, 0.20 m/s slot velocity
									209	7/83 study, 2 mm slot width, 0.20 m/s slot velocity
									210	7/83 study, 3 mm slot width, 0.20 m/s slot velocity
									241	7/83 study, 2 mm slot width, 0.095 m/s slot velocity
									242	7/83 study, 2 mm slot width, 0.19 m/s slot velocity
									243	7/83 study, 2 mm slot width, 0.40 m/s slot velocity

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
118	Biological Evaluation of a Fine-Mesh Traveling Screen for Protecting Organisms	Edward taft, Thomas Horst, and John Dowling – Stone and Webster Engineering Corporation	DCN 10-5492	1981	Impingement	Big Bend Power Station	Ocean	Traveling Screen – Fine Mesh	74	Test
									75	Control
									76	Test
									77	Control
									84	Test
									85	Control
									86	Test
									87	Control
125	Review of Portions of NJPDES Renewal Application for the PSE&G salem Generating Station	NJ DEP; Prepared by ESSA Technologies	DCN 4-1516	2000	Impingement	Salem Generating Station	Estuary	Behavioral Systems II	60	Sound on
									61	Sound off
126	Effectiveness, Operation and Maintenance, and Costs of a Barrier Net System for Impingement Reduction at the Chalk Point Generating Station	David Baily, Jules Loos, Ann Wearmouth, Pat Langley, Elgin Perry	DCN 6-5046E		Impingement	Chalk Point Generating Station	Estuary	Barriers	113	1976-77 estimates
									114	1984-85 estimates
130	The Impact of Entrainment and Impingement on Fish Populations in the Hudson River Estuary for Six Fish Populations Inhabiting the Hudson River Estuary	J. Boreman, L.W. Barnthouse, D.S. Vaughan, C.P. Goodyear, S.W. Christensen, K.D. Kumar, B.L. Kirk, W. Van Winkle	DCN 5-4361	1982	Entrainment	Bowline Point Generating Station	River/ Freshwater	Traveling Screen – Coarse Mesh	218	GBC estimation method
									224	MU method
						Danskammer Point Generating Station	River/ Freshwater	Traveling Screen – Coarse Mesh	221	GBC estimation method
									227	MU method
						Indian Point Generating Station	River/ Freshwater	Traveling Screen – Coarse Mesh	217	GBC estimation method –Unit 2
									220	GBC estimation method – Unit 1
									223	MU method – Unit 2
									226	MU method – Unit 1
						Lovett Generating Station	River/ Freshwater	Traveling Screen – Coarse Mesh	219	GBC estimation method
									225	MU method
						Multiple test facilities	River/ Freshwater	Traveling Screen – Coarse Mesh	62	Historical estimates – GBC or RDM methods
									63	Historical estimates – MU method
						Roseton Generating Station	River/ Freshwater	Traveling Screen – Coarse Mesh	216	GBC estimation method
									222	

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
136	Intake Debris Screen Postimpingement Survival Evaluation Study: Roseton Generating Station 1990	Lawler, Matusky & Skelly Engineers	DCN 5-4317	1991	Impingement	Roseton Generating Station	Estuary	Traveling Screen – Coarse Mesh	68	Dual Flow Screens
									70	Dual Flow Screens
									72	Conventional Traveling Screens
									129	Conventional Traveling Screens
138	Fish Return System Efficacy and Impingement Monitoring Studies for JEA's Northside Generating System	Isabel C. Johnson and Steve Moser	DCN 6-5046H	0	Impingement	JEA Northside Generating System	Estuary	Traveling Screen – Coarse Mesh	186	Fish impingement
									187	Invertebrate
								Traveling Screen – Coarse Mesh	47	Continuous operation
									48	1.5 hours off, 0.5 hours on
									51	Continuous operation
						Roseton Generating Station	Estuary	Traveling Screen – Coarse Mesh	49	1.5 hours off, 0.5 hours on
141	A Study of Fish Impingement and Screen Passage at Hanford Generation Project – A Progress Report	R. H. Gray, T. L. Page, E. G. Wolf, M. J. Schneider (Batelle)	DCN 5-4363	1975	Impingement	Hanford Generating Project	River/ Freshwater	Traveling Screen – Coarse Mesh	43	¼ in. screen
									44	1/8 in. screen
143	Final Report: Biological Evaluation of a Modified Traveling Screen Mystic Station – Unit No. 7	Stone & Webster Engineering Corporation	DCN 5-4369	1981	Impingement	Mystic Generating Station	River/Fresh-Salt-Mixed	Traveling Screen – Coarse Mesh	88	Low Velocity Screen Speed
									89	Medium Velocity Screen Speed
									90	High Velocity Screen Speed
146	Design of Water Intake Structures for Fish Protection	American Society of Civil Engineers	DCN 6-5057	1982	Impingement	No facility specified		Other technologies	73	
147	1974 Evaluation of the Glenn-Colusa Irrigation District Fish Screen	Ronald J. Decoto	DCN 5-4308	1974	Diversion (not impinged or entrained)	Glenn-Colusa Irrigation District Fish Screen	River/ Freshwater	Other technologies	64	
151	Design and Testing Specification for a Deterrent Bubble Barrier for Heysham Power Stations 1 & 2	AWH Turnpenny, PA Henderson	DCN 5-4315	1992	Diversion (not impinged or entrained)	Heysham Power Station	Ocean	Behavioral Systems II	52	Air
									53	Strobes On
									54	Strobe/air
152	Experiments on the Use of Sound as a Fish Deterrent	A W H Turnpenny, K P Thatcher, R Wood, P H Loeffelman	DCN 5-4316	1993	Diversion (not impinged or entrained)	Fawley Aquatic Research Laboratory	Ocean	Behavioral Systems II	56	Sound off
									57	Sound on

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
163	Impingement Survival Studies on White Perch, Striped Bass, and Atlantic Tomcod at Three Hudson River Power Plants	Lawrence R. King, Jay B. Hutchison Jr., Thomas G. Huggins	DCN 10-5332	1977	Impingement	Bowline Point Generating Station	Estuary	Traveling Screen – Coarse Mesh	153	
						Roseton Generating Station	River/Fresh-Salt-Mixed	Traveling Screen – Coarse Mesh	154	
164	Survival of Fishes and Macroinvertibrates Impinged at Oyster Creek Generatiing Station	Thomas R. Thathom, David L. Thomas, Gerald J. Miller	DCN 10-5333	1977	Impingement	Oyster Creek Nuclear Generating Station	Estuary	Traveling Screen – Coarse Mesh	150	
167	A Practical Intake Screen which Substantially Reduces the Entrainment and Impingement of Early Life Stages of Fish	Brian N. Hanson, Wiliam H. Bason, Barry E. Beitz, Kevin E. Charles	DCN 10-5536	0	Entrainment	Delmarva Ecological Laboratory	Not Applicable	Fixed Screen – Fine Mesh	253	
168	Survival of Dominant Estuarine Organisms Impinged on Fine-Mesh Traveling Screens at the Barney M. Davis Power Station	L.S. Murray and T.S. Jinnette	DCN 5-4379	1977	Impingement	Barney Davis Power Station	Estuary	Traveling Screen – Fine Mesh	66	
169	Investigations on the Protection of Fish Larvae at Water Intakes Using Fine-Mesh Screening	D.A. Tomljanovich, J.H. Heuer, and C.W. Voigtlander	DCN 5-4379	1978	Impingement	TVA laboratory		Fixed Screen – Fine Mesh	151	
					Retention	TVA laboratory	Not Applicable	Fixed Screen – Fine Mesh	248	0.5 mm mesh
									249	1.0 mm mesh
									250	1.3 mm mesh
									251	1.8 mm mesh
									252	2.5 mm mesh

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
170	A Study on the Protection of Fish Larvae at Water Intakes Using Wedge-Wire Screens	J.H. Heuer and D.A. Tomljanovich	DCN 5-4379	1987	Diversion (not impinged or entrained)	TVA laboratory	Not Applicable	Fixed Screen – Fine Mesh	92	Horizontal Screen – 0.5mm slot
									93	Horizontal Screen – 1.0 mm slot
									94	Horizontal Screen – 2.0mm slot
									95	Vertical Screen – 0.5mm slot
									96	Vertical Screen – 1.0mm slot
									97	Vertical Screen – 2.0mm slot
									132	Horizontal Screen – 0.5mm slot
									133	Horizontal Screen – 0.5mm slot
									134	Horizontal Screen – 1.0 mm slot
									135	Horizontal Screen – 1.0 mm slot
									136	Horizontal Screen – 2.0mm slot
									137	Horizontal Screen – 2.0mm slot
									138	Vertical Screen – 0.5mm slot
									139	Vertical Screen – 0.5mm slot
									140	Vertical Screen – 1.0mm slot
									141	Vertical Screen – 1.0mm slot
									142	Vertical Screen – 2.0mm slot
									143	Vertical Screen – 2.0mm slot
171	Practicality of Profile-Wire Screen in Reducing Entrainment and Impingement	B.N. hanson, W.H. Bason, B.E. Beitz, and K.E. Charles	DCN 5-4379	1977	Impingement	Test laboratory		Fixed Screen – Fine Mesh	152	Test

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
175	Seminole Plant Units 1&2 316b Study Report	Dames and Moore	DCN 7-4530		Entrainment	Test barge (St. John's River)		Fixed Screen – Fine Mesh	213	1 mm mesh
									214	2 mm mesh
180	316(a) and 316(b) Demonstration Cumberland Steam Plant	Tennessee Valley Authority	DCN 10-5547		Entrainment	Cumberland Steam Plant		Traveling Screen – Coarse Mesh	215	
184	Brunswick Steam Electric Plant Cape Fear Studies Interpretive Report	Carolina Power & Light Company	DCN 8-4513		Entrainment	Brunswick Steam Electric Plant	Estuary	Traveling Screen – Fine Mesh	244	
187	Vienna Power Station Perdiction of Aquatic Impacts of the Proposed Cooling Water Intake A Section 316(b) Demonstration	Delmarva Power & Light Company	DCN 10-5554		Entrainment	Vienna Power Station	Estuary	Fixed Screen – Fine Mesh	245	Screen type #1
									247	Screen type #2
191	Field evaluation of wedgewire screens for protecting early life stages at cooling water intake structures: Chesapeake Bay studies	EPRI	DCN 10-6806	2006	Entrainment	Test barge (Chesapeake Bay)	River/ Freshwater	Fixed Screen – Fine Mesh	200	0.5 mm mesh, 0.15 m/s slot vel.
									201	0.5 mm mesh, 0.3 m/s slot velocity
									202	1.0 mm mesh, 0.15 m/s slot vel.
									203	1.0 mm mesh, 0.3 m/s slot velocity
192	Laboratory evaluation of modified Ristroph traveling screens for protecting fish at cooling water intakes	EPRI	DCN 10-6801	2006	Impingement	Test laboratory	Not Applicable	Traveling Screen – Fine Mesh	112	1 ft/s velocity
									130	2 ft/s velocity
									131	3 ft/s velocity
193	Fish Protection at Cooling Water Intake Structures: A Technical Reference Manual	EPRI	DCN 10-6813	2007	Entrainment	Test barge (Oyster Creek)	Estuary	Fixed Screen – Fine Mesh	211	1 mm mesh
									212	2 mm mesh
						Test barge (Portage River)	River/ Freshwater	Fixed Screen – Fine Mesh	196	0.5 mm mesh, 0.15 m/s slot vel.
									197	0.5 mm mesh, 0.3 m/s slot velocity
									198	1.0 mm mesh, 0.15 m/s slot vel.
									199	1.0 mm mesh, 0.3 m/s slot velocity
									193	0.5 mm mesh, 0.3 m/s slot velocity
									194	1.0 mm mesh, 0.15 m/s slot vel.

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
193	Fish Protection at Cooling Water Intake Structures: A Technical Reference Manual	EPRI	DCN 10-6813	2007	Impingement	Test barge (Sakkonet River)	River/ Freshwater	Fixed Screen – Fine Mesh	192	0.5 mm mesh, 0.15 m/s slot vel.
									193	0.5 mm mesh, 0.3 m/s slot velocity
									194	1.0 mm mesh, 0.15 m/s slot vel.
									195	1.0 mm mesh, 0.3 m/s slot velocity
						Tracy Fish Collecting Facility	River/ Freshwater	Other technologies	182	Technology in Place
									183	Control
						Arthur Kill Generating Station	River/ Freshwater	Fixed Screen - Fine Mesh	155	Original Screen
						Bowline Point Generating Station	Estuary	Traveling Screen - Coarse Mesh	176	Screenwash - Continuous
									177	Screenwash - 2hr hold
									178	Screenwash - 4hr hold
						Brayton Point Generating Station Unit 4	Estuary	Traveling Screen - Fine Mesh	180	Initial survival
									181	Extended survival
						Brunswick Steam Electric Plant	Estuary	Traveling Screen - Fine Mesh	165	Technology in Place
									166	Technology in Place
						Danskammer Point Generating Station	Estuary	Traveling Screen - Coarse Mesh	168	Screenwash - Continuous
									169	Screenwash - 2hr hold
						Dunkirk Steam Station	Great Lakes	Traveling Screen - Coarse Mesh	159	Dual Flow Screens
						Indian Point Generating Station	River/ Freshwater	Traveling Screen - Coarse Mesh	163	Ristroph Screen
								Traveling Screen - Fine Mesh	190	Original Screen
						Mystic Generating Station	River/ Freshwater	Traveling Screen - Coarse Mesh	172	Screenwash - Continuous
									173	Screenwash - 2hr hold
									174	Screenwash - 4hr hold
									175	Screenwash - 8hr hold

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
193	Fish Protection at Cooling Water Intake Structures: A Technical Reference Manual	EPRI	DCN 10-6813	2007	Impingement	Oswego Steam Station	Great Lakes	Off-shore Location (any combination other than velocity cap)	158	
						Oyster Creek Nuclear Generating Station	Estuary	Traveling Screen - Coarse Mesh	179	
						Prairie Island Nuclear Generating Station	River/ Freshwater	Traveling Screen - Fine Mesh	160	
						Salem Generating Station	Estuary	Traveling Screen - Coarse Mesh	161	Modified Screen
								Traveling Screen - Fine Mesh	162	Original Screen
						Sioux		Other technologies	185	
195	Laboratory evaluation of fine-mesh traveling water screens for protecting early life stages of fish at cooling water intakes	EPRI	DCN 10-6802	2008	Impingement	Test laboratory	Not Applicable	Fixed Screen - Fine Mesh	117	
					Retention	Test laboratory	Not Applicable	Fixed Screen - Fine Mesh	116	
196	Latent impingement mortality assessment of the Geiger Multi-Disc screening system at Potomac River Generating Station	EPRI	DCN 10-6814	2007	Impingement	Potomac River	River/ Freshwater	Traveling Screen - Coarse Mesh	91	
205	Calvert Cliffs Nuclear Power Plant Finfish Survival Study	D.L.Breitburg and T.A.Thoman	DCN 10-5571	1986	Impingement	Calvert Cliffs Nuclear Generating Station	Estuary	Traveling Screen - Coarse Mesh	236	Beauderey TS
									237	FMC dual-speed TS
									238	FMC single-speed TS
									239	FMC single-speed TS
206	Full-scale Operational Demonstration of Fine Mesh Screens at Power Plant Intakes	V. Brueggemeyer, D.Cowdrick, K. Durrell, S. Mahadevan and D. Bruzek	DCN 10-5572	1998	Impingement	Big Bend Power Station	Estuary	Traveling Screen - Fine Mesh	233	Screenwash
									234	Org. Return Discharge
									235	At intake (control)
207	Dunkirk Station Biological Studies	Beak Consultants Incorporated	DCN 10-5573	1988	Impingement	Dunkirk Steam Station	Great Lakes	Traveling Screen - Fine Mesh	228	High Velocity Screen Speed
									229	Low Velocity Screen Speed

Exhibit 11B-3. (Continued)

Doc. ID	Document Title	Authors	DCN	Date	Data Classification	Facility Name	Water Body Type	Technology Category	Study ID	Test Conditions[a]
208	Brunswick Steam Electric Plant: 1984 Biological Monitoring Report	Carolina Power and Light Company	DCN 10-5574	1984	Impingement	Brunswick Steam Electric Plant	Estuary	Traveling Screen - Fine Mesh	167	Control
									230	High Velocity Screen Speed
									231	Low Velocity Screen Speed
									232	Juvenile/adults

[a] Specified primarily to distinguish between different rows for the same facility, technology, and data type.

In general, a row of the data table contains quantitative performance measures presented for a given species (possibly of a certain age) at a given point in time, taken from either a table of the document or within text. Records between the two database tables were linked by study ID.

For a given document, the performance study database contains selected data that represented one of the above data types and met acceptance criteria for the summaries and analyses. If there was any uncertainty in how to interpret the data in a given document, then that data were not entered into the database until the data could be further reviewed. In addition, a given performance measure could be defined differently in different documents. For example, as stored in the database, data on percent survival could represent actual survival following impingement in one document, and percent diversion from impingement or entrainment in another document. Survival counts may include injured fish in one document and not in another.

11B.2.6 Classifying data (e.g., impingement, entrainment)

From available information in a document, reviewers determined whether a particular set of performance data related to either impingement or entrainment of fish. This classification was done primarily by noting how the document classified the data as impingement or entrainment, typically within text or in titles to tables or sections of the document. Occasionally, it was not possible to determine an exact classification of data. For example, data may have represented a percent of fish that were diverted from the areas close to the cooling water intakes of a facility, where no information was provided on the age or size categories of the fish. In this case, it was undetermined whether the diverted fish would have been impinged or entrained. Because they could represent either situation, such data are categorized in the performance study database as diverted, but neither impinged nor entrained. They were placed in a category separate from impingement and entrainment data when conducting data summaries and analyses.

11B.3 Statistical Data Summaries

When considering all of the performance data that were entered into the performance study database, two types of data were primarily encountered:

- Data that originate from simple observational studies (i.e., studies that provide impingement/entrainment data at one or more points in time, when the given technology is in operation).
- Paired data sets that correspond to either "before/after implementation" of the technology or "treatment/control," which allow for comparisons to be made to some baseline condition when evaluating technology performance at a given location.

The first type of data was primarily percentage in nature. When expressed in relative (percentage) terms rather than in absolute terms, data are more likely to be comparable across different studies and different testing situations. Of these data, percent mortality and/or survival were reported most often in the documents. Prior to the statistical summaries and analyses, percent survival data were converted to percent mortality data (by subtracting the percentage from 100 percent) so that survival-related data among the studies could be reported as percent mortality. Note, however, that when percent survival data represented a percentage of a positive outcome, such as successful diversion, then percent mortality would represent the percentage of the opposite outcome. Data that correspond to the numerator and/or denominator of such a percentage (i.e., fish counts or biomass) were also entered in the database when they were reported within the documents.

The second type of data represents situations where a document reported either counts or percentages of organisms as measured under a baseline condition as well as conditions when the technology was in place (i.e., "treatment" conditions). Ideally, baseline conditions should match treatment conditions except for the technology not being in operation. A document was more likely to have these two types of data when reporting the results of controlled laboratory studies. When a document reported both treatment and control data for a given technology, both sets of data were entered into the performance study database (under different study IDs but the same document ID). For the statistical summaries, these results were expressed as a percentage change from baseline or control:

$$\frac{Baseline - Treatment}{Baseline} * 100\%$$

Here, "*Baseline*" and "*Treatment*" can represent any of the percentage or count measures noted in Section 11B.2, but both must represent the same type of measure within a given calculation.

This section presents simple statistical summaries of performance measurements stored within the performance study database, with separate summaries presented for the two data classifications. These data originate from the documents listed in Exhibit 11B-3. Separate summaries were also prepared for data classified as impingement, entrainment, or other, and for data associated with different technology categories. In addition, for percent mortality data, summaries are presented according to the observation time (e.g., number of hours following impingement or entrainment when the mortality or survival of fish was noted).

The statistical summaries presented in this section include the number of measurements (N), arithmetic mean, standard deviation, minimum, maximum, and selected percentiles (25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles). These summaries represent measurements that span different documents, studies, implementations of the technology, test conditions, species, age categories, time periods/seasons, etc. Thus, the variability observed among these data contains many different components. However, the number of different studies, documents, and test conditions entering into each set of summary statistics will vary among the different technology categories and data classifications. Because data for a particular type of performance measure were generated under different conditions and could have slightly different interpretations and definitions from study to study, it is not feasible to assume that all data in a combined dataset originate from a common underlying distribution. Therefore, the summaries presented in this section do not assume an underlying distribution to the data, such as normality, but rather, are calculated using only the observed data.

11B.3.1 Summaries of Observational Data Expressed as Percentages

Exhibits 11B-4 through 11B-6 contain descriptive statistics for data on percent mortality, percent biomass, and percent injury, respectively. The nearly 2,000 data values summarized in these tables represent only those conditions in which the specified technology was deemed to be in operation (e.g., any data labeled as collected under control conditions were excluded). To help determine how data entering into these tables may be distributed among different documents and test conditions within documents, Section 11B.5 contains the mean, minimum, and maximum data value for each combination of document and study (test condition), for each technology category. The tables in Section 11B.5 also list the facilities from which the data originate.

Some findings noted from the summaries of the percent mortality data presented in Exhibit 11B-4 are as follows:

- Across species, time points, and studies, percent mortality data were observed to cover the range of 0 to 100 percent among the technology categories, especially for impingement.
- Approximately two-thirds of the percent mortality data, obtained from 33 documents, are associated with impingement.
    - For traveling screens, the ranges of percent impingement mortality data are similar between coarse and fine mesh.
        - Mean percent mortality associated with traveling screens (coarse mesh) range from 16 to 53 percent across the different duration times following impingement. The data originate from 46 different test conditions within 18 documents.
        - For traveling screens (fine mesh), mean percent mortality ranges from 18 to 37 percent across duration times, but all time points have percent mortality data that covers a range from 0 to 100 percent. They represent 31 test conditions across 12 documents.
    - The five remaining technology categories with percent mortality data for impingement had data that originated from eight documents. Of these technologies, barriers had the highest range of percent mortality values, with a median of 91.9 percent. Data on off-shore location technology also covered a high range overall, but only eight data points were present.
- When mortality data were available at different elapsed times following impingement, an increase in mortality was occasionally seen with higher elapsed times. However, a clear increasing trend in time is not observed due to considering different studies and test conditions.

Exhibit 11B-4. Descriptive Statistics on Percent Mortality Performance Data, by Technology Category and Mortality Observation Time

Technology Category	Mortality Obs. Time	N	Mean	Std. Dev.	Min.	Max.	Percentiles 25th	50th	75th	95th
Entrainment										
Fixed Screen - Fine Mesh	0 hr.	13	18.7	31.7	0.0	100.0	0.0	0.0	24.1	100.0
	24 hr.	12	41.5	41.7	0.0	100.0	0.0	33.8	82.4	100.0
	48 hr.	12	53.3	43.6	0.0	100.0	5.0	56.3	100.0	100.0
Other technologies	0 hr.	11	1.0	0.6	0.0	1.9	0.4	1.1	1.4	1.9
Reduced Intake Flows - Other	0 hr.	177	27.9	23.3	0.0	88.4	7.4	24.9	42.6	76.0
Traveling Screen - Coarse Mesh	0 hr.	115	4.1	9.7	0.1	83.9	0.5	1.3	3.3	20.3
	24 hr.	133	6.3	11.4	0.1	77.8	0.7	2.0	5.7	25.4
	96 hr.	1	92.2	.	92.2	92.2	92.2	92.2	92.2	92.2
Impingement										
Barriers	0 hr.	21	71.1	35.7	1.3	98.7	54.9	91.9	97.7	98.7
Behavioral Systems I	0 hr.	12	39.8	40.1	1.2	100.0	7.0	23.3	85.1	100.0
Fixed Screen - Fine Mesh	0 hr.	38	23.7	27.6	0.0	91.8	0.8	10.5	44.9	81.1
	12 hr.	10	27.2	32.3	0.0	91.0	3.0	16.5	28.0	91.0
	24 hr.	40	43.0	38.3	0.0	100.0	4.0	32.2	84.9	100.0
	48 hr.	10	30.7	33.3	1.0	91.0	3.0	22.0	31.0	91.0
Off-shore Location (any combination othe	0 hr.	8	48.3	23.6	8.0	85.2	37.5	46.3	62.9	85.2
Other technologies	0 hr.	6	7.5	11.4	0.0	30.0	0.0	4.0	7.0	30.0
Traveling Screen - Coarse Mesh	0 hr.	684	26.4	33.4	0.0	100.0	0.0	9.2	45.4	100.0
	18 hr.	26	31.7	25.4	2.0	82.0	12.0	26.5	42.0	80.0
	24 hr.	233	16.0	28.5	0.0	100.0	0.0	1.4	16.8	100.0
	48 hr.	34	23.9	37.0	0.0	100.0	0.0	0.0	45.7	100.0
	84 hr.	18	15.5	25.1	0.0	80.2	0.0	4.7	15.8	80.2
	96 hr.	91	52.7	38.3	0.0	100.0	16.7	50.0	100.0	100.0
Traveling Screen - Fine Mesh	0 hr.	373	25.5	32.9	0.0	100.0	0.0	8.0	43.2	98.5
	8 hr.	67	22.4	32.5	0.0	100.0	0.0	4.9	30.3	100.0
	24 hr.	67	28.6	34.9	0.0	100.0	0.0	12.6	50.0	100.0
	48 hr.	82	17.7	30.2	0.0	100.0	1.0	3.9	15.9	96.8
	96 hr.	70	37.4	35.8	0.0	100.0	5.1	26.4	63.6	100.0
Diversion (not impinged or entrained)										
Behavioral Systems I	0 hr.	64	24.6	31.4	0.0	100.0	2.4	9.4	36.8	95.5
Behavioral Systems II	0 hr.	5	81.7	25.9	38.2	100.0	77.4	96.2	96.5	100.0
Fixed Screen - Coarse Mesh	0 hr.	12	0.5	0.5	0.0	1.4	0.1	0.4	0.9	1.4
Fixed Screen - Fine Mesh	0 hr.	296	11.5	16.0	0.0	86.5	0.6	5.0	17.6	47.0
Other technologies	0 hr.	2	74.2	11.5	66.0	82.3	66.0	74.2	82.3	82.3
Other										
Traveling Screen - Coarse Mesh	24 hr.	16	12.0	18.4	0.0	53.5	0.0	1.4	24.6	53.5
	48 hr.	16	21.2	27.2	0.0	69.6	1.9	4.7	45.2	69.6

Exhibit 11B-5. Descriptive Statistics on Percent Biomass Performance Data, by Technology Category

Technology Category	N	Mean	Std. Dev.	Min.	Max.	Percentiles			
						25th	50th	75th	95th
Entrainment									
Barriers	5	18.9	31.9	3.3	76.0	4.4	5.1	5.8	76.0
Fixed Screen - Coarse Mesh	13	5.5	5.8	0.1	18.0	2.0	3.0	9.0	18.0
Impingement									
Off-shore Location with velocity Cap	7	42.1	64.9	0.2	180.0	1.4	6.5	52.0	180.0
Traveling Screen - Coarse Mesh	48	1.4	2.6	0.0	12.8	0.1	0.3	1.2	7.6

Exhibit 11B-6. Descriptive Statistics on Percent Injury Performance Data, by Technology Category

Technology Category	N	Mean	Std. Dev.	Min.	Max.	Percentiles			
						25th	50th	75th	95th
Impingement									
Traveling Screen - Coarse Mesh	20	28.1	15.9	5.0	64.0	12.5	28.5	38.5	57.0
Traveling Screen - Fine Mesh	30	7.3	9.9	0.0	34.0	0.4	2.9	9.5	29.8
Diversion (not impinged or entrained)									
Fixed Screen - Coarse Mesh	12	8.0	7.8	1.5	22.5	2.3	4.4	13.1	22.5

- Entrainment data represented 17 percent of the percent mortality data and originated from six different documents.
    - Of the four technology categories for which entrainment data existed, fixed screen (fine mesh) was associated with the lowest range of percent mortality data (when mortality was noted immediately following entrainment). These data originated primarily from Green Island Hydroelectric Project (Document 47) and represented primarily blueback and American shad juveniles.
    - The traveling screen (coarse mesh) technology was represented by percent mortality data from two documents, but from several test facilities. Document 18 (Potrero power plant) contributed the two largest values (83.9 and 92.2 percent), while Document 130 (multiple test facilities) provided values ranging from 0.1 to 77.8 percent.
- Five technology categories were associated with diversion data that could not be expressed as either impingement or entrainment. These data represented approximately 14 percent of all percent mortality data and originated from six documents and six different facilities. Within a technology category, data originated from either one or two documents. For some categories, such as Behavioral Systems II, different studies or test conditions appeared to be a major source of variation in the data.

The "other" category represented data from a single document (Document 61), collected from a controlled study at the California Delta Pumping Plant. The data represent the outcome of decompression tests in which fish were subjected to various pressure levels and evaluated for survival after one and two days. These tests evaluated the ability of fish to withstand hydrostatic pressures between various points of the facility and the release point.

Exhibits 11B-5 and 11B-6 note that very little biomass or injury performance data are represented within the database. Percent biomass data represent approximately four percent of the performance data expressed as a percentage, while percent injury data represent about three percent. In a given row of these two tables, the summarized data originate from only one reviewed document and from one to four studies within that document. Some findings noted in these two tables are as follows:

- Entrainment data existed as a percent of total biomass for two technology categories: barriers and fixed screen – coarse mesh. The 18 entrainment data points represent four different facilities owned by a single utility and originate from Document 49, which labeled the data points as a percent of total water body production. While the largest reported measure is 76 percent (measured at a facility that utilized barriers), which represented entrainment of bay anchovies, it is considerably higher than the second highest reported measure, 18 percent.
- Impingement data expressed as a percent of total biomass were reported for only two technology categories. For one category (offshore location with velocity cap), the data represented different species from various coastal stations in the United Kingdom in 1990 (Document 78). The summarized percentages for this category were calculated from total biomass that was reported in this document. The other category (traveling screens – coarse mesh) represents percentage data for Quad Cities Generating Station that was reported for Document 60. These data were considerably lower than for the other technology category.
- Traveling screen performance data were expressed as a percentage of total injured fish for two documents: Document 164 (coarse mesh) and Document 192 (fine mesh). The latter document reported on the outcome of controlled testing in a laboratory under three different velocity measures (1, 2, and 3 feet per second).

11B.3.2 Summaries of Observational Data Expressed as Mortality/Survival Counts

Exhibits 11B-7 and 11B-8 contain descriptive statistics on mortality count data and survival count data, respectively, which exist within the database. Count data are reported only when they were provided within a document and were not derived from percentage data. Section 11B.6 contains a finer summary of these data by document, study (test condition), and facility, for each technology category appearing in Exhibits 11B-7 and 11B-8. Some key findings are as follows:

- Few counts listed in the database on mortality or survival are associated with entrainment. For a given technology, available entrainment data originate from one or two documents. Entrainment mortality counts under fine mesh fixed screens tend to be low (Document 18) compared to barriers (Documents 40 and 41).

- For barriers and Behavioral Systems II, both mortality and survival impingement counts are quite high (with higher counts associated with barriers) and originate from different documents.
- When traveling screens (coarse mesh) are in place, mortality counts following impingement vary considerably (from zero to over two million) under different test conditions and facilities, especially immediate mortality. However, the largest mortality counts occur in only a few instances, as noted by low values for the 75th percentile, and median counts are close to zero. Section 11B.6 shows that the highest mortality counts were associated with facilities at Calvert Cliffs and Roseton.
- With the exception of survival counts associated with the Brunswick plant, survival counts associated with impingement were similar between fine and coarse mesh traveling screens.

Because count data can be interpreted differently between studies and can be highly affected by test condition, caution should be taken when making conclusions from summaries of these data.

Exhibit 11B-7. Descriptive Statistics on Mortality Count, by Technology Category and Mortality Observation Time

Technology Category	Mortality Obs. Time	N	Mean	Std. Dev.	Min.	Max.	Percentiles 25th	50th	75th	95th
Entrainment										
Barriers	0 hr.	8	1368	2106	1	6133	106	341	1959	6133
Fixed Screen - Fine Mesh	0 hr.	13	5	9	0	28	0	0	10	28
	24 hr.	12	33	59	0	170	0	7	28	170
	48 hr.	12	40	73	0	208	1	7	32	208
Traveling Screen - Coarse Mesh	0 hr.	1	601	.	601	601	601	601	601	601
Impingement										
Barriers	0 hr.	12	396037	635609	232	1948132	14739	118945	489462	1948132
Behavioral Systems II	0 hr.	4	10282	8144	912	20564	4577	9826	15987	20564
Fixed Screen - Fine Mesh	0 hr.	1	129	.	129	129	129	129	129	129
Off-shore Location (any combination)	0 hr.	8	356	625	13	1647	20	31	544	1647
Traveling Screen - Coarse Mesh	0 hr.	478	15596	122127	0	2229859	0	3	50	8985
	24 hr.	130	26	95	0	866	0	0	3	111
	96 hr.	58	26	114	0	848	1	3	10	77
Traveling Screen - Fine Mesh	0 hr.	125	20850	81984	0	521500	4	31	753	113280
Other										
Traveling Screen - Coarse Mesh	24 hr.	28	7	11	0	52	0	1	10	25
	48 hr.	28	14	19	0	82	1	5	25	47

Exhibit 11B-8. Descriptive Statistics on Survival Count, by Technology Category and Mortality Observation Time

Technology Category	Mortality Obs. Time	N	Mean	Std. Dev.	Min.	Max.	Percentiles 25th	50th	75th	95th
Entrainment										
Behavioral Systems II	0 hr.	12	5766	9396	388	23572	477	765	9345	23572
Traveling Screen - Coarse Mesh	0 hr.	1	115	.	115	115	115	115	115	115
	96 hr.	1	56	.	56	56	56	56	56	56
Impingement										
Barriers	0 hr.	18	353149	615659	8914	1948132	19531	37058	191926	1948132
Behavioral Systems II	0 hr.	11	6006	7520	288	22158	1176	2432	7271	22158
Fixed Screen - Fine Mesh	24 hr.	30	34	68	0	342	1	9	35	134
Off-shore Location (any combination)	0 hr.	8	247	487	8	1443	32	69	163	1443
Traveling Screen - Coarse Mesh	0 hr.	386	388	1329	0	17719	2	17	176	2383
	24 hr.	233	170	582	0	5948	2	8	48	875
	48 hr.	1	1236	.	1236	1236	1236	1236	1236	1236
	84 hr.	18	101	43	28	187	71	109	130	187
	96 hr.	63	120	376	0	2253	1	5	45	420
Traveling Screen - Fine Mesh	0 hr.	158	2344712	12842622	0	110000000	7	29	296	11000000
	8 hr.	67	37	83	0	395	1	6	22	237
	24 hr.	67	30	67	0	365	1	5	20	213
Diversion (not impinged or entrained)										
Behavioral Systems I	0 hr.	64	7727	31350	0	198157	36	86	565	44369
Behavioral Systems II	0 hr.	2	7	0	7	8	7	7	8	8
Fixed Screen - Coarse Mesh	0 hr.	12	467	130	148	561	496	518	531	561
Other technologies	0 hr.	2	2311	1795	1042	3580	1042	2311	3580	3580
Other										
Traveling Screen - Coarse Mesh	24 hr.	28	172	231	2	1040	22	78	302	517
	48 hr.	28	164	230	2	1030	16	62	286	517

11B.3.3 Summaries of Percentage Change from Baseline in Mortality

Thirteen of the documents in Exhibit 11B-3 have some measure of mortality or survival data under the given technology as well as under baseline (control) conditions. These two sets of data were brought together to calculate a percentage change from baseline. Within each document, this calculation was done on an individual species basis. For a given document and study, if multiple values for a particular performance measure existed for a given species, age category, and elapsed time to mortality for either the technology or for baseline, then these values were averaged prior to calculating the percent change from baseline.

Exhibits 11B-9 through 11B-11 summarize percentage change from baseline data by technology. Percentage change from baseline was calculated for three types of performance measures: mortality count, survival count, and percent mortality. Section 11B.7 contains the mean, minimum, and maximum percentage change from baseline calculation for each combination of document and study (test condition), as well as facility, for each technology category.

Exhibit 11B-9. Descriptive Statistics on Percentage Change from Baseline in Mortality Count, by Technology Category and Mortality Observation Time

Technology Category	Mortality Obs. Time	N	Mean	Std. Dev.	Min.	Max.	Percentiles 25th	50th	75th	95th
Entrainment										
Barriers	0 hr.	8	12.8	131.0	-304.4	92.3	25.3	51.1	81.0	92.3
Traveling Screen - Coarse Mesh	0 hr.	1	-40.7	.	-40.7	-40.7	-40.7	-40.7	-40.7	-40.7
Impingement										
Barriers	0 hr.	1	-136.1	.	-136.1	-136.1	-136.1	-136.1	-136.1	-136.1
Behavioral Systems II	0 hr.	1	-0.3	.	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
Other										
Traveling Screen - Coarse Mesh	24 hr.	5	-146.3	244.5	-550	66.7	-188.9	-59.3	0.0	66.7
	48 hr.	8	-183.6	373.1	-1075	66.7	-165.6	-94.4	30.0	66.7

Percentage change from baseline was calculated as 100*(*Baseline – Technology)/Baseline.*

Exhibit 11B-10. Descriptive Statistics on Percentage Change from Baseline in Survival Count, by Technology Category and Mortality Observation Time

Technology Category	Mortality Obs. Time	N	Mean	Std. Dev.	Min.	Max.	Percentiles 25th	50th	75th	95th
Entrainment										
Behavioral Systems II	0 hr.	12	6.9	23.2	-30.3	49.4	-6.7	6.5	16.6	49.4
Traveling Screen - Coarse Mesh	0 hr.	1	3.4	.	3.4	3.4	3.4	3.4	3.4	3.4
	96 hr.	1	8.2	.	8.2	8.2	8.2	8.2	8.2	8.2
Impingement										
Behavioral Systems II	0 hr.	8	-6.4	42.1	-74.3	41.1	-41.8	2.4	30.4	41.1
Traveling Screen - Coarse Mesh	48 hr.	1	-97.8	.	-97.8	-97.8	-97.8	-97.8	-97.8	-97.8
Diversion (not impinged or entrained)										
Behavioral Systems II	0 hr.	1	47.9	.	47.9	47.9	47.9	47.9	47.9	47.9
Other										
Traveling Screen - Coarse Mesh	24 hr.	8	-44.6	79.5	-220.0	35.0	-66.9	-22.6	3.5	35.0
	48 hr.	8	-38.0	81.2	-220.0	41.5	-58.2	-15.1	10.5	41.5

Percentage change from baseline was calculated as 100*(*Baseline – Technology)/Baseline.* Survival could represent numbers of organisms experiencing any positive outcome.

Exhibit 11B-11. Descriptive Statistics on Percentage Change from Baseline in Percent Mortality, by Technology Category and Mortality Observation Time

Technology Category	Mortality Obs. Time	N	Mean	Std. Dev.	Min.	Max.	Percentiles 25th	50th	75th	95th
Entrainment										
Other technologies	0 hr.	2	-102.7	203.6	-246.7	41.2	-246.7	-102.7	41.2	41.2
Traveling Screen - Coarse Mesh	0 hr.	1	-7.3	.	-7.3	-7.3	-7.3	-7.3	-7.3	-7.3
	96 hr.	1	-3.8	.	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8
Impingement										
Traveling Screen - Coarse Mesh	48 hr.	1	50.9	.	50.9	50.9	50.9	50.9	50.9	50.9
Traveling Screen - Fine Mesh	0 hr.	15	-1021	3459.5	-13450	87.1	-278.0	-11.2	52.4	87.1
	48 hr.	16	-26.1	57.8	-133.3	63.7	-63.8	-15.9	18.2	63.7
	96 hr.	20	-22.3	74.3	-241.9	68.8	-33.1	3.9	21.9	52.6
Diversion (not impinged or entrained)										
Behavioral Systems II	0 hr.	1	-3.6	.	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6
Other										
Traveling Screen - Coarse Mesh	24 hr.	3	-70.3	115.5	-179.3	50.8	-179.3	-82.3	50.8	50.8
	48 hr.	4	-167.3	290.2	-595.2	50.8	-328.8	-62.3	-5.7	50.8

Percentage change from baseline was calculated as 100*(*Baseline – Technology)/Baseline.*

Among these performance measures, a percentage change from baseline that exceeds zero indicates that levels were higher under baseline conditions than under conditions with the technology in place. Under effective technologies, this would be expected to occur with mortality-related performance measures.

As seen in Exhibits 11B-9 through 11B-11, the number of percentage change from baseline values within a particular technology category was less than what was observed in the previous summary tables. Exhibit 11B-10 shows that for entrainment, mean and median values for percent change from baseline in survival counts are positive, indicating that observed survival counts (from the three documents contributing entrainment data) were higher under baseline conditions. Under the Behavioral Systems II technology category, survival counts immediately following impingement (originating from Documents 17 and 76) were close to being equivalent between baseline and technology conditions, as the mean and median in Exhibit 11B-10 are close to zero. Exhibit 11B-11 shows that some values of percent change from baseline in percent mortality (i.e., for some species) could be very large and negative. This occurs when percent mortality at baseline is close to zero. This is one contributor to noting mean percentage changes from baseline in Exhibit 11B-11 being negative for percent mortality.

As a result of the limited number of values, along with high uncertainty in the numbers entering into the calculations and the interpretation of these numbers, percentage change from baseline values were only summarized and not further statistically analyzed.

11B.4 Statistical Modeling

In order to assess and account for various factors that are likely to influence the performance measures (percent mortality) for a given technology category, selected performance measure data (pooled across documents and studies) were statistically analyzed using analysis of variance (ANOVA) modeling techniques. The objective of this analysis was to yield a predicted average performance measure for specified levels of the factors of interest. This analysis assumes two primary components of variability in the performance measures: "between-study" variability (which represents how the average value for a given performance measure may vary from one study to another as a result of different test conditions, facilities, etc.), and "within-study" variability (which represents how these values can vary within a study or facility, such as among different species, time points, etc.).

Based upon numbers of available data (as noted in the data summaries of the previous section), statistical modeling was applied only to percent mortality data associated with impingement or entrainment. Separate fits of the statistical model were made to impingement and entrainment data, as well as for each of the technology categories having available data.

The ANOVA model used in this analysis had both "random" and "fixed" effects. When data were available for multiple studies, the model included a random "study" effect to allow for both between-study and within-study variability to be estimated. The model had the following fixed effects:

- Season at the start of data collection (fall, winter, spring, summer);
- Age category of fish (as noted within the document source); and
- Elapsed time from impingement/entrainment to mortality (in hours).

The fixed effects allowed the model to generate different performance predictions for different combinations of fixed effects (e.g., different seasons of the year, different age categories) present among the data. If data were available for only one level of a given effect (e.g., one age category), then that effect was omitted from the model.

If p represents the proportion of outcomes classified as mortality, then the model assumed that $\log(p/(1-p))$ was a linear function of the fixed effects. The model assumed independence in the value of the performance measure between different species and time points within a study. We fit this model using the GLIMMIX procedure in the SAS® System.

The statistical model was successfully applied to the following sets of data:

- Entrainment data under fixed screens (fine mesh) (n=36 data points)
    - Data were available for one study and season (fall), indicating that the random study effect and fixed season effect were removed from the model.
- Entrainment data under the reduced intake flow (other) technology (n=177 data points)
    - Data were available for one season (fall) and mortality observation time (0 hrs.), indicating that these two effects were removed from the model.
- Impingement data under traveling screens (coarse mesh) (n=683 data points)
- Impingement data under traveling screens (fine mesh) (n=254 data points)

The ANOVA model was used to estimate mean predicted values for the performance measure, for various combinations of fixed effects that were observed in the database. These values are given in the last two columns of Exhibits 11B-12 through 11B-15, with separate tables appearing for each model fitting (i.e., a particular technology category). The fixed effects entering into each model appear in the other columns of this table, with the levels of these effects corresponding to what was observed in the data.

Some conclusions made from the prediction estimates in Exhibits 11B-12 through 11B-15, are as follows (with references to statistical significance made at the 0.05 level):

- For entrainment under fixed screen (fine mesh), results in Exhibit 11B-12 suggest that the model was only able to accurately estimate mean percent mortality for juveniles (40 percent).
- Under reduced intake flow technology, average percent mortality following entrainment were predicted only for selected age categories. Exhibit 11B-13 shows that among the early age categories (e.g., larvae, juvenile), this average ranged from 27 to 34 percent. These averages did not differ significantly among age categories at the 0.05 level.
- Under traveling screens with coarse mesh, average percent mortality for impinged fish differed significantly among seasons of the year, age categories, and mortality observation times following impingement. According to Exhibit 11B-14, average percent mortality was highest in summer months, with one-half mortality estimated, compared to nearly one-third mortality in other seasons. Percent mortality averaged slightly above 50 percent for adults and juveniles, while estimate mortality at 48 hours post-impingement is nearly twice that of immediately following impingement.
- Like with coarse mesh screens, average percent mortality for impinged fish differed significantly among seasons of the year, age categories, and mortality observation times following impingement for traveling screens with fine mesh. Similar trends in estimated average percent mortality among seasons of the year were observed between fine and coarse mesh screens. These estimates cover a wide range among the different age categories, reflecting in part the small sample sizes associated with some age categories. The estimates at 8 and 24 hours post-impingement are quite high and highly variable due to smaller sample sizes (from a single study) compared to the other post-impingement time points. Thus, their estimates should be interpreted with caution.

Exhibit 11B-12. Mean Predicted Values for Percent Mortality Associated with Entrainment Under Fixed Screen (Fine Mesh), as Estimated from Mixed Model ANOVA Modeling

Factor	Level	Mean Predicted Percent Mortality
Age Category	Adult	0.0
	Juvenile	40.0
Mortality Observation Time	0 hrs.	0.0
	24 hrs.	0.1
	48 hrs.	0.2

Exhibit 11B-13. Mean Predicted Values for Percent Mortality Associated with Entrainment Under Reduced Intake Flows (Other), as Estimated from Mixed Model ANOVA Modeling

Factor	Level	Mean Predicted Percent Mortality
Age Category	Juvenile	34.2
	Larvae	27.9
	Not specified	26.6

Exhibit 11B-14. Mean Predicted Values for Percent Mortality Associated with Impingement Under Traveling Screens (Coarse Mesh), as Estimated from Mixed Model ANOVA Modeling

Factor	Level	Mean Predicted Percent Mortality
Season*	Fall	30.5
	Winter	31.9
	Spring	36.7
	Summer	50.1
Age Category*	Adult	52.8
	Juvenile	56.0
	Not specified	25.7
	Adults/Juveniles	19.6
Mortality Observation Time*	0 hrs.	21.3
	18 hrs.	41.2
	24 hrs.	34.0
	48 hrs.	38.9
	84 hrs.	37.1
	96 hrs.	53.2

* Significant differences exist among means at the 0.05 level for selected levels of this factor.

Exhibit 11B-15. Mean Predicted Values for Percent Mortality Associated with Impingement Under Traveling Screens (Fine Mesh), as Estimated from Mixed Model ANOVA Modeling

Factor	Level	Mean Predicted Percent Mortality
Season*	Fall	39.4
	Winter	23.1
	Spring	52.5
	Summer	58.6
Age Category*	Adult	2.8
	Eggs	78.0
	Juvenile	2.3
	Larvae	87.8
	Megalops	24.7
	Not specified	69.3
	Adults/Juveniles	84.3
	Zoea Stage 1	4.5
	Zoea Unstaged	39.3
	Postlarvae	96.1
Mortality Observation Time*	0 hrs.	7.8
	8 hrs.	90.9
	24 hrs.	94.0
	48 hrs.	5.7
	96 hrs.	22.3

* Significant differences exist among means at the 0.05 level for selected levels of this factor.

11B.5 Summaries of Percent Mortality, Percent Biomass, and Percent Injury Data By Technology Category, Document, and Study (Test Condition)

These exhibits provide additional detail for data summaries presented in Exhibits 11B-4 through 11B-6.

Exhibit 11B-16. Summary of Percent Mortality, Percent Biomass, and Percent Injury Data Associated with Entrainment, by Technology Category, Document, and Study (Test Condition)

Technology Category	Facility Name	Doc. ID	Study ID	Percent Immediate Mortality				Percent Biomass				Percent Injury			
				N	Mean	Min.	Max.	N	Mean	Min.	Max.	N	Mean	Min.	Max.
Barriers	Chalk Point Generating Station	49	14	0	.	.	.	5	18.9	3.3	76.0	0	.	.	.
Fixed Screen - Coarse Mesh	Dickerson	49	10	0	.	.	.	4	11.3	2.0	18.0	0	.	.	.
Fixed Screen - Coarse Mesh	Potomac River	49	12	0	.	.	.	3	5.7	3.0	9.0	0	.	.	.
Fixed Screen - Coarse Mesh	Morgantown	49	13	0	.	.	.	6	1.7	0.1	4.4	0	.	.	.
Fixed Screen - Fine Mesh	Green Island Hydroelectric Project	47	2	12	18.9	0.0	100.0	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	Delmarva Ecological Laboratory	167	253	1	16.0	16.0	16.0	0	.	.	.	0	.	.	.
Other technologies	Tracy Fish Collecting Facility	193	182	11	1.0	0.0	1.9	0	.	.	.	0	.	.	.
Reduced Intake Flows - Other	Anclote Power Plant	4	58	87	32.6	0.0	88.4	0	.	.	.	0	.	.	.
Reduced Intake Flows - Other	Anclote Power Plant	4	59	90	23.4	0.0	81.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	1	83.9	83.9	83.9	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Roseton Generating Station	130	216	10	1.1	0.2	3.3	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	217	10	4.8	0.7	12.1	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	130	218	10	4.4	0.1	20.3	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Lovett Generating Station	130	219	10	3.8	0.2	19.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	220	10	1.2	0.1	5.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	130	221	10	1.1	0.1	1.9	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Roseton Generating Station	130	222	9	1.6	0.2	4.3	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	223	9	9.9	0.9	44.7	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	130	224	9	4.6	0.1	20.3	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Lovett Generating Station	130	225	9	3.6	0.2	13.5	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	226	9	3.3	0.1	22.5	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	130	227	9	1.6	0.1	5.6	0	.	.	.	0	.	.	.

Exhibit 11B-17. Summary of Percent Mortality Data Associated with Entrainment, by Technology Category, Document, Study (Test Condition), and Mortality Observation Time

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Observation Tme	Percent Mortality			
					N	Mean	Minimum	Maximum
Fixed Screen - Fine Mesh	Green Island Hydroelectric Project	47	2	0 hr.	12	18.9	0.0	100.0
Fixed Screen - Fine Mesh	Green Island Hydroelectric Project	47	2	24 hr.	12	41.5	0.0	100.0
Fixed Screen - Fine Mesh	Green Island Hydroelectric Project	47	2	48 hr.	12	53.3	0.0	100.0
Fixed Screen - Fine Mesh	Delmarva Ecological Laboratory	167	253	0 hr.	1	16.0	16.0	16.0
Other technologies	Tracy Fish Collecting Facility	193	182	0 hr.	11	1.0	0.0	1.9
Reduced Intake Flows - Other	Anclote Power Plant	4	58	0 hr.	87	32.6	0.0	88.4
Reduced Intake Flows - Other	Anclote Power Plant	4	59	0 hr.	90	23.4	0.0	81.0
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	0 hr.	1	83.9	83.9	83.9
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	96 hr.	1	92.2	92.2	92.2
Traveling Screen - Coarse Mesh	Multiple test facilities	130	62	24 hr.	10	17.5	4.1	54.1
Traveling Screen - Coarse Mesh	Multiple test facilities	130	63	24 hr.	9	22.4	3.5	77.8
Traveling Screen - Coarse Mesh	Roseton Generating Station	130	216	0 hr.	10	1.1	0.2	3.3
Traveling Screen - Coarse Mesh	Roseton Generating Station	130	216	24 hr.	10	1.4	0.2	3.7
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	217	0 hr.	10	4.8	0.7	12.1
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	217	24 hr.	10	5.7	0.8	14.3
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	130	218	0 hr.	10	4.4	0.1	20.3
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	130	218	24 hr.	10	5.4	0.1	25.4
Traveling Screen - Coarse Mesh	Lovett Generating Station	130	219	0 hr.	10	3.8	0.2	19.0
Traveling Screen - Coarse Mesh	Lovett Generating Station	130	219	24 hr.	10	4.8	0.2	24.0
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	220	0 hr.	10	1.2	0.1	5.0
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	220	24 hr.	10	1.5	0.1	6.0
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	130	221	0 hr.	10	1.1	0.1	1.9
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	130	221	24 hr.	10	1.3	0.1	2.4
Traveling Screen - Coarse Mesh	Roseton Generating Station	130	222	0 hr.	9	1.6	0.2	4.3
Traveling Screen - Coarse Mesh	Roseton Generating Station	130	222	24 hr.	9	1.9	0.2	4.8
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	223	0 hr.	9	9.9	0.9	44.7
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	223	24 hr.	9	11.8	1.0	53.7
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	130	224	0 hr.	9	4.6	0.1	20.3
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	130	224	24 hr.	9	5.7	0.1	25.4
Traveling Screen - Coarse Mesh	Lovett Generating Station	130	225	0 hr.	9	3.6	0.2	13.5
Traveling Screen - Coarse Mesh	Lovett Generating Station	130	225	24 hr.	9	4.0	0.3	15.4
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	226	0 hr.	9	3.3	0.1	22.5
Traveling Screen - Coarse Mesh	Indian Point Generating Station	130	226	24 hr.	9	4.1	0.1	28.5
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	130	227	0 hr.	9	1.6	0.1	5.6
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	130	227	24 hr.	9	1.8	0.1	5.7

Exhibit 11B-18. Summary of Percent Mortality, Percent Biomass, and Percent Injury Data Associated with Impingement, by Technology Category, Document, and Study (Test Condition)

Technology Category	Facility Name	Doc. ID	Study ID	Percent Immediate Mortality				Percent Biomass				Percent Injury			
				N	Mean	Min.	Max.	N	Mean	Min.	Max.	N	Mean	Min.	Max.
Barriers	Bowline Point Generating Station	38	106	1	1.6	1.6	1.6	0	.	.	.	0	.	.	.
Barriers	Bowline Point Generating Station	38	189	2	1.4	1.3	1.6	0	.	.	.	0	.	.	.
Barriers	Chalk Point Generating Station	126	113	8	82.1	43.1	98.7	0	.	.	.	0	.	.	.
Barriers	Chalk Point Generating Station	126	114	10	83.2	24.7	98.3	0	.	.	.	0	.	.	.
Behavioral Systems I	Brayton Point Generating Station Unit 4	46	119	12	39.8	1.2	100.0	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	169	151	10	16.2	0.0	65.0	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	Test laboratory	171	152	1	3.7	3.7	3.7	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	Test laboratory	195	117	27	27.3	0.0	91.8	0	.	.	.	0	.	.	.
Off-shore Location (any combination othe	Oswego Steam Station	193	158	8	48.3	8.0	85.2	0	.	.	.	0	.	.	.
Off-shore Location with velocity Cap	Various Coastal Stations in the U.K.	78	46	0	.	.	.	7	42.1	0.2	180.0	0	.	.	.
Other technologies	No facility specified	146	73	6	7.5	0.0	30.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Moss Landing	18	102	8	51.4	0.0	94.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Moss Landing	18	103	7	54.9	3.0	86.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Moss Landing	18	104	7	55.1	20.0	83.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Surry Power Station	43	18	12	3.9	0.0	18.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Dunkirk Steam Station	44	8	85	8.4	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	46	78	6	53.6	0.0	93.7	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Indian Point Generating Station	46	82	3	28.3	8.0	39.8	0	.	.	.	0	.	.	.

Exhibit 11B-18. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID	Percent Immediate Mortality				Percent Biomass				Percent Injury			
				N	Mean	Min.	Max.	N	Mean	Min.	Max.	N	Mean	Min.	Max.
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	46	118	6	52.7	4.6	95.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Huntley Steam Station	51	1	32	12.4	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Quad Cities Generating Station	60	9	0	.	.	.	48	1.4	0.0	12.8	0	.	.	.
Traveling Screen - Coarse Mesh	Oyster Creek Nuclear Generating Station	62	19	83	21.3	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	65	50	57	23.0	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	66	71	42	13.7	0.5	41.2	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	68	34	31.3	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	70	22	42.1	0.0	99.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	72	22	53.1	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	129	31	48.6	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	47	8	8.6	0.0	18.5	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	48	8	24.4	0.0	78.3	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Roseton Generating Station	138	49	4	5.7	2.2	12.1	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	51	4	2.0	0.0	3.7	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	88	16	29.9	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	89	5	57.4	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	90	21	17.4	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	163	153	4	8.5	3.0	16.0	0	.	.	.	0	.	.	.

Exhibit 11B-18. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID	Percent Immediate Mortality N	Mean	Min.	Max.	Percent Biomass N	Mean	Min.	Max.	Percent Injury N	Mean	Min.	Max.
Traveling Screen - Coarse Mesh	Roseton Generating Station	163	154	4	9.8	2.0	21.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Oyster Creek Nuclear Generating Station	164	150	20	27.3	5.0	78.0	0	.	.	.	20	28.1	5.0	64.0
Traveling Screen - Coarse Mesh	Dunkirk Steam Station	193	159	16	18.6	0.0	68.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	168	9	0.2	0.0	1.7	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	169	9	0.1	0.0	0.8	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	172	1	2.6	2.6	2.6	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	173	1	22.3	22.3	22.3	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	174	1	41.4	41.4	41.4	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	175	1	35.6	35.6	35.6	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	176	5	10.8	3.0	20.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	177	2	9.0	8.0	10.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	178	1	29.0	29.0	29.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	205	236	21	49.6	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	205	237	22	43.4	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	205	238	24	54.3	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	205	239	20	42.2	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Barney Davis Power Station	43	21	5	40.9	4.0	76.6	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Dunkirk Steam Station	46	79	16	7.1	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Somerset Generating Station	64	5	31	1.8	0.0	36.9	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Le Blayais	73	6	18	53.9	0.0	100.0	0	.	.	.	0	.	.	.

Exhibit 11B-18. (Continued)

				Percent Immediate Mortality				Percent Biomass				Percent Injury			
Technology Category	Facility Name	Doc. ID	Study ID	N	Mean	Min.	Max.	N	Mean	Min.	Max.	N	Mean	Min.	Max.
Traveling Screen - Fine Mesh	Big Bend Power Station	106	16	11	51.7	1.2	98.5	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Big Bend Power Station	118	74	8	24.1	0.0	56.8	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Big Bend Power Station	118	76	8	87.6	57.1	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Big Bend Power Station	118	84	8	3.4	0.0	8.7	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Big Bend Power Station	118	86	8	4.4	0.0	34.9	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Barney Davis Power Station	168	66	34	6.8	0.0	45.5	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Test laboratory	192	112	1	24.4	24.4	24.4	0	.	.	.	10	7.7	0.0	34.0
Traveling Screen - Fine Mesh	Test laboratory	192	130	0	.	.	.	0	.	.	.	10	8.1	0.0	29.8
Traveling Screen - Fine Mesh	Test laboratory	192	131	0	.	.	.	0	.	.	.	10	6.0	0.0	26.7
Traveling Screen - Fine Mesh	Prairie Island Nuclear Generating Station	193	160	33	55.6	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Salem Generating Station	193	162	31	43.4	8.0	90.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	193	165	16	14.1	0.0	54.2	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	193	166	11	30.1	3.0	90.1	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Brayton Point Generating Station Unit 4	193	180	12	25.2	0.9	98.3	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Indian Point Generating Station	193	190	11	36.6	0.0	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Big Bend Power Station	206	233	7	35.4	1.0	84.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Big Bend Power Station	206	234	7	39.1	10.0	71.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Big Bend Power Station	206	235	7	32.1	12.0	84.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	228	56	1.5	0.0	25.5	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	229	11	0.2	0.0	2.7	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	230	8	48.9	9.8	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	231	5	63.1	13.7	100.0	0	.	.	.	0	.	.	.
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	232	10	39.0	6.3	100.0	0	.	.	.	0	.	.	.

Exhibit 11B-19. Summary of Percent Mortality Data Associated with Impingement, by Technology Category, Document, Study (Test Condition), and Mortality Observation Time

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Observation Time	Percent Mortality N	Mean	Minimum	Maximum
Barriers	Bowline Point Generating Station	38	106	0 hr.	1	1.6	1.6	1.6
Barriers	Bowline Point Generating Station	38	189	0 hr.	2	1.4	1.3	1.6
Barriers	Chalk Point Generating Station	126	113	0 hr.	8	82.1	43.1	98.7
Barriers	Chalk Point Generating Station	126	114	0 hr.	10	83.2	24.7	98.3
Behavioral Systems I	Brayton Point Generating Station Unit 4	46	119	0 hr.	12	39.8	1.2	100.0
Fixed Screen – Fine Mesh	TVA laboratory	169	151	0 hr.	10	16.2	0.0	65.0
Fixed Screen – Fine Mesh	TVA laboratory	169	151	12 hr.	10	27.2	0.0	91.0
Fixed Screen – Fine Mesh	TVA laboratory	169	151	24 hr.	10	29.1	0.0	91.0
Fixed Screen – Fine Mesh	TVA laboratory	169	151	48 hr.	10	30.7	1.0	91.0
Fixed Screen – Fine Mesh	Test laboratory	171	152	0 hr.	1	3.7	3.7	3.7
Fixed Screen – Fine Mesh	Arthur Kill Generating Station	193	155	24 hr.	30	47.7	0.0	100.0
Fixed Screen – Fine Mesh	Test laboratory	195	117	0 hr.	27	27.3	0.0	91.8
Off-shore Location (any combination othe	Oswego Steam Station	193	158	0 hr.	8	48.3	8.0	85.2
Other technologies	No facility specified	146	73	0 hr.	6	7.5	0.0	30.0
Traveling Screen - Coarse Mesh	Moss Landing	18	102	0 hr.	8	51.4	0.0	94.0
Traveling Screen - Coarse Mesh	Moss Landing	18	102	96 hr.	8	64.0	0.0	100.0
Traveling Screen - Coarse Mesh	Moss Landing	18	103	0 hr.	7	54.9	3.0	86.0
Traveling Screen - Coarse Mesh	Moss Landing	18	103	96 hr.	7	76.6	16.0	100.0
Traveling Screen - Coarse Mesh	Moss Landing	18	104	0 hr.	7	55.1	20.0	83.0
Traveling Screen - Coarse Mesh	Moss Landing	18	104	96 hr.	7	72.9	24.0	100.0
Traveling Screen - Coarse Mesh	Surry Power Station	43	18	0 hr.	12	3.9	0.0	18.0
Traveling Screen - Coarse Mesh	Dunkirk Steam Station	44	8	0 hr.	85	8.4	0.0	100.0
Traveling Screen - Coarse Mesh	Dunkirk Steam Station	44	8	24 hr.	85	15.1	0.0	100.0
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	46	78	0 hr.	6	53.6	0.0	93.7
Traveling Screen - Coarse Mesh	Indian Point Generating Station	46	82	0 hr.	3	28.3	8.0	39.8
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	46	118	0 hr.	6	52.7	4.6	95.0
Traveling Screen - Coarse Mesh	Huntley Steam Station	51	1	0 hr.	32	12.4	0.0	100.0
Traveling Screen - Coarse Mesh	Huntley Steam Station	51	1	24 hr.	32	17.5	0.0	100.0
Traveling Screen - Coarse Mesh	Arthur Kill Generating Station	54	156	24 hr.	54	14.3	0.0	78.1
Traveling Screen - Coarse Mesh	Arthur Kill Generating Station	54	157	24 hr.	49	14.7	0.0	100.0
Traveling Screen - Coarse Mesh	Oyster Creek Nuclear Generating Station	62	19	0 hr.	83	21.3	0.0	100.0
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	65	50	0 hr.	57	23.0	0.0	100.0
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	66	71	0 hr.	42	13.7	0.5	41.2

Exhibit 11B-19. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Observation Time	Percent Mortality			
					N	Mean	Minimum	Maximum
Traveling Screen - Coarse Mesh	Salem Generating Station	85	147	48 hr.	1	20.7	20.7	20.7
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	68	0 hr.	34	31.3	0.0	100.0
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	70	0 hr.	22	42.1	0.0	99.0
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	72	0 hr.	22	53.1	0.0	100.0
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	129	0 hr.	31	48.6	0.0	100.0
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	47	0 hr.	8	8.6	0.0	18.5
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	48	0 hr.	8	24.4	0.0	78.3
Traveling Screen - Coarse Mesh	Roseton Generating Station	138	49	0 hr.	4	5.7	2.2	12.1
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	51	0 hr.	4	2.0	0.0	3.7
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	88	0 hr.	16	29.9	0.0	100.0
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	88	24 hr.	5	38.8	0.0	100.0
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	88	96 hr.	6	66.7	0.0	100.0
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	89	0 hr.	5	57.4	0.0	100.0
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	90	0 hr.	21	17.4	0.0	100.0
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	90	24 hr.	8	26.1	0.0	100.0
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	90	96 hr.	8	54.7	0.0	100.0
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	163	153	0 hr.	4	8.5	3.0	16.0
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	163	153	96 hr.	2	41.0	38.0	44.0
Traveling Screen - Coarse Mesh	Roseton Generating Station	163	154	0 hr.	4	9.8	2.0	21.0
Traveling Screen - Coarse Mesh	Oyster Creek Nuclear Generating Station	164	150	0 hr.	20	27.3	5.0	78.0
Traveling Screen - Coarse Mesh	Dunkirk Steam Station	193	159	0 hr.	16	18.6	0.0	68.0
Traveling Screen - Coarse Mesh	Salem Generating Station	193	161	18 hr.	26	31.7	2.0	82.0
Traveling Screen - Coarse Mesh	Indian Point Generating Station	193	163	96 hr.	44	42.6	0.0	100.0
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	168	0 hr.	9	0.2	0.0	1.7
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	168	84 hr.	9	13.6	0.0	80.2
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	169	0 hr.	9	0.1	0.0	0.8
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	169	84 hr.	9	17.4	0.0	78.5
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	172	0 hr.	1	2.6	2.6	2.6
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	172	96 hr.	1	10.3	10.3	10.3
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	173	0 hr.	1	22.3	22.3	22.3
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	173	96 hr.	1	29.3	29.3	29.3
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	174	0 hr.	1	41.4	41.4	41.4
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	174	96 hr.	1	58.2	58.2	58.2
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	175	0 hr.	1	35.6	35.6	35.6
Traveling Screen - Coarse Mesh	Mystic Generating Station	193	175	96 hr.	1	38.6	38.6	38.6

Exhibit 11B-19. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Observation Time	Percent Mortality			
					N	Mean	Minimum	Maximum
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	176	0 hr.	5	10.8	3.0	20.0
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	176	96 hr.	2	41.0	38.0	44.0
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	177	0 hr.	2	9.0	8.0	10.0
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	177	96 hr.	2	72.5	71.0	74.0
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	178	0 hr.	1	29.0	29.0	29.0
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	178	96 hr.	1	81.0	81.0	81.0
Traveling Screen - Coarse Mesh	Potomac River	196	91	48 hr.	33	24.0	0.0	100.0
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	205	236	0 hr.	21	49.6	0.0	100.0
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	205	237	0 hr.	22	43.4	0.0	100.0
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	205	238	0 hr.	24	54.3	0.0	100.0
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	205	239	0 hr.	20	42.2	0.0	100.0
Traveling Screen - Fine Mesh	Barney Davis Power Station	43	21	0 hr.	5	40.9	4.0	76.6
Traveling Screen - Fine Mesh	Dunkirk Steam Station	46	79	0 hr.	16	7.1	0.0	100.0
Traveling Screen - Fine Mesh	Brayton Point Generating Station Unit 4	46	83	48 hr.	12	43.5	3.7	100.0
Traveling Screen - Fine Mesh	Somerset Generating Station	64	5	0 hr.	31	1.8	0.0	36.9
Traveling Screen - Fine Mesh	Somerset Generating Station	64	5	96 hr.	31	28.2	0.0	100.0
Traveling Screen - Fine Mesh	Le Blayais	73	6	0 hr.	18	53.9	0.0	100.0
Traveling Screen - Fine Mesh	Big Bend Power Station	106	16	0 hr.	11	51.7	1.2	98.5
Traveling Screen - Fine Mesh	Big Bend Power Station	118	74	0 hr.	8	24.1	0.0	56.8
Traveling Screen - Fine Mesh	Big Bend Power Station	118	74	48 hr.	8	10.5	0.3	17.8
Traveling Screen - Fine Mesh	Big Bend Power Station	118	74	96 hr.	8	24.7	2.1	54.1
Traveling Screen - Fine Mesh	Big Bend Power Station	118	76	0 hr.	8	87.6	57.1	100.0
Traveling Screen - Fine Mesh	Big Bend Power Station	118	76	48 hr.	4	57.6	0.0	89.1
Traveling Screen - Fine Mesh	Big Bend Power Station	118	76	96 hr.	4	57.8	0.0	89.9
Traveling Screen - Fine Mesh	Big Bend Power Station	118	84	0 hr.	8	3.4	0.0	8.7
Traveling Screen - Fine Mesh	Big Bend Power Station	118	84	48 hr.	8	9.5	3.4	16.1
Traveling Screen - Fine Mesh	Big Bend Power Station	118	84	96 hr.	8	37.0	19.8	57.2
Traveling Screen - Fine Mesh	Big Bend Power Station	118	86	0 hr.	8	4.4	0.0	34.9
Traveling Screen - Fine Mesh	Big Bend Power Station	118	86	48 hr.	8	5.5	0.0	28.2
Traveling Screen - Fine Mesh	Big Bend Power Station	118	86	96 hr.	8	18.8	0.0	85.0
Traveling Screen - Fine Mesh	Barney Davis Power Station	168	66	0 hr.	34	6.8	0.0	45.5
Traveling Screen - Fine Mesh	Test laboratory	192	112	0 hr.	1	24.4	24.4	24.4
Traveling Screen - Fine Mesh	Test laboratory	192	112	48 hr.	10	1.2	0.0	4.3
Traveling Screen - Fine Mesh	Test laboratory	192	130	48 hr.	10	1.9	0.0	4.7
Traveling Screen - Fine Mesh	Test laboratory	192	131	48 hr.	10	1.5	0.0	4.5
Traveling Screen - Fine Mesh	Prairie Island Nuclear Generating Station	193	160	0 hr.	33	55.6	0.0	100.0

Exhibit 11B-19. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Observation Time	Percent Mortality			
					N	Mean	Minimum	Maximum
Traveling Screen - Fine Mesh	Salem Generating Station	193	162	0 hr.	31	43.4	8.0	90.0
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	193	165	0 hr.	16	14.1	0.0	54.2
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	193	166	0 hr.	11	30.1	3.0	90.1
Traveling Screen - Fine Mesh	Brayton Point Generating Station Unit 4	193	180	0 hr.	12	25.2	0.9	98.3
Traveling Screen - Fine Mesh	Brayton Point Generating Station Unit 4	193	181	48 hr.	12	37.3	1.6	100.0
Traveling Screen - Fine Mesh	Indian Point Generating Station	193	190	0 hr.	11	36.6	0.0	100.0
Traveling Screen - Fine Mesh	Indian Point Generating Station	193	190	96 hr.	11	78.8	12.0	100.0
Traveling Screen - Fine Mesh	Big Bend Power Station	206	233	0 hr.	7	35.4	1.0	84.0
Traveling Screen - Fine Mesh	Big Bend Power Station	206	234	0 hr.	7	39.1	10.0	71.0
Traveling Screen - Fine Mesh	Big Bend Power Station	206	235	0 hr.	7	32.1	12.0	84.0
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	228	0 hr.	56	1.5	0.0	25.5
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	228	24 hr.	56	28.0	0.0	100.0
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	228	8 hr.	56	22.4	0.0	100.0
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	229	0 hr.	11	0.2	0.0	2.7
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	229	24 hr.	11	31.3	0.0	100.0
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	229	8 hr.	11	22.5	0.0	100.0
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	230	0 hr.	8	48.9	9.8	100.0
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	231	0 hr.	5	63.1	13.7	100.0
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	232	0 hr.	10	39.0	6.3	100.0

Exhibit 11B-20. Summary of Percent Mortality, Percent Biomass, and Percent Injury Data Associated with <u>Diversion (not impingement or entrainment)</u>, by Technology Category, Document, and Study (Test Condition)

Technology Category	Facility Name	Doc. ID	Study ID	Percent Immediate Mortality				Percent Biomass				Percent Injury			
				N	Mean	Min.	Max.	N	Mean	Min.	Max.	N	Mean	Min.	Max.
Behavioral Systems I	San Onofre Nuclear Generating Station (SONGS)	53	65	64	24.6	0.0	100.0	0	.	.	.	0	.	.	.
Behavioral Systems II	Heysham Power Station	151	52	1	100.0	100.0	100.0	0	.	.	.	0	.	.	.
Behavioral Systems II	Heysham Power Station	151	53	1	77.4	77.4	77.4	0	.	.	.	0	.	.	.
Behavioral Systems II	Heysham Power Station	151	54	1	38.2	38.2	38.2	0	.	.	.	0	.	.	.
Behavioral Systems II	Fawley Aquatic Research Laboratory	152	57	2	96.3	96.2	96.5	0	.	.	.	0	.	.	.
Fixed Screen - Coarse Mesh	Elwha Dam	42	4	4	0.6	0.0	1.2	0	.	.	.	0	.	.	.
Fixed Screen - Coarse Mesh	Elwha Dam	42	7	0	.	.	.	0	.	.	.	4	1.9	1.5	2.6
Fixed Screen - Coarse Mesh	Elwha Dam	42	121	4	0.2	0.0	0.4	0	.	.	.	0	.	.	.
Fixed Screen - Coarse Mesh	Elwha Dam	42	122	2	0.2	0.0	0.4	0	.	.	.	0	.	.	.
Fixed Screen - Coarse Mesh	Elwha Dam	42	123	2	1.2	0.9	1.4	0	.	.	.	0	.	.	.
Fixed Screen - Coarse Mesh	Elwha Dam	42	125	0	.	.	.	0	.	.	.	4	4.5	3.5	5.8
Fixed Screen - Coarse Mesh	Elwha Dam	42	126	0	.	.	.	0	.	.	.	2	13.1	10.8	15.4
Fixed Screen - Coarse Mesh	Elwha Dam	42	127	0	.	.	.	0	.	.	.	2	22.1	21.7	22.5
Fixed Screen - Fine Mesh	TVA laboratory	170	92	11	0.7	0.0	3.6	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	93	17	5.1	0.0	22.0	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	94	19	6.9	0.5	29.5	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	95	11	1.1	0.0	4.7	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	96	17	6.4	0.0	46.5	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	97	19	4.6	0.0	19.9	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	132	11	2.5	0.0	11.1	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	133	11	5.9	0.0	20.4	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	134	17	10.2	0.0	34.3	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	135	17	16.0	0.0	82.6	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	136	24	16.2	0.0	47.0	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	137	21	26.1	0.0	76.6	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	138	11	5.0	0.0	22.1	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	139	11	12.3	0.0	54.4	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	140	17	10.8	0.0	66.6	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	141	17	15.4	0.0	82.0	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	142	24	14.2	0.6	61.9	0	.	.	.	0	.	.	.
Fixed Screen - Fine Mesh	TVA laboratory	170	143	21	24.2	0.0	86.5	0	.	.	.	0	.	.	.
Other technologies	Glenn-Colusa Irrigation District Fish Screen	147	64	2	74.2	66.0	82.3	0	.	.	.	0	.	.	.

Exhibit 11B-21. Summary of Percent Mortality Data Associated with Diversion (not impingement or entrainment), by Technology Category, Document, Study (Test Condition), and Mortality Observation Time

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Observation Time	Percent Mortality			
					N	Mean	Minimum	Maximum
Behavioral Systems I	San Onofre Nuclear Generating Station (SONGS)	53	65	0 hr.	64	24.6	0.0	100.0
Behavioral Systems II	Heysham Power Station	151	52	0 hr.	1	100.0	100.0	100.0
Behavioral Systems II	Heysham Power Station	151	53	0 hr.	1	77.4	77.4	77.4
Behavioral Systems II	Heysham Power Station	151	54	0 hr.	1	38.2	38.2	38.2
Behavioral Systems II	Fawley Aquatic Research Laboratory	152	57	0 hr.	2	96.3	96.2	96.5
Fixed Screen - Coarse Mesh	Elwha Dam	42	4	0 hr.	4	0.6	0.0	1.2
Fixed Screen - Coarse Mesh	Elwha Dam	42	121	0 hr.	4	0.2	0.0	0.4
Fixed Screen - Coarse Mesh	Elwha Dam	42	122	0 hr.	2	0.2	0.0	0.4
Fixed Screen - Coarse Mesh	Elwha Dam	42	123	0 hr.	2	1.2	0.9	1.4
Fixed Screen - Fine Mesh	TVA laboratory	170	92	0 hr.	11	0.7	0.0	3.6
Fixed Screen - Fine Mesh	TVA laboratory	170	93	0 hr.	17	5.1	0.0	22.0
Fixed Screen - Fine Mesh	TVA laboratory	170	94	0 hr.	19	6.9	0.5	29.5
Fixed Screen - Fine Mesh	TVA laboratory	170	95	0 hr.	11	1.1	0.0	4.7
Fixed Screen - Fine Mesh	TVA laboratory	170	96	0 hr.	17	6.4	0.0	46.5
Fixed Screen - Fine Mesh	TVA laboratory	170	97	0 hr.	19	4.6	0.0	19.9
Fixed Screen - Fine Mesh	TVA laboratory	170	132	0 hr.	11	2.5	0.0	11.1
Fixed Screen - Fine Mesh	TVA laboratory	170	133	0 hr.	11	5.9	0.0	20.4
Fixed Screen - Fine Mesh	TVA laboratory	170	134	0 hr.	17	10.2	0.0	34.3
Fixed Screen - Fine Mesh	TVA laboratory	170	135	0 hr.	17	16.0	0.0	82.6
Fixed Screen - Fine Mesh	TVA laboratory	170	136	0 hr.	24	16.2	0.0	47.0
Fixed Screen - Fine Mesh	TVA laboratory	170	137	0 hr.	21	26.1	0.0	76.6
Fixed Screen - Fine Mesh	TVA laboratory	170	138	0 hr.	11	5.0	0.0	22.1
Fixed Screen - Fine Mesh	TVA laboratory	170	139	0 hr.	11	12.3	0.0	54.4
Fixed Screen - Fine Mesh	TVA laboratory	170	140	0 hr.	17	10.8	0.0	66.6
Fixed Screen - Fine Mesh	TVA laboratory	170	141	0 hr.	17	15.4	0.0	82.0
Fixed Screen - Fine Mesh	TVA laboratory	170	142	0 hr.	24	14.2	0.6	61.9
Fixed Screen - Fine Mesh	TVA laboratory	170	143	0 hr.	21	24.2	0.0	86.5
Other technologies	Glenn-Colusa Irrigation District Fish Screen	147	64	0 hr.	2	74.2	66.0	82.3

Exhibit 11B-22. Summary of Percent Mortality Data for Outcomes Other than Impingement, Entrainment, or Diversion, by Technology Category, Document, Study (Test Condition), and Mortality Observation Time

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Observation Time	Percent Mortality			
					N	Mean	Minimum	Maximum
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	11	24 hr.	16	12.0	0.0	53.5
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	11	48 hr.	16	21.2	0.0	69.6

11B.6 Summary of Mortality and Survival Count Data by Technology Category, Document, Study (Test Condition), and Mortality Observation Time

These exhibits provide additional detail for data summaries presented in Exhibits 11B-7 and 11B-8.

Exhibit 11B-23. Summary of Mortality and Survival Count Data by Technology Category, Document, Study (Test Condition), and Mortality Observation Time

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Obs. Time	Mortality Counts				Survival Counts			
					N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum
Entrainment												
Barriers	Lovett Generating Station	40	108	0 hr.	4	661	1	2432	0	.	.	.
Barriers	Lovett Generating Station	41	110	0 hr.	4	2075	220	6133	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	17	0 hr.	0	.	.	.	1	23572	23572	23572
Behavioral Systems II	Pine Hydroelectric Project	81	25	0 hr.	0	.	.	.	1	22254	22254	22254
Behavioral Systems II	Pine Hydroelectric Project	81	26	0 hr.	0	.	.	.	1	17762	17762	17762
Behavioral Systems II	Pine Hydroelectric Project	81	28	0 hr.	0	.	.	.	1	388	388	388
Behavioral Systems II	Pine Hydroelectric Project	81	29	0 hr.	0	.	.	.	1	467	467	467
Behavioral Systems II	Pine Hydroelectric Project	81	30	0 hr.	0	.	.	.	1	396	396	396
Behavioral Systems II	Pine Hydroelectric Project	81	32	0 hr.	0	.	.	.	1	573	573	573
Behavioral Systems II	Pine Hydroelectric Project	81	33	0 hr.	0	.	.	.	1	781	781	781
Behavioral Systems II	Pine Hydroelectric Project	81	34	0 hr.	0	.	.	.	1	487	487	487
Behavioral Systems II	Pine Hydroelectric Project	81	36	0 hr.	0	.	.	.	1	748	748	748
Behavioral Systems II	Pine Hydroelectric Project	81	37	0 hr.	0	.	.	.	1	839	839	839
Behavioral Systems II	Pine Hydroelectric Project	81	38	0 hr.	0	.	.	.	1	928	928	928
Fixed Screen - Fine Mesh	Green Island Hydroelectric Project	47	2	0 hr.	12	5	0	28	0	.	.	.
Fixed Screen - Fine Mesh	Green Island Hydroelectric Project	47	2	24 hr.	12	33	0	170	0	.	.	.
Fixed Screen - Fine Mesh	Green Island Hydroelectric Project	47	2	48 hr.	12	40	0	208	0	.	.	.
Fixed Screen - Fine Mesh	Delmarva Ecological Laboratory	167	253	0 hr.	1	16	16	16	0	.	.	.
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	0 hr.	1	601	601	601	1	115	115	115
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	96 hr.	0	.	.	.	1	56	56	56
Impingement												
Barriers	Bowline Point Generating Station	38	106	0 hr.	2	1941	232	3649	0	.	.	.
Barriers	Chalk Point Generating Station	49	15	0 hr.	5	863291	41910	1948132	0	.	.	.
Barriers	Chalk Point Generating Station	49	120	0 hr.	5	86421	10459	164738	0	.	.	.

Exhibit 11B-23. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Obs. Time	Mortality Counts				Survival Counts			
					N	Mean	Mini-mum	Maxi-mum	N	Mean	Mini-mum	Maxi-mum
Barriers	Chalk Point Generating Station	126	113	0 hr.	0	.	.	.	8	533702	29908	1948132
Barriers	Chalk Point Generating Station	126	114	0 hr.	0	.	.	.	10	208707	8914	1599762
Behavioral Systems II	Hinkley Point Power Station	17	98	0 hr.	0	.	.	.	6	3624	1176	7271
Behavioral Systems II	Heysham Power Station	76	41	0 hr.	0	.	.	.	5	8863	288	22158
Behavioral Systems II	Salem Generating Station	125	60	0 hr.	4	10282	912	20564	0	.	.	.
Fixed Screen - Fine Mesh	Test laboratory	171	152	0 hr.	1	129	129	129	0	.	.	.
Fixed Screen - Fine Mesh	Arthur Kill Generating Station	193	155	24 hr.	0	.	.	.	30	34	0	342
Off-shore Location (any combination othe	Oswego Steam Station	193	158	0 hr.	8	356	13	1647	8	247	8	1443
Traveling Screen - Coarse Mesh	Dunkirk Steam Station	44	8	0 hr.	85	5	0	62	85	251	0	6002
Traveling Screen - Coarse Mesh	Dunkirk Steam Station	44	8	24 hr.	85	15	0	142	85	239	0	5948
Traveling Screen - Coarse Mesh	Huntley Steam Station	51	1	0 hr.	32	13	0	282	32	374	0	3357
Traveling Screen - Coarse Mesh	Huntley Steam Station	51	1	24 hr.	32	64	0	866	32	319	0	2878
Traveling Screen - Coarse Mesh	Arthur Kill Generating Station	54	156	24 hr.	0	.	.	.	54	107	1	1331
Traveling Screen - Coarse Mesh	Arthur Kill Generating Station	54	157	24 hr.	0	.	.	.	49	65	0	721
Traveling Screen - Coarse Mesh	Oyster Creek Nuclear Generating Station	62	19	0 hr.	83	47	0	1343	83	167	0	6457
Traveling Screen - Coarse Mesh	Calvert Cliffs Nuclear Generating Station	66	71	0 hr.	42	175844	442	2229859	0	.	.	.
Traveling Screen - Coarse Mesh	Salem Generating Station	85	147	48 hr.	0	.	.	.	1	1236	1236	1236
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	68	0 hr.	34	1061	0	24759	34	352	0	4045
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	70	0 hr.	0	.	.	.	22	2215	28	17719
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	72	0 hr.	0	.	.	.	22	619	6	3426
Traveling Screen - Coarse Mesh	Roseton Generating Station	136	129	0 hr.	31	308	0	5307	31	116	0	1442
Traveling Screen - Coarse Mesh	Roseton Generating Station	138	49	0 hr.	0	.	.	.	4	346	37	524
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	51	0 hr.	0	.	.	.	4	658	32	1167
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	186	0 hr.	50	169	1	1646	0	.	.	.
Traveling Screen - Coarse Mesh	JEA Northside Generating System	138	187	0 hr.	41	136	1	1642	0	.	.	.
Traveling Screen - Coarse Mesh	Hanford Generating Project	141	43	0 hr.	26	20	1	216	0	.	.	.
Traveling Screen - Coarse Mesh	Hanford Generating Project	141	44	0 hr.	11	239	1	2398	0	.	.	.
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	88	0 hr.	11	1	0	5	11	7	0	28
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	88	24 hr.	5	7	0	31	5	7	0	28

Exhibit 11B-23. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Obs. Time	Mortality Counts N	Mortality Counts Mean	Mortality Counts Minimum	Mortality Counts Maximum	Survival Counts N	Survival Counts Mean	Survival Counts Minimum	Survival Counts Maximum
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	88	96 hr.	6	2	0	8	6	1	0	2
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	90	0 hr.	16	0	0	3	16	6	0	26
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	90	24 hr.	8	4	0	29	8	3	0	10
Traveling Screen - Coarse Mesh	Mystic Generating Station	143	90	96 hr.	8	2	0	12	8	3	0	11
Traveling Screen - Coarse Mesh	Dunkirk Steam Station	193	159	0 hr.	16	105	0	663	16	372	1	2877
Traveling Screen - Coarse Mesh	Indian Point Generating Station	193	163	96 hr.	44	34	0	848	44	85	0	1839
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	168	0 hr.	0	.	.	.	9	95	28	145
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	168	84 hr.	0	.	.	.	9	95	28	145
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	169	0 hr.	0	.	.	.	9	107	38	187
Traveling Screen - Coarse Mesh	Danskammer Point Generating Station	193	169	84 hr.	0	.	.	.	9	107	38	187
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	176	0 hr.	0	.	.	.	5	1966	412	5891
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	176	96 hr.	0	.	.	.	2	1323	393	2253
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	177	0 hr.	0	.	.	.	2	1320	256	2383
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	177	96 hr.	0	.	.	.	2	471	237	705
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	178	0 hr.	0	.	.	.	1	254	254	254
Traveling Screen - Coarse Mesh	Bowline Point Generating Station	193	178	96 hr.	0	.	.	.	1	181	181	181
Traveling Screen - Fine Mesh	Monroe Power Plant	103	188	0 hr.	58	43994	2	521500	0	.	.	.
Traveling Screen - Fine Mesh	Barney Davis Power Station	168	66	0 hr.	34	49	0	853	34	305	5	3868
Traveling Screen - Fine Mesh	Test laboratory	192	112	0 hr.	0	.	.	.	1	14665	14665	14665
Traveling Screen - Fine Mesh	Prairie Island Nuclear Generating Station	193	160	0 hr.	33	1604	0	20134	33	375	0	5765
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	228	0 hr.	0	.	.	.	56	59	1	505
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	228	24 hr.	0	.	.	.	56	31	0	365
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	228	8 hr.	0	.	.	.	56	38	0	395
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	229	0 hr.	0	.	.	.	11	38	1	250
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	229	24 hr.	0	.	.	.	11	26	0	213

Exhibit 11B-23. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID	Mortality Obs. Time	Mortality Counts N	Mortality Counts Mean	Mortality Counts Minimum	Mortality Counts Maximum	Survival Counts N	Survival Counts Mean	Survival Counts Minimum	Survival Counts Maximum
Traveling Screen - Fine Mesh	Dunkirk Steam Station	207	229	8 hr.	0	.	.	.	11	33	0	237
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	230	0 hr.	0	.	.	.	8	27201250	0	110000000
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	231	0 hr.	0	.	.	.	5	30400000	0	100000000
Traveling Screen - Fine Mesh	Brunswick Steam Electric Plant	208	232	0 hr.	0	.	.	.	10	81337	0	268569
Diversion (not impinged or entrained)												
Behavioral Systems I	San Onofre Nuclear Generating Station (SONGS)	53	65	0 hr.	0	.	.	.	64	7727	0	198157
Behavioral Systems II	Fawley Aquatic Research Laboratory	152	57	0 hr.	0	.	.	.	2	7	7	8
Fixed Screen - Coarse Mesh	Elwha Dam	42	4	0 hr.	0	.	.	.	4	509	482	528
Fixed Screen - Coarse Mesh	Elwha Dam	42	121	0 hr.	0	.	.	.	4	521	509	534
Fixed Screen - Coarse Mesh	Elwha Dam	42	122	0 hr.	0	.	.	.	2	195	148	241
Fixed Screen - Coarse Mesh	Elwha Dam	42	123	0 hr.	0	.	.	.	2	550	538	561
Other technologies	Glenn-Colusa Irrigation District Fish Screen	147	64	0 hr.	0	.	.	.	2	2311	1042	3580
Other												
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	11	24 hr.	16	9	0	52	16	191	5	1040
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	11	48 hr.	16	19	0	82	16	181	5	1030
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	24	24 hr.	12	4	0	25	12	145	2	517
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	24	48 hr.	12	8	0	32	12	142	2	517

11B.7 Summaries of Percentage Change from Baseline in Mortality and Survival Counts, and Percent Survival, By Technology Category, Document, and Study (Test Condition)

These exhibits provide additional detail for data summaries presented in Exhibits 11B-9 through 11B-11.

Exhibit 11B-24. Summary of Calculated Percentage Change from Baseline in Immediate Mortality and Survival Counts, by Technology Category, Document, and Study (Test Condition)

Technology Category	Facility Name	Doc. ID	Study ID[1]	Change from Baseline in Immediate Mortality Counts				Change from Baseline in Immediate Survival Counts			
				N	Mean	Min.	Max.	N	Mean	Min.	Max.
Entrainment											
Barriers	Lovett Generating Station	40	108	4	56.9	24.2	92.3	0	.	.	.
Barriers	Lovett Generating Station	41	110	4	-31.2	-304.4	84.7	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	17	0	.	.	.	1	-30.3	-30.3	-30.3
Behavioral Systems II	Pine Hydroelectric Project	81	25	0	.	.	.	1	-23.0	-23.0	-23.0
Behavioral Systems II	Pine Hydroelectric Project	81	26	0	.	.	.	1	1.9	1.9	1.9
Behavioral Systems II	Pine Hydroelectric Project	81	28	0	.	.	.	1	14.3	14.3	14.3
Behavioral Systems II	Pine Hydroelectric Project	81	29	0	.	.	.	1	-3.1	-3.1	-3.1
Behavioral Systems II	Pine Hydroelectric Project	81	30	0	.	.	.	1	12.6	12.6	12.6
Behavioral Systems II	Pine Hydroelectric Project	81	32	0	.	.	.	1	40.5	40.5	40.5
Behavioral Systems II	Pine Hydroelectric Project	81	33	0	.	.	.	1	18.9	18.9	18.9
Behavioral Systems II	Pine Hydroelectric Project	81	34	0	.	.	.	1	49.4	49.4	49.4
Behavioral Systems II	Pine Hydroelectric Project	81	36	0	.	.	.	1	11.1	11.1	11.1
Behavioral Systems II	Pine Hydroelectric Project	81	37	0	.	.	.	1	0.2	0.2	0.2
Behavioral Systems II	Pine Hydroelectric Project	81	38	0	.	.	.	1	-10.3	-10.3	-10.3
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	1	-40.7	-40.7	-40.7	1	3.4	3.4	3.4
Impingement											
Barriers	Bowline Point Generating Station	38	106	1	-136.1	-136.1	-136.1	0	.	.	.
Behavioral Systems II	Hinkley Point Power Station	17	98	0	.	.	.	3	-52.6	-74.3	-33.0
Behavioral Systems II	Heysham Power Station	76	41	0	.	.	.	5	21.3	-1.5	41.1
Behavioral Systems II	Salem Generating Station	125	60	1	-0.3	-0.3	-0.3	0	.	.	.
Diversion (not impingement or entrainment)											
Behavioral Systems II	Fawley Aquatic Research Laboratory	152	57	0	.	.	.	1	47.9	47.9	47.9

[1] Study ID associated with test conditions when the technology is in place.

Exhibit 11B-25. Summary of Calculated Percentage Change from Baseline in Mortality and Survival Related Measures, by Technology Category, Document, Study (Test Condition), and Mortality Observation Time

Technology Category	Facility Name	Doc. ID	Study ID[1]	Mortality Observation Time	Change from Baseline in Mortality Counts				Change from Baseline in Survival Counts				Change from Baseline in Percent Mortality			
					N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum
Entrainment																
Barriers	Lovett Generating Station	40	108	0 hr.	4	56.9	24.2	92.3	0	.	.	.	0	.	.	.
Barriers	Lovett Generating Station	41	110	0 hr.	4	-31.2	-304.4	84.7	0	.	.	.	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	17	0 hr.	0	.	.	.	1	-30.3	-30.3	-30.3	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	25	0 hr.	0	.	.	.	1	-23.0	-23.0	-23.0	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	26	0 hr.	0	.	.	.	1	1.9	1.9	1.9	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	28	0 hr.	0	.	.	.	1	14.3	14.3	14.3	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	29	0 hr.	0	.	.	.	1	-3.1	-3.1	-3.1	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	30	0 hr.	0	.	.	.	1	12.6	12.6	12.6	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	32	0 hr.	0	.	.	.	1	40.5	40.5	40.5	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	33	0 hr.	0	.	.	.	1	18.9	18.9	18.9	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	34	0 hr.	0	.	.	.	1	49.4	49.4	49.4	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	36	0 hr.	0	.	.	.	1	11.1	11.1	11.1	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	37	0 hr.	0	.	.	.	1	0.2	0.2	0.2	0	.	.	.
Behavioral Systems II	Pine Hydroelectric Project	81	38	0 hr.	0	.	.	.	1	-10.3	-10.3	-10.3	0	.	.	.
Other technologies	Tracy Fish Collecting Facility	193	182	0 hr.	0	.	.	.	0	.	.	.	2	-102.7	-246.7	41.2
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	0 hr.	1	-40.7	-40.7	-40.7	1	3.4	3.4	3.4	1	-7.3	-7.3	-7.3

Exhibit 11B-25. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID[1]	Mortality Observation Time	Change from Baseline in Mortality Counts				Change from Baseline in Survival Counts				Change from Baseline in Percent Mortality			
					N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	96 hr.	0	.	.	.	1	8.2	8.2	8.2	1	-3.8	-3.8	-3.8
Impingement																
Barriers	Bowline Point Generating Station	38	106	0 hr.	1	-136.1	-136.1	-136.1	0	.	.	.	0	.	.	.
Behavioral Systems II	Hinkley Point Power Station	17	98	0 hr.	0	.	.	.	3	-52.6	-74.3	-33.0	0	.	.	.
Behavioral Systems II	Heysham Power Station	76	41	0 hr.	0	.	.	.	5	21.3	-1.5	41.1	0	.	.	.
Behavioral Systems II	Salem Generating Station	125	60	0 hr.	1	-0.3	-0.3	-0.3	0	.	.	.	0	.	.	.
Traveling Screen - Coarse Mesh	Salem Generating Station	85	147	48 hr.	0	.	.	.	1	-97.8	-97.8	-97.8	1	50.9	50.9	50.9
Traveling Screen - Fine Mesh	Big Bend Power Station	118	74	0 hr.	0	.	.	.	0	.	.	.	4	-3865.9	-13450.0	-278.0
Traveling Screen - Fine Mesh	Big Bend Power Station	118	74	48 hr.	0	.	.	.	0	.	.	.	6	-59.8	-120.5	14.3
Traveling Screen - Fine Mesh	Big Bend Power Station	118	74	96 hr.	0	.	.	.	0	.	.	.	7	-53.3	-241.9	25.3
Traveling Screen - Fine Mesh	Big Bend Power Station	118	76	0 hr.	0	.	.	.	0	.	.	.	6	-24.5	-61.6	15.7
Traveling Screen - Fine Mesh	Big Bend Power Station	118	76	48 hr.	0	.	.	.	0	.	.	.	3	23.2	10.9	36.4
Traveling Screen - Fine Mesh	Big Bend Power Station	118	76	96 hr.	0	.	.	.	0	.	.	.	3	22.9	10.1	36.4
Traveling Screen - Fine Mesh	Big Bend Power Station	118	84	0 hr.	0	.	.	.	0	.	.	.	4	62.3	22.2	87.1
Traveling Screen - Fine Mesh	Big Bend Power Station	118	84	48 hr.	0	.	.	.	0	.	.	.	7	-18.3	-133.3	63.7
Traveling Screen - Fine Mesh	Big Bend Power Station	118	84	96 hr.	0	.	.	.	0	.	.	.	8	-9.6	-178.9	68.8
Traveling Screen - Fine Mesh	Big Bend Power Station	118	86	0 hr.	0	.	.	.	0	.	.	.	1	52.4	52.4	52.4
Traveling Screen - Fine Mesh	Big Bend Power Station	118	86	96 hr.	0	.	.	.	0	.	.	.	2	-32.8	-87.1	21.6

Exhibit 11B-25. (Continued)

Technology Category	Facility Name	Doc. ID	Study ID[1]	Mortality Observation Time	Change from Baseline in Mortality Counts				Change from Baseline in Survival Counts				Change from Baseline in Percent Mortality			
					N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum	N	Mean	Minimum	Maximum
Diversion (not impingement or entrainment)																
Behavioral Systems II	Fawley Aquatic Research Laboratory	152	57	0 hr.	0	.	.	.	1	47.9	47.9	47.9	1	-3.6	-3.6	-3.6
Other																
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	11	24 hr.	3	-246.3	-550.0	0.0	4	-94.8	-220.0	-25.4	3	-70.3	-179.3	50.8
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	11	48 hr.	4	-348.8	-1075.0	0.0	4	-83.0	-220.0	4.3	4	-167.3	-595.2	50.8
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	24	24 hr.	2	3.7	-59.3	66.7	4	5.6	-19.7	35.0	0	.	.	.
Traveling Screen - Coarse Mesh	California Delta Pumping Plant	61	24	48 hr.	4	-18.3	-166.7	66.7	4	7.0	-19.5	41.5	0	.	.	.

[1] Study ID associated with test conditions when the technology is in place.

Exhibit 11B-26. Summary of Calculated Percentage Change from Baseline in <u>Percent Immediate Mortality</u>, by Technology Category, Document, and Study (Test Condition)

Technology Category	Facility Name	Doc. ID	Study ID[1]	Change from Baseline in Percent Immediate Mortality			
				N	Mean	Min.	Max.
Entrainment							
Other technologies	Tracy Fish Collecting Facility	193	182	2	-102.7	-246.7	41.2
Traveling Screen - Coarse Mesh	Potrero Power Plant	18	101	1	-7.3	-7.3	-7.3
Impingement							
Traveling Screen - Fine Mesh	Big Bend Power Station	118	74	4	-3865.9	-13450.0	-278.0
Traveling Screen - Fine Mesh	Big Bend Power Station	118	76	6	-24.5	-61.6	15.7
Traveling Screen - Fine Mesh	Big Bend Power Station	118	84	4	62.3	22.2	87.1
Traveling Screen - Fine Mesh	Big Bend Power Station	118	86	1	52.4	52.4	52.4
Diversion (not impingement or entrainment)							
Behavioral Systems II	Fawley Aquatic Research Laboratory	152	57	1	-3.6	-3.6	-3.6

[1] Study ID associated with test conditions when the technology is in place.

Appendix C to Chapter 11: Impingement and Entrainment Data

The tables in this appendix list the impingement and entrainment data evaluated in Chapter 11.

- Exhibit 11C-1 lists the impingement data.
- Exhibit11C-2 lists the entrainment data.

Exhibit 11C-1. Impingement Mortality Data Used to Develop the Proposed Limitations

Study ID	Facility Name	Species Name	Life Stage	Delayed Mortality (hrs.)	Start Season	Start Month	Start Year	End Season	End Month	End Year	# Impinged That Died	# Impinged That Survived	Total # Impinged	% Impingement Mortality	% Impingement Survival
156	Arthur Kill	Alewife		24	Winter	2	1994	Summer	7	1995	2	35	37	5.4	94.6
156	Arthur Kill	American eel		24	Winter	2	1994	Summer	7	1995	1	6	7	14.3	85.7
156	Arthur Kill	American shad		24	Winter	2	1994	Summer	7	1995	7	24	31	22.6	77.4
156	Arthur Kill	Atlantic Croaker		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Atlantic herring		24	Winter	2	1994	Summer	7	1995	321	90	411	78.1	21.9
156	Arthur Kill	Atlantic silverside		24	Winter	2	1994	Summer	7	1995	14	617	631	2.2	97.8
156	Arthur Kill	Atlantic tomcod		24	Winter	2	1994	Summer	7	1995	1	18	19	5.3	94.7
156	Arthur Kill	Bay Anchovy		24	Winter	2	1994	Summer	7	1995	490	346	836	58.6	41.4
156	Arthur Kill	Black Sea bass		24	Winter	2	1994	Summer	7	1995	1	16	17	5.9	94.1
156	Arthur Kill	Blueback Herring		24	Winter	2	1994	Summer	7	1995	355	1331	1686	21.1	78.9
156	Arthur Kill	Bluecrab		24	Winter	2	1994	Summer	7	1995	1	657	658	0.2	99.8
156	Arthur Kill	Bluefish		24	Winter	2	1994	Summer	7	1995	6	2	8	75.0	25.0
156	Arthur Kill	Butterfish		24	Winter	2	1994	Summer	7	1995	15	39	54	27.8	72.2
156	Arthur Kill	Conger eel		24	Winter	2	1994	Summer	7	1995	1	6	7	14.3	85.7
156	Arthur Kill	Crevalle Jack		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Cunner		24	Winter	2	1994	Summer	7	1995	0	8	8	0.0	100.0
156	Arthur Kill	Cusk eel		24	Winter	2	1994	Summer	7	1995	1	4	5	20.0	80.0
156	Arthur Kill	Feather blenny		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Gizzard shad		24	Winter	2	1994	Summer	7	1995	0	2	2	0.0	100.0
156	Arthur Kill	Gray snapper		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Grubby		24	Winter	2	1994	Summer	7	1995	0	7	7	0.0	100.0
156	Arthur Kill	Lookdown		24	Winter	2	1994	Summer	7	1995	0	6	6	0.0	100.0
156	Arthur Kill	Mackeral		24	Winter	2	1994	Summer	7	1995	1	2	3	33.3	66.7
156	Arthur Kill	Menhaden		24	Winter	2	1994	Summer	7	1995	12	37	49	24.5	75.5
156	Arthur Kill	Mummichog		24	Winter	2	1994	Summer	7	1995	7	84	91	7.7	92.3
156	Arthur Kill	Naked Goby		24	Winter	2	1994	Summer	7	1995	2	1	3	66.7	33.3
156	Arthur Kill	Northern kingfish		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Northern pipefish		24	Winter	2	1994	Summer	7	1995	3	89	92	3.3	96.7
156	Arthur Kill	Northern puffer		24	Winter	2	1994	Summer	7	1995	0	25	25	0.0	100.0
156	Arthur Kill	Northern searobin		24	Winter	2	1994	Summer	7	1995	4	129	133	3.0	97.0
156	Arthur Kill	Pinfish		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Rainbow Smelt		24	Winter	2	1994	Summer	7	1995	1	56	57	1.8	98.2
156	Arthur Kill	Red hake		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Rock gunnel		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Sea horse		24	Winter	2	1994	Summer	7	1995	0	47	47	0.0	100.0
156	Arthur Kill	Seaboard goby		24	Winter	2	1994	Summer	7	1995	0	22	22	0.0	100.0
156	Arthur Kill	Silver hake		24	Winter	2	1994	Summer	7	1995	4	18	22	18.2	81.8
156	Arthur Kill	Silver perch		24	Winter	2	1994	Summer	7	1995	2	24	26	7.7	92.3
156	Arthur Kill	Smallmouth flounder		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0

Exhibit 11C-1. (Continued)

Study ID	Facility Name	Species Name	Life Stage	Delayed Mortality (hrs.)	Start Season	Start Month	Start Year	End Season	End Month	End Year	# Impinged That Died	# Impinged That Survived	Total # Impinged	% Impingement Mortality	% Impingement Survival
156	Arthur Kill	Spot		24	Winter	2	1994	Summer	7	1995	0	15	15	0.0	100.0
156	Arthur Kill	Spotted hake		24	Winter	2	1994	Summer	7	1995	7	48	55	12.7	87.3
156	Arthur Kill	Star gazer		24	Winter	2	1994	Summer	7	1995	3	1	4	75.0	25.0
156	Arthur Kill	Striped Bass		24	Winter	2	1994	Summer	7	1995	2	22	24	8.3	91.7
156	Arthur Kill	Striped anchovy		24	Winter	2	1994	Summer	7	1995	9	6	15	60.0	40.0
156	Arthur Kill	Striped cusk-eel		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
156	Arthur Kill	Striped killifish		24	Winter	2	1994	Summer	7	1995	7	48	55	12.7	87.3
156	Arthur Kill	Striped searobin		24	Winter	2	1994	Summer	7	1995	1	4	5	20.0	80.0
156	Arthur Kill	Summer flounder		24	Winter	2	1994	Summer	7	1995	5	8	13	38.5	61.5
156	Arthur Kill	Tautog (blackfish)		24	Winter	2	1994	Summer	7	1995	0	2	2	0.0	100.0
156	Arthur Kill	Threespine stickleback		24	Winter	2	1994	Summer	7	1995	2	878	880	0.2	99.8
156	Arthur Kill	Weakfish		24	Winter	2	1994	Summer	7	1995	64	695	759	8.4	91.6
156	Arthur Kill	White perch		24	Winter	2	1994	Summer	7	1995	7	61	68	10.3	89.7
156	Arthur Kill	Windowpane flounder		24	Winter	2	1994	Summer	7	1995	1	21	22	3.5	96.5
156	Arthur Kill	Winter flounder		24	Winter	2	1994	Summer	7	1995	6	197	203	3.0	97.0
157	Arthur Kill	Alewife		24	Winter	2	1994	Summer	7	1995	1	30	31	3.2	96.8
157	Arthur Kill	American eel		24	Winter	2	1994	Summer	7	1995	0	4	4	0.0	100.0
157	Arthur Kill	American shad		24	Winter	2	1994	Summer	7	1995	3	11	14	21.4	78.6
157	Arthur Kill	Atlantic Croaker		24	Winter	2	1994	Summer	7	1995	1	0	1	100.0	0.0
157	Arthur Kill	Atlantic herring		24	Winter	2	1994	Summer	7	1995	15	10	25	60.0	40.0
157	Arthur Kill	Atlantic silverside		24	Winter	2	1994	Summer	7	1995	3	329	332	0.9	99.1
157	Arthur Kill	Atlantic tomcod		24	Winter	2	1994	Summer	7	1995	0	8	8	0.0	100.0
157	Arthur Kill	Banded killifish		24	Winter	2	1994	Summer	7	1995	0	4	4	0.0	100.0
157	Arthur Kill	Bay Anchovy		24	Winter	2	1994	Summer	7	1995	93	100	193	48.2	51.8
157	Arthur Kill	Black Sea bass		24	Winter	2	1994	Summer	7	1995	1	12	13	7.7	92.3
157	Arthur Kill	Blueback Herring		24	Winter	2	1994	Summer	7	1995	16	355	371	4.3	95.7
157	Arthur Kill	Bluecrab		24	Winter	2	1994	Summer	7	1995	3	368	371	0.8	99.2
157	Arthur Kill	Bluefish		24	Winter	2	1994	Summer	7	1995	2	2	4	50.0	50.0
157	Arthur Kill	Butterfish		24	Winter	2	1994	Summer	7	1995	17	54	71	23.9	76.1
157	Arthur Kill	Conger eel		24	Winter	2	1994	Summer	7	1995	0	4	4	0.0	100.0
157	Arthur Kill	Crevalle Jack		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
157	Arthur Kill	Cunner		24	Winter	2	1994	Summer	7	1995	0	8	8	0.0	100.0
157	Arthur Kill	Gray snapper		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
157	Arthur Kill	Grubby		24	Winter	2	1994	Summer	7	1995	0	2	2	0.0	100.0
157	Arthur Kill	Lookdown		24	Winter	2	1994	Summer	7	1995	1	2	3	33.3	66.7
157	Arthur Kill	Menhaden		24	Winter	2	1994	Summer	7	1995	10	24	34	29.4	70.6
157	Arthur Kill	Mummichog		24	Winter	2	1994	Summer	7	1995	4	16	20	20.0	80.0
157	Arthur Kill	Northern pipefish		24	Winter	2	1994	Summer	7	1995	0	19	19	0.0	100.0
157	Arthur Kill	Northern puffer		24	Winter	2	1994	Summer	7	1995	0	8	8	0.0	100.0
157	Arthur Kill	Northern searobin		24	Winter	2	1994	Summer	7	1995	5	47	52	9.6	90.4

Exhibit 11C-1. (Continued)

Study ID	Facility Name	Species Name	Life Stage	Delayed Mortality (hrs.)	Start Season	Start Month	Start Year	End Season	End Month	End Year	# Impinged That Died	# Impinged That Survived	Total # Impinged	% Impingement Mortality	% Impingement Survival
157	Arthur Kill	Orange filefish		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
157	Arthur Kill	Rainbow Smelt		24	Winter	2	1994	Summer	7	1995	0	21	21	0.0	100.0
157	Arthur Kill	Red hake		24	Winter	2	1994	Summer	7	1995	0	5	5	0.0	100.0
157	Arthur Kill	Rock gunnel		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
157	Arthur Kill	Sea horse		24	Winter	2	1994	Summer	7	1995	0	27	27	0.0	100.0
157	Arthur Kill	Seaboard goby		24	Winter	2	1994	Summer	7	1995	0	2	2	0.0	100.0
157	Arthur Kill	Silver hake		24	Winter	2	1994	Summer	7	1995	0	15	15	0.0	100.0
157	Arthur Kill	Silver perch		24	Winter	2	1994	Summer	7	1995	0	18	18	0.0	100.0
157	Arthur Kill	Smallmouth flounder		24	Winter	2	1994	Summer	7	1995	0	1	1	0.0	100.0
157	Arthur Kill	Spot		24	Winter	2	1994	Summer	7	1995	1	9	10	10.0	90.0
157	Arthur Kill	Spotted hake		24	Winter	2	1994	Summer	7	1995	1	18	19	5.3	94.7
157	Arthur Kill	Star gazer		24	Winter	2	1994	Summer	7	1995	2	5	7	28.6	71.4
157	Arthur Kill	Striped Bass		24	Winter	2	1994	Summer	7	1995	2	7	9	22.2	77.8
157	Arthur Kill	Striped anchovy		24	Winter	2	1994	Summer	7	1995	9	9	18	50.0	50.0
157	Arthur Kill	Striped killifish		24	Winter	2	1994	Summer	7	1995	1	23	24	4.2	95.8
157	Arthur Kill	Striped searobin		24	Winter	2	1994	Summer	7	1995	0	2	2	0.0	100.0
157	Arthur Kill	Summer flounder		24	Winter	2	1994	Summer	7	1995	7	7	14	50.0	50.0
157	Arthur Kill	Tautog (blackfish)		24	Winter	2	1994	Summer	7	1995	0	3	3	0.0	100.0
157	Arthur Kill	Threespine stickleback		24	Winter	2	1994	Summer	7	1995	0	639	639	0.0	100.0
157	Arthur Kill	Weakfish		24	Winter	2	1994	Summer	7	1995	24	721	745	3.2	96.8
157	Arthur Kill	White perch		24	Winter	2	1994	Summer	7	1995	6	35	41	14.6	85.4
157	Arthur Kill	Windowpane flounder		24	Winter	2	1994	Summer	7	1995	2	11	13	15.4	84.6
157	Arthur Kill	Winter flounder		24	Winter	2	1994	Summer	7	1995	5	174	179	2.8	97.2
8	Dunkirk	Bluegill	N.S.	24	Fall	11	1999	Fall	11	1999	0	25	25	0.0	100.0
8	Dunkirk	Bluntnose Minnow	N.S.	24	Fall	11	1999	Fall	11	1999	1	5	6	16.7	83.3
8	Dunkirk	Brook Silverside	N.S.	24	Fall	11	1999	Fall	11	1999	0	1	1	0.0	100.0
8	Dunkirk	Brown Bullhead	N.S.	24	Fall	11	1999	Fall	11	1999	0	4	4	0.0	100.0
8	Dunkirk	Carp	N.S.	24	Fall	11	1999	Fall	11	1999	0	1	1	0.0	100.0
8	Dunkirk	Channel Catfish	N.S.	24	Fall	11	1999	Fall	11	1999	0	5	5	0.0	100.0
8	Dunkirk	Emerald Shiner	N.S.	24	Fall	11	1999	Fall	11	1999	111	5948	6072	2.0	98.0
8	Dunkirk	Freshwater Drum	N.S.	24	Fall	11	1999	Fall	11	1999	0	0	1	100.0	0.0
8	Dunkirk	Gizzard shad	Adult	24	Fall	11	1999	Fall	11	1999	0	11	12	8.3	91.7
8	Dunkirk	Gizzard shad	Juvenile	24	Fall	11	1999	Fall	11	1999	21	1456	1477	1.4	98.6
8	Dunkirk	Goldfish	N.S.	24	Fall	11	1999	Fall	11	1999	0	6	6	0.0	100.0
8	Dunkirk	Largemouth Bass	N.S.	24	Fall	11	1999	Fall	11	1999	0	1	1	0.0	100.0
8	Dunkirk	Log Perch	N.S.	24	Fall	11	1999	Fall	11	1999	0	10	10	0.0	100.0
8	Dunkirk	Longnose Dace	N.S.	24	Fall	11	1999	Fall	11	1999	0	2	2	0.0	100.0
8	Dunkirk	Pumpkinseed	N.S.	24	Fall	11	1999	Fall	11	1999	0	14	14	0.0	100.0
8	Dunkirk	Rainbow Smelt	N.S.	24	Fall	11	1999	Fall	11	1999	103	359	473	24.1	75.9
8	Dunkirk	Rainbow Trout	N.S.	24	Fall	11	1999	Fall	11	1999	0	2	2	0.0	100.0

Exhibit 11C-1. (Continued)

Study ID	Facility Name	Species Name	Life Stage	Delayed Mortality (hrs.)	Start Season	Start Month	Start Year	End Season	End Month	End Year	# Impinged That Died	# Impinged That Survived	Total # Impinged	% Impingement Mortality	% Impingement Survival
8	Dunkirk	Rock bass	N.S.	24	Fall	11	1999	Fall	11	1999	0	157	157	0.0	100.0
8	Dunkirk	Round Goby	N.S.	24	Fall	11	1999	Fall	11	1999	0	4	4	0.0	100.0
8	Dunkirk	Sculpin	N.S.	24	Fall	11	1999	Fall	11	1999	0	5	5	0.0	100.0
8	Dunkirk	Smallmouth Bass	N.S.	24	Fall	11	1999	Fall	11	1999	1	5	6	16.7	83.3
8	Dunkirk	Spottail Shiner	N.S.	24	Fall	11	1999	Fall	11	1999	3	259	263	1.5	98.5
8	Dunkirk	Stonecat	N.S.	24	Fall	11	1999	Fall	11	1999	0	6	6	0.0	100.0
8	Dunkirk	Trout Perch	N.S.	24	Fall	11	1999	Fall	11	1999	0	1	1	0.0	100.0
8	Dunkirk	White bass	N.S.	24	Fall	11	1999	Fall	11	1999	2	145	147	1.4	98.6
8	Dunkirk	White perch	N.S.	24	Fall	11	1999	Fall	11	1999	0	45	45	0.0	100.0
8	Dunkirk	White Sucker	N.S.	24	Fall	11	1999	Fall	11	1999	0	4	4	0.0	100.0
8	Dunkirk	Yellow Perch	N.S.	24	Fall	11	1999	Fall	11	1999	1	176	178	1.1	98.9
8	Dunkirk	Bluegill	N.S.	24	Winter	12	1998	Winter	1	1999	0	3	3	0.0	100.0
8	Dunkirk	Emerald Shiner	N.S.	24	Winter	12	1998	Winter	1	1999	68	3669	3738	1.8	98.2
8	Dunkirk	Freshwater Drum	N.S.	24	Winter	12	1998	Winter	1	1999	0	1	1	0.0	100.0
8	Dunkirk	Gizzard shad	Adult	24	Winter	12	1998	Winter	1	1999	4	86	93	7.5	92.5
8	Dunkirk	Gizzard shad	Juvenile	24	Winter	12	1998	Winter	1	1999	88	1825	1927	5.3	94.7
8	Dunkirk	Largemouth Bass	N.S.	24	Winter	12	1998	Winter	1	1999	0	1	1	0.0	100.0
8	Dunkirk	Rainbow Smelt	Adult	24	Winter	12	1998	Winter	1	1999	44.5	377.6	426.1	11.4	88.6
8	Dunkirk	Rainbow Smelt	Juvenile	24	Winter	12	1998	Winter	1	1999	50.5	133.4	187.9	29.0	71.0
8	Dunkirk	Rock bass	N.S.	24	Winter	12	1998	Winter	1	1999	2	22	24	8.3	91.7
8	Dunkirk	Sculpin	N.S.	24	Winter	12	1998	Winter	1	1999	0	1	1	0.0	100.0
8	Dunkirk	Shorthead Redhorse	N.S.	24	Winter	12	1998	Winter	1	1999	0	1	1	0.0	100.0
8	Dunkirk	Spottail Shiner	N.S.	24	Winter	12	1998	Winter	1	1999	1	296	297	0.3	99.7
8	Dunkirk	Trout Perch	N.S.	24	Winter	12	1998	Winter	1	1999	3	5	8	37.5	62.5
8	Dunkirk	White bass	N.S.	24	Winter	12	1998	Winter	1	1999	0	1	1	0.0	100.0
8	Dunkirk	Yellow Perch	N.S.	24	Winter	12	1998	Winter	1	1999	0	66	66	0.0	100.0
8	Dunkirk	Alewife	N.S.	24	Spring	4	1999	Spring	4	1999	142	78	260	70.0	30.0
8	Dunkirk	Black Crappie	N.S.	24	Spring	4	1999	Spring	4	1999	0	1	1	0.0	100.0
8	Dunkirk	Bluegill	N.S.	24	Spring	4	1999	Spring	4	1999	0	1	1	0.0	100.0
8	Dunkirk	Bluntnose Minnow	N.S.	24	Spring	4	1999	Spring	4	1999	0	1	1	0.0	100.0
8	Dunkirk	Emerald Shiner	N.S.	24	Spring	4	1999	Spring	4	1999	104	2436	2564	5.0	95.0
8	Dunkirk	Fathead Minnow	N.S.	24	Spring	4	1999	Spring	4	1999	0	1	1	0.0	100.0
8	Dunkirk	Freshwater Drum	N.S.	24	Spring	4	1999	Spring	4	1999	1	0	1	100.0	0.0
8	Dunkirk	Gizzard shad	Adult	24	Spring	4	1999	Spring	4	1999	0	2	3	33.3	66.7
8	Dunkirk	Gizzard shad	Juvenile	24	Spring	4	1999	Spring	4	1999	68	137	211	35.1	64.9
8	Dunkirk	Johnny Darter	N.S.	24	Spring	4	1999	Spring	4	1999	0	2	2	0.0	100.0
8	Dunkirk	Quilback Sucker	N.S.	24	Spring	4	1999	Spring	4	1999	1	0	1	100.0	0.0
8	Dunkirk	Rainbow Smelt	N.S.	24	Spring	4	1999	Spring	4	1999	115	201	318	36.8	63.2
8	Dunkirk	Rainbow Trout	N.S.	24	Spring	4	1999	Spring	4	1999	0	3	3	0.0	100.0
8	Dunkirk	Rock bass	N.S.	24	Spring	4	1999	Spring	4	1999	0	4	4	0.0	100.0
8	Dunkirk	Round Goby	N.S.	24	Spring	4	1999	Spring	4	1999	0	2	2	0.0	100.0

Exhibit 11C-1. (Continued)

Study ID	Facility Name	Species Name	Life Stage	Delayed Mortality (hrs.)	Start Season	Start Month	Start Year	End Season	End Month	End Year	# Impinged That Died	# Impinged That Survived	Total # Impinged	% Impingement Mortality	% Impingement Survival
8	Dunkirk	Sculpin	N.S.	24	Spring	4	1999	Spring	4	1999	0	2	2	0.0	100.0
8	Dunkirk	Spottail Shiner	N.S.	24	Spring	4	1999	Spring	4	1999	1	130	132	1.5	98.5
8	Dunkirk	Trout Perch	N.S.	24	Spring	4	1999	Spring	4	1999	3	48	51	5.9	94.1
8	Dunkirk	White bass	N.S.	24	Spring	4	1999	Spring	4	1999	0	1	1	0.0	100.0
8	Dunkirk	White perch	N.S.	24	Spring	4	1999	Spring	4	1999	0	2	2	0.0	100.0
8	Dunkirk	Yellow Perch	N.S.	24	Spring	4	1999	Spring	4	1999	0	1	1	0.0	100.0
8	Dunkirk	Alewife	N.S.	24	Summer	8	1999	Fall	9	1999	10	0	12	100.0	0.0
8	Dunkirk	Bluegill	N.S.	24	Summer	8	1999	Fall	9	1999	0	5	5	0.0	100.0
8	Dunkirk	Emerald Shiner	N.S.	24	Summer	8	1999	Fall	9	1999	14	31	46	32.6	67.4
8	Dunkirk	Freshwater Drum	N.S.	24	Summer	8	1999	Fall	9	1999	0	0	1	100.0	0.0
8	Dunkirk	Gizzard shad	N.S.	24	Summer	8	1999	Fall	9	1999	84	239	338	29.3	70.7
8	Dunkirk	Largemouth Bass	N.S.	24	Summer	8	1999	Fall	9	1999	0	3	3	0.0	100.0
8	Dunkirk	Log Perch	N.S.	24	Summer	8	1999	Fall	9	1999	0	1	1	0.0	100.0
8	Dunkirk	Rainbow Smelt	N.S.	24	Summer	8	1999	Fall	9	1999	39	9	48	81.2	18.8
8	Dunkirk	Rock bass	N.S.	24	Summer	8	1999	Fall	9	1999	1	298	300	0.7	99.3
8	Dunkirk	Round Goby	N.S.	24	Summer	8	1999	Fall	9	1999	0	10	10	0.0	100.0
8	Dunkirk	Smallmouth Bass	N.S.	24	Summer	8	1999	Fall	9	1999	1	17	18	5.6	94.4
8	Dunkirk	Spottail Shiner	N.S.	24	Summer	8	1999	Fall	9	1999	31	357	393	9.2	90.8
8	Dunkirk	Stonecat	N.S.	24	Summer	8	1999	Fall	9	1999	0	0	2	100.0	0.0
8	Dunkirk	Trout Perch	N.S.	24	Summer	8	1999	Fall	9	1999	1	0	1	100.0	0.0
8	Dunkirk	White bass	N.S.	24	Summer	8	1999	Fall	9	1999	1	5	6	16.7	83.3
8	Dunkirk	White perch	N.S.	24	Summer	8	1999	Fall	9	1999	0	22	22	0.0	100.0
8	Dunkirk	Yellow Perch	N.S.	24	Summer	8	1999	Fall	9	1999	0	13	14	7.1	92.9
1	Huntley	Alewife	N.S.	24	Fall	10	1999	Fall	10	1999	139	41	183	77.6	22.4
1	Huntley	Black Crappie	N.S.	24	Fall	10	1999	Fall	10	1999	0	1	1	0.0	100.0
1	Huntley	Brook Silverside	N.S.	24	Fall	10	1999	Fall	10	1999	0	1	1	0.0	100.0
1	Huntley	Darters	N.S.	24	Fall	10	1999	Fall	10	1999	0	5	5	0.0	100.0
1	Huntley	Emerald Shiner	N.S.	24	Fall	10	1999	Fall	10	1999	14	611	628	2.7	97.3
1	Huntley	Gizzard shad	N.S.	24	Fall	10	1999	Fall	10	1999	2	63	65	3.1	96.9
1	Huntley	Goldfish	N.S.	24	Fall	10	1999	Fall	10	1999	0	1	1	0.0	100.0
1	Huntley	Pumpkinseed	N.S.	24	Fall	10	1999	Fall	10	1999	0	1	1	0.0	100.0
1	Huntley	Rainbow Smelt	N.S.	24	Fall	10	1999	Fall	10	1999	866	875	1824	52.0	48.0
1	Huntley	Rock bass	N.S.	24	Fall	10	1999	Fall	10	1999	0	178	180	1.1	98.9
1	Huntley	Smallmouth Bass	N.S.	24	Fall	10	1999	Fall	10	1999	0	6	6	0.0	100.0
1	Huntley	Spottail Shiner	N.S.	24	Fall	10	1999	Fall	10	1999	3	226	231	2.2	97.8
1	Huntley	White bass	N.S.	24	Fall	10	1999	Fall	10	1999	1	124	127	2.4	97.6
1	Huntley	White perch	N.S.	24	Fall	10	1999	Fall	10	1999	0	4	4	0.0	100.0
1	Huntley	Yellow Perch	N.S.	24	Fall	10	1999	Fall	10	1999	0	1	1	0.0	100.0
1	Huntley	Alewife	N.S.	24	Winter	1	1999	Winter	1	1999	4	0	30	100.0	0.0
1	Huntley	Bluntnose Minnow	N.S.	24	Winter	1	1999	Winter	1	1999	0	3	3	0.0	100.0
1	Huntley	Darters	N.S.	24	Winter	1	1999	Winter	1	1999	0	2	2	0.0	100.0

Exhibit 11C-1. (Continued)

Study ID	Facility Name	Species Name	Life Stage	Delayed Mortality (hrs.)	Start Season	Start Month	Start Year	End Season	End Month	End Year	# Impinged That Died	# Impinged That Survived	Total # Impinged	% Impingement Mortality	% Impingement Survival
1	Huntley	Emerald Shiner	N.S.	24	Winter	1	1999	Winter	1	1999	33	2146	2201	2.5	97.5
1	Huntley	Gizzard shad	Adult	24	Winter	1	1999	Winter	1	1999	0	0	3	100.0	0.0
1	Huntley	Gizzard shad	Juvenile	24	Winter	1	1999	Winter	1	1999	57	16	315	94.9	5.1
1	Huntley	Rainbow Smelt	Adult	24	Winter	1	1999	Winter	1	1999	83	1588.7	1684.9	5.2	94.8
1	Huntley	Rainbow Smelt	Juvenile	24	Winter	1	1999	Winter	1	1999	379	1289.3	1733.1	23.3	76.7
1	Huntley	Redhorse sucker	N.S.	24	Winter	1	1999	Winter	1	1999	0	2	2	0.0	100.0
1	Huntley	Rock bass	N.S.	24	Winter	1	1999	Winter	1	1999	1	17	19	10.5	89.5
1	Huntley	Smallmouth Bass	N.S.	24	Winter	1	1999	Winter	1	1999	0	3	3	0.0	100.0
1	Huntley	Spottail Shiner	N.S.	24	Winter	1	1999	Winter	1	1999	0	17	18	5.6	94.4
1	Huntley	Trout Perch	N.S.	24	Winter	1	1999	Winter	1	1999	0	67	67	0.0	100.0
1	Huntley	White perch	N.S.	24	Winter	1	1999	Winter	1	1999	4	3	8	62.5	37.5
1	Huntley	White Sucker	N.S.	24	Winter	1	1999	Winter	1	1999	0	11	11	0.0	100.0
1	Huntley	Yellow Perch	N.S.	24	Winter	1	1999	Winter	1	1999	0	20	20	0.0	100.0

N.S. = No specified age category.

Exhibit 11C-2. Entrainment Data Evaluated in Chapter 11

Study ID	Year	Facility Name or Location	Techno-logy	Screen Mesh Size, Slot Velocity (Larval Length)	Species Name	Life Stage	Density Units	Density Behind Technology	Density in Front of Technology	Percent Reduction
244		Brunswick	TS-F		All fish	Larvae	#/1000 m3	99	543	81.77
240		Logan	CW-F		All fish	Larvae	#	41	637	93.56
206	1982	Chalk Point	CW-F	1 mm (5-7 mm length)	Bay Anchovy	Larvae	#/1000m3	0.0	4.1	100.00
206	1982	Chalk Point	CW-F	1 mm (8-10 mm length)	Bay Anchovy	Larvae	#/1000m3	0.0	1.6	100.00
206	1982	Chalk Point	CW-F	1 mm (11-14 mm length)	Bay Anchovy	Larvae	#/1000m3	0.0	31.1	100.00
206	1982	Chalk Point	CW-F	1 mm (>= 15 mm length)	Bay Anchovy	Larvae	#/1000m3	1.5	57.3	97.38
206	1982	Chalk Point	CW-F	1 mm (<= 4 mm length)	Naked Goby	Larvae	#/1000m3	1.5	17.2	91.28
206	1982	Chalk Point	CW-F	1 mm (5-6 mm length)	Naked Goby	Larvae	#/1000m3	6.0	22.9	73.80
206	1982	Chalk Point	CW-F	1 mm (7-8 mm length)	Naked Goby	Larvae	#/1000m3	5.8	38.5	84.94
206	1982	Chalk Point	CW-F	1 mm (>=9 mm length)	Naked Goby	Larvae	#/1000m3	35.8	201.5	82.23
207	1982	Chalk Point	CW-F	2 mm (5-7 mm length)	Bay Anchovy	Larvae	#/1000m3	0.0	4.1	100.00
207	1982	Chalk Point	CW-F	2 mm (8-10 mm length)	Bay Anchovy	Larvae	#/1000m3	1.5	1.6	6.25
207	1982	Chalk Point	CW-F	2 mm (11-14 mm length)	Bay Anchovy	Larvae	#/1000m3	10.5	31.1	66.24
207	1982	Chalk Point	CW-F	2 mm (>= 15 mm length)	Bay Anchovy	Larvae	#/1000m3	15.0	57.3	73.82
207	1982	Chalk Point	CW-F	2 mm (<= 4 mm length)	Naked Goby	Larvae	#/1000m3	13.5	17.2	21.51
207	1982	Chalk Point	CW-F	2 mm (5-6 mm length)	Naked Goby	Larvae	#/1000m3	19.5	22.9	14.85
207	1982	Chalk Point	CW-F	2 mm (7-8 mm length)	Naked Goby	Larvae	#/1000m3	16.5	38.5	57.14
207	1982	Chalk Point	CW-F	2 mm (>=9 mm length)	Naked Goby	Larvae	#/1000m3	64.6	201.5	67.94
208	1983	Chalk Point	CW-F	1 mm (<= 4 mm length)	Bay Anchovy	Larvae	#/1000m3	9.2	9.6	4.17
208	1983	Chalk Point	CW-F	1 mm (5-7 mm length)	Bay Anchovy	Larvae	#/1000m3	10.8	20.1	46.27
208	1983	Chalk Point	CW-F	1 mm (8-10 mm length)	Bay Anchovy	Larvae	#/1000m3	1.0	7.7	87.01
208	1983	Chalk Point	CW-F	1 mm (11-14 mm length)	Bay Anchovy	Larvae	#/1000m3	0.0	1.3	100.00
208	1983	Chalk Point	CW-F	1 mm (>= 15 mm length)	Bay Anchovy	Larvae	#/1000m3	0.0	3.3	100.00
208	1983	Chalk Point	CW-F	1 mm (<= 4 mm length)	Naked Goby	Larvae	#/1000m3	562.5	535.7	-5.00
208	1983	Chalk Point	CW-F	1 mm (5-6 mm length)	Naked Goby	Larvae	#/1000m3	66.5	148.7	55.28
208	1983	Chalk Point	CW-F	1 mm (7-8 mm length)	Naked Goby	Larvae	#/1000m3	3.9	49.7	92.15
208	1983	Chalk Point	CW-F	1 mm (>=9 mm length)	Naked Goby	Larvae	#/1000m3	1.9	49.1	96.13
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (<= 4 mm length)	Bay Anchovy	Larvae	#/1000m3	21.0	9.6	-118.75
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (5-7 mm length)	Bay Anchovy	Larvae	#/1000m3	9.2	20.1	54.23
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (8-10 mm length)	Bay Anchovy	Larvae	#/1000m3	1.6	7.7	79.22
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (11-14 mm length)	Bay Anchovy	Larvae	#/1000m3	0.0	1.3	100.00
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (>= 15 mm length)	Bay Anchovy	Larvae	#/1000m3	0.4	3.3	87.88
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (<= 4 mm length)	Naked Goby	Larvae	#/1000m3	513.4	535.7	4.16
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (5-6 mm length)	Naked Goby	Larvae	#/1000m3	81.6	148.7	45.12
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (7-8 mm length)	Naked Goby	Larvae	#/1000m3	9.6	49.7	80.68
209	1983	Chalk Point	CW-F	2 mm, 0.2 m/s (>=9 mm length)	Naked Goby	Larvae	#/1000m3	4.4	49.1	91.04
210	1983	Chalk Point	CW-F	3 mm	Bay Anchovy	Eggs	#/1000m3	1707.0	2341.0	27.08
210	1983	Chalk Point	CW-F	3 mm (<= 4 mm length)	Bay Anchovy	Larvae	#/1000m3	13.6	9.6	-41.67
210	1983	Chalk Point	CW-F	3 mm (5-7 mm length)	Bay Anchovy	Larvae	#/1000m3	11.3	20.1	43.78
210	1983	Chalk Point	CW-F	3 mm (8-10 mm length)	Bay Anchovy	Larvae	#/1000m3	2.6	7.7	66.23

Exhibit 11C-2. (Continued)

Study ID	Year	Facility Name or Location	Techno-logy	Screen Mesh Size, Slot Velocity (Larval Length)	Species Name	Life Stage	Density Units	Density Behind Technology	Density in Front of Technology	Percent Reduction
210	1983	Chalk Point	CW-F	3 mm (11-14 mm length)	Bay Anchovy	Larvae	#/1000m3	0.3	1.3	76.92
210	1983	Chalk Point	CW-F	3 mm (>= 15 mm length)	Bay Anchovy	Larvae	#/1000m3	0.5	3.3	84.85
210	1983	Chalk Point	CW-F	3 mm (<= 4 mm length)	Naked Goby	Larvae	#/1000m3	557.1	535.7	-3.99
210	1983	Chalk Point	CW-F	3 mm (5-6 mm length)	Naked Goby	Larvae	#/1000m3	87.6	148.7	41.09
210	1983	Chalk Point	CW-F	3 mm (7-8 mm length)	Naked Goby	Larvae	#/1000m3	11.2	49.7	77.46
210	1983	Chalk Point	CW-F	3 mm (>=9 mm length)	Naked Goby	Larvae	#/1000m3	7.8	49.1	84.11
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (<= 4 mm length)	Bay Anchovy	Larvae	#/1000m3	23.7	9.6	-146.88
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (5-7 mm length)	Bay Anchovy	Larvae	#/1000m3	15.7	20.1	21.89
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (8-10 mm length)	Bay Anchovy	Larvae	#/1000m3	1.9	7.7	75.32
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (11-14 mm length)	Bay Anchovy	Larvae	#/1000m3	0	1.3	100.00
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (>= 15 mm length)	Bay Anchovy	Larvae	#/1000m3	0.3	3.3	90.91
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (<= 4 mm length)	Naked Goby	Larvae	#/1000m3	400.5	535.7	25.24
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (5-6 mm length)	Naked Goby	Larvae	#/1000m3	58.4	148.7	60.73
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (7-8 mm length)	Naked Goby	Larvae	#/1000m3	6.6	49.7	86.72
241	1983	Chalk Point	CW-F	2 mm, 0.095 m/s (>=9 mm length)	Naked Goby	Larvae	#/1000m3	4.7	49.1	90.43
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (<= 4 mm length)	Bay Anchovy	Larvae	#/1000m3	32.3	9.6	-236.46
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (5-7 mm length)	Bay Anchovy	Larvae	#/1000m3	16.3	20.1	18.91
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (8-10 mm length)	Bay Anchovy	Larvae	#/1000m3	3.3	7.7	57.14
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (11-14 mm length)	Bay Anchovy	Larvae	#/1000m3	0.3	1.3	76.92
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (>= 15 mm length)	Bay Anchovy	Larvae	#/1000m3	0.8	3.3	75.76
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (<= 4 mm length)	Naked Goby	Larvae	#/1000m3	424.8	535.7	20.70
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (5-6 mm length)	Naked Goby	Larvae	#/1000m3	109.4	148.7	26.43
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (7-8 mm length)	Naked Goby	Larvae	#/1000m3	7.7	49.7	84.51
242	1983	Chalk Point	CW-F	2 mm, 0.19 m/s (>=9 mm length)	Naked Goby	Larvae	#/1000m3	3.6	49.1	92.67
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (<= 4 mm length)	Bay Anchovy	Larvae	#/1000m3	8.8	9.6	8.33
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (5-7 mm length)	Bay Anchovy	Larvae	#/1000m3	13	20.1	35.32
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (8-10 mm length)	Bay Anchovy	Larvae	#/1000m3	3.3	7.7	57.14
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (11-14 mm length)	Bay Anchovy	Larvae	#/1000m3	0.5	1.3	76.92
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (>= 15 mm length)	Bay Anchovy	Larvae	#/1000m3	0.8	3.3	75.76
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (<= 4 mm length)	Naked Goby	Larvae	#/1000m3	598.6	535.7	-11.74
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (5-6 mm length)	Naked Goby	Larvae	#/1000m3	119.2	148.7	19.84
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (7-8 mm length)	Naked Goby	Larvae	#/1000m3	27.1	49.7	45.47
243	1983	Chalk Point	CW-F	2 mm, 0.4 m/s (>=9 mm length)	Naked Goby	Larvae	#/1000m3	11.4	49.1	76.78
200		Chesapeake Bay	CW-F	0.5 mm; 0.15 m/sec	All fish	Larvae	#/100m3	41.7	146.6	71.56
200		Chesapeake Bay	CW-F	0.5 mm; 0.15 m/sec	Bay Anchovy	Eggs	#/100m3	134.1	998.8	86.57
200		Chesapeake Bay	CW-F	0.5 mm; 0.15 m/sec	Bay Anchovy	Larvae	#/100m3	2.3	15.0	84.67
200		Chesapeake Bay	CW-F	0.5 mm; 0.15 m/sec	Naked Goby	Larvae	#/100m3	20.0	98.2	79.63
200		Chesapeake Bay	CW-F	0.5 mm; 0.15 m/sec	Northern pipefish	Larvae	#/100m3	0.4	2.3	82.61
200		Chesapeake Bay	CW-F	0.5 mm; 0.15 m/sec	Skilletfish	Larvae	#/100m3	0.5	2.5	80.00
200		Chesapeake Bay	CW-F	0.5 mm; 0.15 m/sec	Striped Blenny	Larvae	#/100m3	0.3	1.9	84.21

Exhibit 11C-2. (Continued)

Study ID	Year	Facility Name or Location	Techno-logy	Screen Mesh Size, Slot Velocity (Larval Length)	Species Name	Life Stage	Density Units	Density Behind Technology	Density in Front of Technology	Percent Reduction
201		Chesapeake Bay	CW-F	0.5 mm; 0.30 m/sec	All fish	Larvae	#/100m3	36.8	87.6	57.99
201		Chesapeake Bay	CW-F	0.5 mm; 0.30 m/sec	Bay Anchovy	Eggs	#/100m3	406.2	503.1	19.26
201		Chesapeake Bay	CW-F	0.5 mm; 0.30 m/sec	Bay Anchovy	Larvae	#/100m3	1.1	8.1	86.42
201		Chesapeake Bay	CW-F	0.5 mm; 0.30 m/sec	Naked Goby	Larvae	#/100m3	19.3	54.6	64.65
201		Chesapeake Bay	CW-F	0.5 mm; 0.30 m/sec	Northern pipefish	Larvae	#/100m3	0.5	2.5	80.00
201		Chesapeake Bay	CW-F	0.5 mm; 0.30 m/sec	Skilletfish	Larvae	#/100m3	0.8	1.6	50.00
201		Chesapeake Bay	CW-F	0.5 mm; 0.30 m/sec	Striped Blenny	Larvae	#/100m3	0.9	2.3	60.87
202		Chesapeake Bay	CW-F	1.0 mm; 0.15 m/sec	All fish	Larvae	#/100m3	45.7	71.0	35.63
202		Chesapeake Bay	CW-F	1.0 mm; 0.15 m/sec	Bay Anchovy	Eggs	#/100m3	682.3	774.0	11.85
202		Chesapeake Bay	CW-F	1.0 mm; 0.15 m/sec	Bay Anchovy	Larvae	#/100m3	4.7	6.0	21.67
202		Chesapeake Bay	CW-F	1.0 mm; 0.15 m/sec	Naked Goby	Larvae	#/100m3	16.9	35.3	52.12
202		Chesapeake Bay	CW-F	1.0 mm; 0.15 m/sec	Northern pipefish	Larvae	#/100m3	0.4	1.2	66.67
202		Chesapeake Bay	CW-F	1.0 mm; 0.15 m/sec	Skilletfish	Larvae	#/100m3	0.7	1.9	63.16
202		Chesapeake Bay	CW-F	1.0 mm; 0.15 m/sec	Striped Blenny	Larvae	#/100m3	0.9	1.6	43.75
203		Chesapeake Bay	CW-F	1.0 mm; 0.30 m/sec	All fish	Larvae	#/100m3	49.9	106.3	53.06
203		Chesapeake Bay	CW-F	1.0 mm; 0.30 m/sec	Bay Anchovy	Eggs	#/100m3	356.9	271.7	-31.36
203		Chesapeake Bay	CW-F	1.0 mm; 0.30 m/sec	Bay Anchovy	Larvae	#/100m3	1.6	3.5	54.29
203		Chesapeake Bay	CW-F	1.0 mm; 0.30 m/sec	Naked Goby	Larvae	#/100m3	33.0	74.3	55.59
203		Chesapeake Bay	CW-F	1.0 mm; 0.30 m/sec	Northern pipefish	Larvae	#/100m3	0.5	1.1	54.55
203		Chesapeake Bay	CW-F	1.0 mm; 0.30 m/sec	Skilletfish	Larvae	#/100m3	1.4	2.4	41.67
203		Chesapeake Bay	CW-F	1.0 mm; 0.30 m/sec	Striped Blenny	Larvae	#/100m3	1.0	1.9	47.37
211		Oyster Creek)	CW-F	1.0 mm	Opossum Shrimp		#/m3	8.9	19.3	53.89
211		Oyster Creek)	CW-F	1.0 mm	Opossum Shrimp		#/m3	16.2	20.0	19.00
212		Oyster Creek)	CW-F	2.0 mm	Opossum Shrimp		#/m3	22.4	19.3	-16.06
212		Oyster Creek)	CW-F	2.0 mm	Opossum Shrimp		#/m3	26.6	20.0	-33.00
196		Portage River	CW-F	0.5 mm; 0.15 m/sec	All fish	Eggs	#/100m3	1.1	45.1	97.56
196		Portage River	CW-F	0.5 mm; 0.15 m/sec	Bass	Larvae	#/100m3	0.5	1.6	68.75
196		Portage River	CW-F	0.5 mm; 0.15 m/sec	Carp	Larvae	#/100m3	2.7	2.2	-22.73
196		Portage River	CW-F	0.5 mm; 0.15 m/sec	Freshwater Drum	Larvae	#/100m3	0.1	2.5	96.00
196		Portage River	CW-F	0.5 mm; 0.15 m/sec	Shad	Larvae	#/100m3	116.9	148.2	21.12
197		Portage River	CW-F	0.5 mm; 0.30 m/sec	All fish	Eggs	#/100m3	2.8	42.0	93.33
197		Portage River	CW-F	0.5 mm; 0.30 m/sec	Bass	Larvae	#/100m3	0.2	0.7	71.43
197		Portage River	CW-F	0.5 mm; 0.30 m/sec	Carp	Larvae	#/100m3	1.1	1.5	26.67
197		Portage River	CW-F	0.5 mm; 0.30 m/sec	Freshwater Drum	Larvae	#/100m3	0.6	14.2	95.77
197		Portage River	CW-F	0.5 mm; 0.30 m/sec	Shad	Larvae	#/100m3	123.3	244.4	49.55
198		Portage River	CW-F	1.0 mm; 0.15 m/sec	All fish	Eggs	#/100m3	4.5	102.9	95.63
198		Portage River	CW-F	1.0 mm; 0.15 m/sec	Bass	Larvae	#/100m3	0.0	0.4	100.00
198		Portage River	CW-F	1.0 mm; 0.15 m/sec	Carp	Larvae	#/100m3	2.1	1.3	-61.54
198		Portage River	CW-F	1.0 mm; 0.15 m/sec	Shad	Larvae	#/100m3	511.1	614.9	16.88
199		Portage River	CW-F	1.0 mm; 0.30 m/sec	All fish	Eggs	#/100m3	97.1	117.2	17.15
199		Portage River	CW-F	1.0 mm; 0.30 m/sec	Bass	Larvae	#/100m3	0.0	0.4	100.00
199		Portage River	CW-F	1.0 mm; 0.30 m/sec	Carp	Larvae	#/100m3	2.7	6.0	55.00

Exhibit 11C-2. (Continued)

Study ID	Year	Facility Name or Location	Techno-logy	Screen Mesh Size, Slot Velocity (Larval Length)	Species Name	Life Stage	Density Units	Density Behind Technology	Density in Front of Technology	Percent Reduction
199		Portage River	CW-F	1.0 mm; 0.30 m/sec	Freshwater Drum	Larvae	#/100m3	2.8	9.9	71.72
199		Portage River	CW-F	1.0 mm; 0.30 m/sec	Shad	Larvae	#/100m3	530.9	571.3	7.07
192		Sakkonet River	CW-F	0.5 mm; 0.15 m/sec	All fish	Eggs	#/100m3	1.1	14.5	92.41
192		Sakkonet River	CW-F	0.5 mm; 0.15 m/sec	All fish	Larvae	#/100m3	14.5	81.1	82.12
192		Sakkonet River	CW-F	0.5 mm; 0.15 m/sec	Grubby	Larvae	#/100m3	0.4	13.7	97.08
192		Sakkonet River	CW-F	0.5 mm; 0.15 m/sec	Sand Lance	Larvae	#/100m3	3.2	47.5	93.26
192		Sakkonet River	CW-F	0.5 mm; 0.15 m/sec	Winter flounder	Larvae	#/100m3	11.3	25.7	56.03
193		Sakkonet River	CW-F	0.5 mm; 0.30 m/sec	All fish	Eggs	#/100m3	0.0	22.8	100.00
193		Sakkonet River	CW-F	0.5 mm; 0.30 m/sec	All fish	Larvae	#/100m3	14.5	52.6	72.43
193		Sakkonet River	CW-F	0.5 mm; 0.30 m/sec	Grubby	Larvae	#/100m3	0.8	10.4	92.31
193		Sakkonet River	CW-F	0.5 mm; 0.30 m/sec	Sand Lance	Larvae	#/100m3	4.9	24.9	80.32
193		Sakkonet River	CW-F	0.5 mm; 0.30 m/sec	Winter flounder	Larvae	#/100m3	9.8	17.4	43.68
194		Sakkonet River	CW-F	1.0 mm; 0.15 m/sec	All fish	Eggs	#/100m3	30.6	42.0	27.14
194		Sakkonet River	CW-F	1.0 mm; 0.15 m/sec	All fish	Larvae	#/100m3	42.2	43.5	2.99
194		Sakkonet River	CW-F	1.0 mm; 0.15 m/sec	Grubby	Larvae	#/100m3	6.0	10.8	44.44
194		Sakkonet River	CW-F	1.0 mm; 0.15 m/sec	Sand Lance	Larvae	#/100m3	15.5	12.8	-21.09
194		Sakkonet River	CW-F	1.0 mm; 0.15 m/sec	Winter flounder	Larvae	#/100m3	21.7	20.4	-6.37
195		Sakkonet River	CW-F	1.0 mm; 0.30 m/sec	All fish	Eggs	#/100m3	39.6	42.9	7.69
195		Sakkonet River	CW-F	1.0 mm; 0.30 m/sec	All fish	Larvae	#/100m3	35.7	43.3	17.55
195		Sakkonet River	CW-F	1.0 mm; 0.30 m/sec	Grubby	Larvae	#/100m3	3.7	7.3	49.32
195		Sakkonet River	CW-F	1.0 mm; 0.30 m/sec	Sand Lance	Larvae	#/100m3	18.6	19.0	2.11
195		Sakkonet River	CW-F	1.0 mm; 0.30 m/sec	Winter flounder	Larvae	#/100m3	12.1	14.5	16.55
213		St. John's River	CW-F	1.0 mm	All fish	Larvae	#	13152507.0	38692597.0	66.01
213		St. John's River	CW-F	1.0 mm	Gobiosoma bosci	Larvae	#	5783474.0	13318458.0	56.58
213		St. John's River	CW-F	1.0 mm	Lepomis spp.	Larvae	#	71462.0	460793.0	84.49
213		St. John's River	CW-F	1.0 mm	Lucania parva	Larvae	#	36461.0	33517.0	-8.78
213		St. John's River	CW-F	1.0 mm	Menidia beryllina	Larvae	#	1762408.0	2345561.0	24.86
213		St. John's River	CW-F	1.0 mm	Microgobius gulosus	Larvae	#	530668.0	14240799.0	96.27
213		St. John's River	CW-F	1.0 mm	Unidentified	Larvae	#	4534611.0	7975672.0	43.14
214		St. John's River	CW-F	2.0 mm	All fish	Larvae	#	14530529.0	38692597.0	62.45
214		St. John's River	CW-F	2.0 mm	Gobiosoma bosci	Larvae	#	5660498.0	13318458.0	57.50
214		St. John's River	CW-F	2.0 mm	Lepomis spp.	Larvae	#	63975.0	460793.0	86.12
214		St. John's River	CW-F	2.0 mm	Lucania parva	Larvae	#	11539.0	33517.0	65.57
214		St. John's River	CW-F	2.0 mm	Menidia beryllina	Larvae	#	1748200.0	2345561.0	25.47
214		St. John's River	CW-F	2.0 mm	Microgobius gulosus	Larvae	#	1778814.0	14240799.0	87.51
214		St. John's River	CW-F	2.0 mm	Strongylura marina	Larvae	#	1915.0	10582.0	81.90
214		St. John's River	CW-F	2.0 mm	Unidentified	Larvae	#	5008284.0	7975672.0	37.21
191		Big Bend	TS-F		Anchoa mitchilli	Eggs	#/100m3	1071.0	12860.0	91.67
191		Big Bend	TS-F		Anchoa mitchilli	Larvae	#/100m3	26.8	239.6	88.81
191		Big Bend	TS-F		Bardiella chrysura	Larvae	#/100m3	0.0	2.0	100.00
191		Big Bend	TS-F		Blenniidae	Larvae	#/100m3	5.3	29.7	82.15

Exhibit 11C-2. (Continued)

Study ID	Year	Facility Name or Location	Techno-logy	Screen Mesh Size, Slot Velocity (Larval Length)	Species Name	Life Stage	Density Units	Density Behind Technology	Density in Front of Technology	Percent Reduction
191		Big Bend	TS-F		Cynoscion nebulosus	Larvae	#/100m3	0.0	1.1	100.00
191		Big Bend	TS-F		Gobiesox strumosus	Larvae	#/100m3	1.1	8.9	87.64
191		Big Bend	TS-F		Gobiidae	Larvae	#/100m3	7.6	30.3	74.92
191		Big Bend	TS-F		Menippe mercenaria	Zoea (unstaged)	#/100m3	0.3	24.6	98.78
191		Big Bend	TS-F		Penaeus	Juvenile	#/100m3	0.0	1.9	100.00
191		Big Bend	TS-F		Sciaenidae	Eggs	#/100m3	1062.0	38595.0	97.25

Technology codes: TS-F=Fine-mesh traveling screens; CW-F=fine-mesh wedgewire screens

Appendix D to Chapter 11: Statistical Procedures for Estimating the Mean and 95th Percentile of Impingement Mortality Percentages

11D.0 Introduction

This appendix describes the beta distribution model used to develop the proposed impingement mortality limitations described in Chapter 11. It also describes alternative statistical methods that EPA considered in developing the proposed limitations. For the final rule, EPA intends to reevaluate its selection of the beta distribution for impingement mortality percentage data.

11D.1 The Beta Distribution

This section presents an overview of the beta distribution and its application to the impingement mortality percentages used as a basis for the proposed limitations. Section 11D.1.1 presents an overview of the beta distribution. Section 11D.1.2 describes the estimation procedures for its parameters. Section 11D.1.3 derives the mean and 95th percentile using the parameters. Section 11D.1.4 provides an example of the calculations using impingement mortality percentage data.

11D.1.1 Overview of the Beta Distribution

The beta distribution assigns positive probability to numbers between 0 and 1 (or, equivalently, percentages between 0 percent and 100 percent). Therefore, this distribution is used frequently to model proportions (Casella and Berger, 2002).

Unlike the symmetric and bell-shaped form of the normal distribution, the beta distribution does not have a single characteristic form in all situations. A beta distribution can hold a variety of shapes depending on the values of its two parameters, α and β (which both must be positive). This makes the beta distribution very flexible to apply to a specific scenario.

The following exhibits provide some examples of the beta distribution for different values of α and β.

- If the two parameters are equal to each other, then the beta distribution is symmetric about 0.5 and the mean is equal to 0.5. In the case where α and β both equal 1 as shown in Exhibit 1, the beta distribution is equivalent to the uniform distribution over the range (0, 1). The distribution is U-shaped if the common value is less than 1. Exhibit 2 shows this pattern for α and β both equal to 0.5.

Exhibit 11D-1. Shape of the beta distribution when $\alpha = 1$ and $\beta = 1$

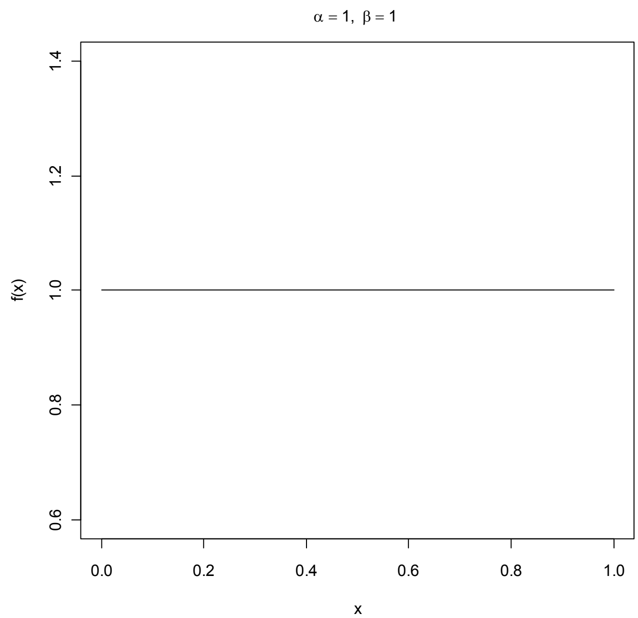
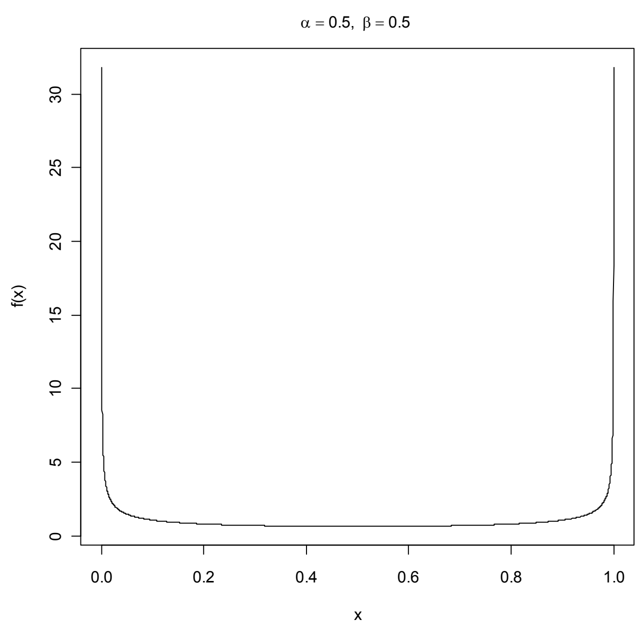
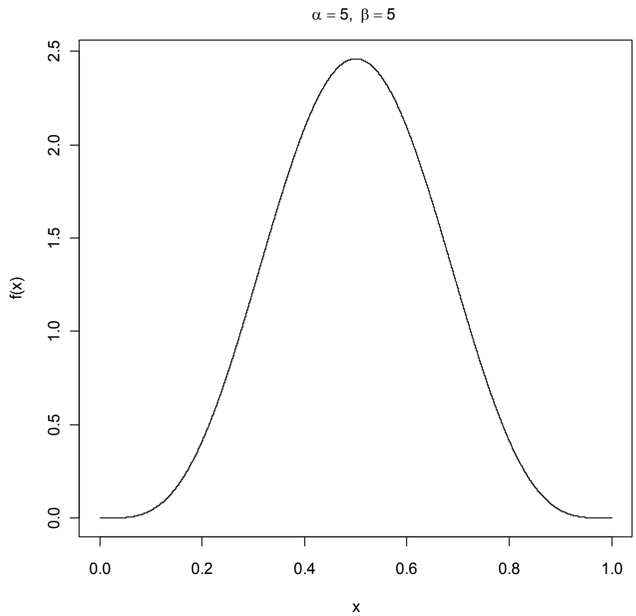


Exhibit 11D-2. Shape of the beta distribution when $\alpha = 0.5$ and $\beta = 0.5$



- If α and β have the same value and the value is greater than 2, the beta distribution resembles a symmetric bell-shaped curve. Exhibit 11D-3 shows this shape for α and β both equal to 5.

Exhibit 11D-3. Shape of the beta distribution when α = 5 and β = 5



- The distribution is unimodal (i.e., has a single peak) if both α and β are greater than 1. The beta distribution is skewed left when α is greater than β (see Exhibit 11D-4), and skewed right when α is less than β. If α and β are unequal but only one parameter exceeds 1, then the distribution is constantly decreasing if β exceeds 1 (see Exhibit 11D-5), and is constantly increasing if α exceeds 1.

Exhibit 11D-4. Shape of the beta distribution when $\alpha = 5$ and $\beta = 2$

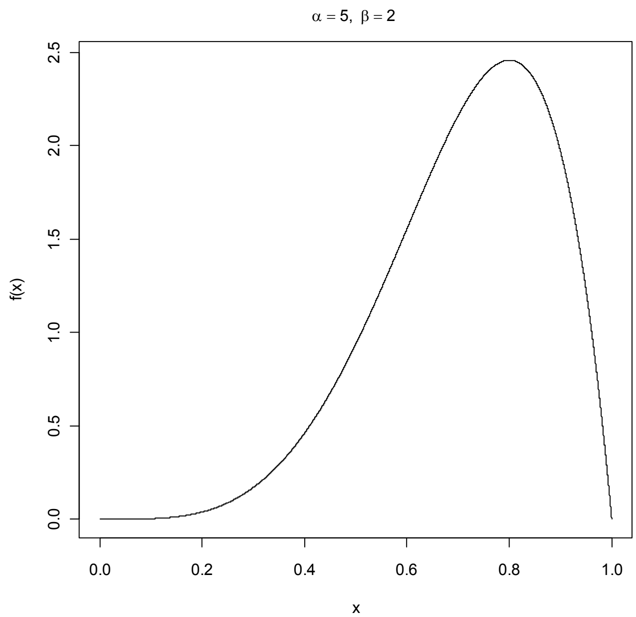
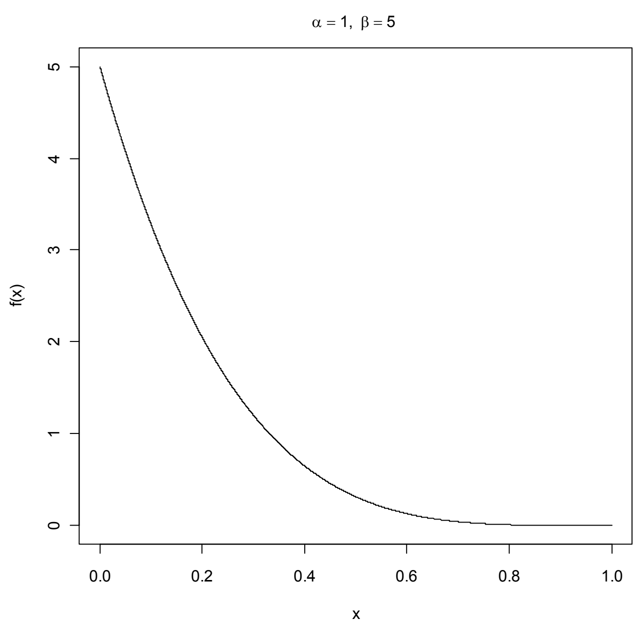


Exhibit 11D-5. Shape of the beta distribution when $\alpha = 1$ and $\beta = 5$



If X is a random variable with a beta distribution, then the cumulative probability distribution function of X (i.e., the probability that X can hold values less than or equal to some specified value x) takes the following form:

$$P[X \leq x] = \int_0^x \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} t^{\alpha-1}(1-t)^{\beta-1} dt,$$

where $\Gamma(c)$ denotes the gamma function, defined as

$$\Gamma(c) = \int_0^\infty z^{c-1} e^{-z} dz.$$

If c is an integer, then

$$\begin{aligned} \Gamma(c) &= (c-1)! \\ &= (c-1) \times (c-2) \times (c-3) \times \ldots \times 2 \times 1. \end{aligned}$$

If c is not an integer, then $\Gamma(c)$ must be approximated using a computer. The expected value and variance of X can be expressed in terms of its parameters α and β as follows:

$$\begin{aligned} E(X) &= \frac{\alpha}{\alpha+\beta} \\ Var(X) &= \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)}. \end{aligned}$$

11D.1.2 Parameter Estimation for the Beta Distribution

EPA estimated α and β using a procedure called *method of moments* (MOM) estimation that can be used for parameter estimation for beta and other distributions. While it also is possible to estimate the parameters for the beta distribution using maximum likelihood estimation (MLE), the MLE approach requires iterative computer algorithms to solve equations that are documented in references such as Johnson and Kotz (1970). In estimating the proposed limitations, EPA selected the MOM estimation procedure because it is simpler and the values can be directly estimated from a series of equations. The following describes the estimation procedure.

For a set of n independent observations $\{x_1, ..., x_n\}$ originating from a common distribution, the k^{th} *sample moment* is defined as:

$$m_k = \frac{1}{n} \sum_{i=1}^{n} x_i^k$$

The first sample moment, m_1, equals the simple average of the n observations. The k^{th} *population moment* of the random variable X equals $E(X^k)$. Therefore, the first population moment equals the expected value, or mean, of X (i.e., $E(X)$). The second population moment equals the variance of X plus the square of the mean of X. Thus, if X has a beta distribution, the first and second population moments are given by the following expressions:

$$
\begin{aligned}
E(X) &= \frac{\alpha}{\alpha+\beta} \\
E(X^2) &= \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)} + \left(\frac{\alpha}{\alpha+\beta}\right)^2
\end{aligned}
$$

The MOM estimators are found by setting the first *k* sample moments equal to the first *k* population moments, where *k* is typically equal to the number of parameters being estimated. Thus, for the beta distribution, which has two parameters to estimate, the MOM estimators are found by setting the first sample moment equal to the first population moment and the second sample moment equal to the second population moment, and then solving for the parameters in terms of the observations.

If the *n* independent observations $\{x_1, \ldots, x_n\}$ originate from a beta distribution, then setting the sample mean (the first sample moment) equal to the expected value results in the following equation:

$$
\begin{aligned}
\frac{1}{n}\sum_{i=1}^{n} x_i &= E(X) \\
&= \frac{\alpha}{\alpha+\beta}
\end{aligned} \tag{11D.1}
$$

Setting the second sample moment equal to the second population moment results in the following equation:

$$
\begin{aligned}
\frac{1}{n}\sum_{i=1}^{n} x_i^2 &= E(X^2) \\
&= \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)} + \left(\frac{\alpha}{\alpha+\beta}\right)^2
\end{aligned} \tag{11D.2}
$$

We then solve Equation (11D.1) and Equation (11D.2) simultaneously for α and β to obtain the estimators $\hat{\alpha}$ and $\hat{\beta}$. This produces the following result:

$$
\begin{aligned}
\hat{\alpha} &= \bar{X}\left(\frac{\bar{X}(1-\bar{X})}{V} - 1\right) \\
\hat{\beta} &= (1-\bar{X})\left(\frac{\bar{X}(1-\bar{X})}{V} - 1\right),
\end{aligned} \tag{11D.3}
$$

where $\bar{X}$ is the simple average of the *n* observations and *V* equals the following quantity:

$$V = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{X})^2.$$

Note that *V* is similar to the common formula for the sample variance except that the denominator equals *n* instead of $(n-1)$.

11D.1.3 Estimation of the Mean and 95th Percentile Under the Beta Distribution

If X represents percent impingement mortality, then we are assuming that X has a beta distribution with parameters α and β. Once Equation (A.3) is applied to reported values of percent impingement mortality data to estimate α and β, these estimates are then used to estimate the mean and 95th percentile of the distribution. We do not assume a specific form of the beta distribution. The observed data will specify the shape through the estimates of α and β.

The mean of the distribution is estimated by the following:

$$E(X) = \frac{\hat{\alpha}}{\hat{\alpha} + \hat{\beta}}$$

where $\hat{\alpha}$ and $\hat{\beta}$ denote the MOM estimates of α and β, respectively (Equation 11D.3). However, no simple expressions exist for estimating the 95th percentile using these estimates of α and β. Johnson and Kotz (1970) provide some approximations for percentiles of the beta distribution. Many statistical software packages, including R and SAS, have procedures for estimating the 95th percentile of a beta distribution. In R, the following command returns an approximation of the 95th percentile:

qbeta(0.95, $\hat{\alpha}$, $\hat{\beta}$).

The following command can be used to approximate the 95th percentile of the beta distribution in SAS or Excel:

betainv(0.95, $\hat{\alpha}$, $\hat{\beta}$).

11D.1.4 Example: Applying the Beta Distribution Model to Impingement Data

This section provides an example on estimating the expected value and 95th percentile under the beta distribution. This example considers the set of impingement mortality data which EPA used to derive the monthly average limitation on impingement mortality. Also presented in Exhibit 11-4, these data are listed in Exhibit 11D-6. The average $\bar{X}$ of the percent impingement mortality column equals 12.56 percent, or 0.1256. The value of V (the mean squared difference between the individual values and the overall average) equals 0.78 percent, or 0.0078. Thus, the MOM estimate of α is:

$$\begin{aligned} \hat{\alpha} &= 0.1256 \left(\frac{0.1256(1 - 0.1256)}{0.0078} - 1 \right) \\ &= 1.64. \end{aligned}$$

The MOM estimate of β is:

$$\hat{\beta} = (1 - 0.1256)\left(\frac{0.1256(1-0.1256)}{0.0078} - 1\right) = 11.44.$$

Since we estimate both α and β to be greater than 1 and α to be less than β, our estimated beta distribution is unimodal and skewed right (i.e., the highest probabilities are associated with data below 0.5, or 50 percent impingement mortality).

We estimate the mean of the distribution to be the following:

$$E(X) = \frac{\hat{\alpha}}{\hat{\alpha}+\hat{\beta}} = \frac{1.64}{1.64+11.44} = 0.125 = 12.5\%.$$

which EPA rounded to 12 for the proposed annual average limitation.

We estimate the 95th percentile using built-in functions of readily available software. For example, if we run the R function

qbeta(0.95, 1.64, 11.44),

we obtain a value of 0.298, or 29.8 percent. The Excel function betainv(0.95,1.64,11.44) also returns a value of 0.298. Thus, we estimate the 95th percentile of the population to be 29.8 percent (which EPA rounded to 30 percent for the proposed monthly average limitation).

Exhibit 11D-6. Impingement Mortality Data Used to Calculate Mean and 95th Percentile of the Beta Distribution in This Example

Facility Name	Sampling Period	Total Number of Impinged Fish	Total Number of Impinged Fish that Died	Percent Impingement Mortality
Arthur Kill	Unit 20, 1994-1995	7,130	1,366	19.2
	Unit 30, 1994-1995	3,408	235	6.9
Dunkirk	12/20/98 to 01/09/99	6,775	261	3.9
	04/20/99 to 04/28/99	3,562	435	12.2
	08/16/99 to 09/04/99	1,220	182	14.9
	11/02/99 to 11/11/99	8,928	243	2.7
Huntley	01/21/99 to 01/25/99	6,120	561	9.2
	10/24/99 to 10/29/99	3,258	1,025	31.5

11D.2 Alternatives to the Beta Distribution

In addition to the beta distribution model, EPA identified other alternative statistical models that might be appropriate for developing limitations related to impingement mortality data. Although EPA determined that the beta distribution was appropriate in developing the proposed limitations, it intends to reevaluate whether other statistical methods or data types might be more appropriate for the final rule. The following sections describe six alternatives. The first four model the same type of data used for the proposed limitations (i.e., impingement mortality percentages). These four alternatives are: a normal distribution model, methods which focus on estimating upper percentiles of a distribution, survival analysis, and a nonparametric approach. The last two alternatives model different data types: the number of fish killed and Age-1 Equivalents.

11D.2.1 Normal Distribution Model

One alternative approach is based on the normal distribution, which has many well-known properties and is the basic assumption for many statistical methods. While normally distributed data can hold any positive or negative value, percent impingement mortality can range only from 0 to 100. Thus, in this approach, the logit function would be applied to the percentages (expressed as proportions). The logit function is defined as the natural logarithm of the odds of impingement mortality. Statisticians have often used this approach to transform proportions into values that satisfy the assumptions of the normal distribution. If p is impingement mortality expressed as a proportion between 0 and 1 (e.g., 20 percent mortality becomes a proportion of 0.2), then the logit of p is equal to the following:

$$logit(p) = \log\left(\frac{p}{1-p}\right).$$

To estimate the expected value of the distribution, the arithmetic mean ($\bar{X}$) of the logit-transformed proportion data (e.g., data from Exhibit 11D-5) is calculated. This mean is then transformed back to the proportion scale by using the following inverse logit function, which yields an estimated expected value for the proportion of impingement mortality:

$$p = \frac{\exp(\bar{X})}{1+\exp(\bar{X})}$$

The 95th percentile is estimated by first calculating the following:

$$z_{0.95} = \bar{X} + 1.645S,$$

where S is the standard deviation of the logit-transformed proportion data. The value $z_{0.95}$ is then transformed back to the proportion scale by applying the inverse logit function, yielding the estimated 95th percentile for the proportion of impingement mortality. The expected value and 95th percentile for proportions are converted to percentages by multiplying by 100.

For data reported as proportions (or percentages), the beta distribution model is more flexible than the logit model based on the normal distribution. When applying the beta distribution, the data are used to estimate α and β directly, so the shape of the beta distribution reflects the data collected. In contrast, the shape of the underlying distribution of the percentages under the normal distribution model is influenced by the choice of the logit function and the assumption that the transformed data are normally distributed. Also, transformation bias that may be introduced under the normal distribution model is not encountered with the beta distribution model. Thus, for these reasons, EPA selected the beta distribution model over the normal distribution model to develop the proposed limitations.

11D.2.2 Methods for Estimating Upper Percentiles

While the beta distribution approach appears to perform well in characterizing the overall distribution of percent impingement mortality, EPA may evaluate statistical methods that focus on characterizing the upper tail of a distribution of percentages. One possible approach would be to truncate data within the lower tail of the distribution, so that data important to characterizing the upper tail of the distribution have greater weight. Such an approach also reduces the impact that the choice of distribution model has on the estimate of the 95^{th} percentile. However, these methods would not be used to estimate other distributional parameters such as the expected value. In its evaluation, EPA would determine if methods such as these can lead to a more accurate estimate of the 95th percentile of the distribution of percent impingement mortality.

11D.2.3 Survival Analysis

For the final rule, EPA may consider survival analysis procedures. This approach would require mortality data that were measured at different times following impingement. The data used as the basis for the proposed limitation all reported mortality at 24 hours, and thus, the data were not suitable for a survival analysis approach. However, for the final rule, it is possible that EPA will select a different set of data that may measure mortality at different time points. If several studies considered a variety of different time points at which it monitored impingement-related deaths, it may be possible to model impingement mortality data using survival analysis techniques such as a Kaplan-Meier or probit-type approach. This may result in an alternative estimate for the expected impingement mortality (or survival) that occurs at a given point in time, which may be appropriate for characterizing an achievable long-term performance among the facilities.

11D.2.4 Nonparametric Procedures

Nonparametric procedures exist for estimating the average and 95th percentile. Nonparametric procedures use the ordered data values to approximate percentiles. The 95th percentile would be estimated by the observed value below which fall the values of 95 percent of the observations. A nonparametric approach is sometimes appropriate because it does not place assumptions on the type of underlying distribution. However, this method is not very precise for small sample sizes. For this reason, EPA determined that it was not appropriate to take a nonparametric approach with the data that were used as the basis of the proposed limitations. For example, with a data set containing ten observations, the same observation (the one with the largest value) would be used to approximate the 91st percentile, the 95th percentile, and the 99th percentile.

11D.2.5 Modeling Number of Fish Instead of Percentages

For the proposed limitations, EPA used the number of fish killed in its calculations of the impingement mortality percentages. EPA then used the percentages as the basis for the proposed limitations. These percentages allow for flexibility in the number of fish in different water bodies and seasons. In other words, more fish impinged, the larger the number that can be killed.

In the preamble to the proposed rule, EPA has requested comment on an alternative for sites where few fish are likely to be impinged. For this alternative approach, EPA calculated a daily average number of fish that were killed during each sampling period as follows:

$$daily\ average = \frac{total\ number\ of\ impinged\ fish\ that\ died}{number\ of\ nights\ in\ sampling\ event}$$

Exhibit 11D-7 shows the results of these calculations. (EPA did not include Arthur Kill data because the number of nights in each sampling event was not available.) For the final rule, if EPA were to consider number of fish killed as an alternative, it might statistically model the data or select the minimum observed value. This minimum value of 23 fish mortalities per day is derived from the Dunkirk study during the summer sampling event.

Exhibit 11D-7. Number of Fish Killed: Daily Averages During Sampling Events

Facility Name	Sampling Period	Number of Nights	Total Number of Impinged Fish	Total Number of Impinged Fish that Died	Arithmetic Average of Dead Fish Per Night of Sampling
Dunkirk	12/20/98 to 01/09/99	8	6,775	261	32.6
	04/20/99 to 04/28/99	8	3,562	435	54.4
	08/16/99 to 09/04/99	8	1,220	182	**22.8**
	11/02/99 to 11/11/99	8	8,928	243	30.4
Huntley	01/21/99 to 01/25/99	5	6,120	561	112.2
	10/24/99 to 10/29/99	5	3,258	1,025	205.0

11D.2.6 Modeling Age-1 Equivalents

Instead of modeling percentages, EPA considered use of age-1 equivalent (A1E) data in developing the proposed limitations. A1E is a metric based on the Equivalent Adult Model (EAM), which has been used by the EPA in their assessment of environmental benefits. The EAM is a method for expressing losses of organisms killed at various ages as if the losses had all occurred at the same age, known as the age of equivalency (Goodyear, 1978). Converting impingement and entrainment losses to the same age provides a common measure of loss that is directly comparable among species, years, facilities, or the regions where mortality occurs. The age of equivalency can be any age of interest. To support section 316(b) benefits analyses, EPA converted impingement and entrainment losses to age-1 equivalents.

Age-1 equivalents are calculated as the product of the age-specific numbers of organisms impinged and entrained, and the age-specific cumulative survival rates of these organisms from the age of loss to age 1. For example, if the cumulative survival rate between the larval stage of a fish species and age 1 is 3 percent, then 100 larval losses would be expressed as 3 A1E. A comprehensive description of the calculations involved in the EAM is provided in Chapter A1 of the Regional Benefits Analysis for Phase III of EPA's Section 316(b) rulemaking (EPA, 2006).

For the benefits assessment for this proposed rulemaking, EPA used life history data for a significant amount of the specific species which the EPA has loss records for at 316(b) facilities. However, this list of species life history data is incomplete and particularly for impingement records lacks specific ages of fish which are observed to be impinged. In addition, EPA recognizes that as live organisms increase in age they are less likely to be impinged at most Phase II facilities.

After evaluating the practicality of developing comprehensive age-1 conversion factors for all species and their life stages in different water bodies, EPA concluded that such an approach was not practical for two main reasons. First, the expertise, data, and time required to accurately calculate specific life history data for all organisms at all facilities were not possible without significant assumptions and uncertainty. Second, EPA recognized the increased burden which would be placed upon facilities, which would have to accurately identify individual species and their specific age, before calculating the A1E. As such, the EPA determined that simply counting individual organisms that are impinged has significantly less uncertainty than calculating A1E and is less burdensome to the states and facilities implementing an impingement limit.

11D.3 References

Casella, George and Berger, Roger L. 2002. *Statistical Inference*, 2nd Edition. Pacific Grove, CA: Duxbury.

Goodyear, C.P. 1978. Entrainment Impact Estimates Using the Equivalent Adult Approach. FWS/OBS - 78/65. U.S. Department of the Interior, Fish & Wildlife Service, Washington, DC. July.

Johnson, Norman L. and Kotz, Samuel. 1970. *Continuous Univariate Distributions – 2*. New York: Wiley.

U.S. Environmental Protection Agency (EPA). 2006. Regional Analysis for the Final Section 316(b) Phase III Existing Facilities Rule. EPA-821-R-06-002. June 2006. Retrieved from http://www.epa.gov/waterscience/316b/phase3/index.html, December 2008.

Appendix E to Chapter 11: Analysis of Variance on Percent Reduction in Entrained Organisms

11E.0 Introduction

This appendix describes an analysis of variance (ANOVA) applied to data collected from several studies (and at several different facilities) that measured entrainment of organisms through fine mesh screens placed on the intakes to cooling water intake structures. The objective of the ANOVA was to evaluate whether screen slot width and/or slot velocity have a statistically significant impact on the percent reduction of organisms entrained through the screens. Section 11.3 of Chapter 11 identifies the entrainment data that were used in the analyses presented in this appendix.

The following sections provide a general overview of ANOVA, the questions addressed in the ANOVA of the entrainment data, the data selected for the ANOVA, and the models and results used to evaluate each question. The appendix also describes potential refinements that EPA may consider for the final rule.

11E.1 General Overview of ANOVA

ANOVA techniques are appropriate for data sets that contain the measure of interest (known as the "dependent variable") and a series of "predictor" (or "independent") variables. In the analysis, the ANOVA expresses the value of the dependent variable as a mathematical function of the predictor variables, known as the *ANOVA model.* A general class of models is specified upfront, and then the "best" model in this class is determined by applying statistical techniques (i.e., "fitting the model") to the available data. As the ANOVA model is fitted to the data, statistical hypothesis tests are performed to determine whether different values of one or more predictor variables significantly affect the value of the dependent variable.

For the outcome of the ANOVA approach applied in this appendix to be statistically valid, the values of dependent variable, after accounting for any effects due to the predictor variables included in the model, must satisfy certain conditions. In particular, the data values must be independent from one another and originate from a common normal (bell-shaped) distribution.

One useful outcome of the ANOVA is a set of *least-squares means* for the dependent variable which can be reported at each value of one or more predictor variables. Named for the statistical technique used to fit the ANOVA model to the data, least-squares means represent what the ANOVA model predicts for the average value of the dependent variable at the specified value(s) of the predictor variable(s). By reviewing these least-squares means (as well as confidence intervals placed on these means, which can also be output from the ANOVA), one can identify where differences are present in the dependent variable among values of the predictor variables.

11E.2 Questions to Address in Entrainment ANOVA

In the entrainment analysis, percent reduction in entrained organisms serves as the dependent variable, and slot width and slot velocity serve as predictor variables. The statistical hypothesis tests within the ANOVA answer the following questions:

1. When both slot width and slot velocity are considered jointly, do differences in the values of either (or both) variables lead to statistically significant differences in the percent reduction in entrained organisms?
2. If only slot width is considered, do differences in the slot width lead to statistically significant differences in the percent reduction in entrained organisms? (EPA formulated question #2 in part because not all facilities provided information on slot velocity when reporting percent reduction in entrainment.)

If the answer to either question is "no," then one can conclude that any observed differences in percent reduction of entrained organisms among different slot widths and/or slot velocities are the result of other unaccounted factors, or perhaps simply due to chance.

EPA used the generalized linear models (GLM) procedure in the SAS® System to perform the ANOVAs. The ANOVA models selected for the GLM procedures differed slightly to address questions #1 and #2. Sections 11E.4 and 11E.5 describe the models.

11E.3 Data Used for the Entrainment ANOVA

In assessing the effects of slot width and slot velocity on percent reduction in entrained organisms, EPA applied an ANOVA separately to three sets of percent reduction data, with the three data sets distinguished by the life stage of the organisms:

1. Entrainment data for eggs only
2. Entrainment data for larvae only (EPA considered "larvae" to be any entrainable life stage other than eggs.)
3. Entrainment data for all organisms (i.e., all life stages).

The percent reduction data which EPA used in each execution of the ANOVA appear in the last columns of Exhibits 11-7, 11-13, and 11-16 in Chapter 11. For question 1, the analysis did not include percent reduction data from the Big Bend study, the Brunswick study, and the 1982 Chalk Point study because references on these studies did not report slot velocity.

EPA used graphical techniques to evaluate the extent that the entrainment data values met the conditions of independence and normality described in Section 11E.1. In some cases (as noted below), EPA found that if the natural logarithm of the percent reduction values were taken, the resulting log-transformed values satisfied the ANOVA requirements better than the percent reduction values themselves. In these cases, EPA applied the ANOVA to log-transformed percent reduction data values. However, because logarithms can be taken only of positive data values, percent reduction data values of less than zero were excluded from the analyses of log-transformed data.

11E.4 Model and Results for Question #1 (effects of slot width and slot velocity on log-transformed percent)

The ANOVA model to address question #1 took the following form:

$$\log(Y_{ijk}) = (\mu + \alpha_i) + \beta V_j + \epsilon_{ijk} \qquad (1)$$

where Y_{ijk} is the percent reduction in entrainment associated with the k^{th} study that utilized the i^{th} slot width and j^{th} slot velocity, μ is an overall constant, α_i is an additional constant amount that is associated with the i^{th} slot width, β is a slope factor, V_j is the j^{th} slot velocity, and ϵ_{ijk} is random error left unexplained by the model. Thus, this model expressed the log-transformed percent reduction in entrained organisms (i.e., the dependent variable) as equal to a constant value ($\mu + \alpha_i$) which could differ for different slot widths. Then, working from this constant value, the model allowed the log-transformed percentage to vary in a linear fashion based on the value of the slot velocity. For each slot width, the model allowed each increase of 1.0 m/s in slot velocity to result in a constant change (represented by β) in the value of the log-transformed percentage. (Preliminary investigation concluded that no statistical evidence existed that the size of the change β needed to vary for different slot widths.)

By fitting this model to the percent reduction data and applying statistical hypothesis tests, EPA answered question #1 by doing the following:

- To determine whether slot width led to statistically significant differences in the (log-transformed) percent reduction data (while also accounting for slot velocity), EPA performed the following statistical hypothesis test:
  - Null hypothesis: the values α_i were each equal to zero (i.e., for each slot width).
  - Alternative hypothesis: at least one value α_i was nonzero.
- To determine whether slot velocity led to statistically significant differences in the (log-transformed) percent reduction data (while also accounting for slot width), EPA performed the following statistical hypothesis test:
  - Null hypothesis: the value β was equal to zero.
  - Alternative hypothesis: the value β was unequal to zero.

In both cases, if the significance level (i.e., *p*-value) of the test was less than 0.05, then EPA concluded that the data were sufficient for rejecting the null hypothesis in favor of the alternative hypothesis.

EPA fitted the ANOVA model in Equation (1) separately to the (log-transformed) percent reduction data for eggs only, larvae only, and total organisms (as given in Tables 11-13, 11-16, and 11-7, respectively). The results of the statistical hypothesis tests performed within the ANOVA were as follows:

- The effect of slot width on percent reduction in entrained organisms was not statistically significant for either total organisms (*p*-value = 0.055), eggs (*p*-value = 0.053), or larvae (*p*-value = 0.169). Note, however, that the *p*-value was just barely above 0.05 in the tests involving data on either total organisms or eggs. This implies that while some differences in percent reduction may be present that could be attributable to different slot widths, the size of the differences among slot widths was not sufficient to conclude significance at the 0.05 level in either case, or variability in the slot width data was high enough to prevent observed differences from being statistically significant at the 0.05 level[1].
- Like slot width, the effect of slot velocity on percent reduction was not statistically significant for either total organisms (*p*-value = 0.183), eggs (*p*-value = 0.154), or larvae (*p*-value = 0.874).

Exhibit 11E-1 lists the least squares means for percent reduction in entrained organisms that were associated with the fitted ANOVA model at each encountered slot width, along with 95 percent confidence intervals. (These least squares means and confidence intervals have been transformed from log-units to percentage units.) While the statistical hypothesis tests involving the slot width effect did not yield statistically significant results at the 0.05 level in any instance, this table shows some interesting patterns in the least squares means. In particular, for each set of data, the largest predicted average percent reduction occurred at a slot width of 0.5 mm. Furthermore, the largest differences among the least squares means (and the least amount of overlap in their confidence intervals) occurred between the 0.5 mm and 1.0 mm mesh sizes.

Exhibit 11E-1. Least Squares Means for Percent Reduction in Entrainment and 95 Percent

Confidence Intervals, for Each Encountered Slot Width, Under the ANOVA Model Addressing Question #1

Data Set	Slot Width (mm)	Least Squares Mean (%)	95% Confidence Interval on Least Squares Mean
Total Organisms	0.5	59.7	(34.8, 102.5)
	1.0	23.8	(15.3, 36.9)
	2.0	48.6	(27.1, 87.2)
	3.0	24.1	(6.5, 89.0)
Eggs Only	0.5	75.0	(37.1, 151.9)
	1.0	20.3	(9.4, 43.9)
	3.0	25.0	(4.5, 140.5)
Larvae Only	0.5	55.6	(27.4, 113.1)
	1.0	24.0	(13.9, 41.5)
	2.0	48.6	(22.5, 105.0)
	3.0	16.1	(2.9, 90.0)

[1] The significance level denotes the maximum observed p-value that will lead to rejecting the hypothesis that slot width has no significant effect on percent reduction, for the alternative hypothesis that the slot width effect is significant. In making the above conclusions, EPA has used 0.05 as the significance level, as it is widely accepted and commonly used by many researchers. However, the choice of the significance level is somewhat arbitrary. Slightly relaxing the requirement to a significance level of 0.1 would also be considered an acceptable and reasonable choice. If a significance level of 0.1 was adopted, then the effect of slot width on percent reduction would be statistically significant for both total organisms and eggs.

To investigate the effect of slot velocity further, EPA also considered a variation on the ANOVA model for which the slot velocity effect was represented as a categorical variable rather than a continuous variable (i.e., similar to how slot width is represented in the model). Even when slot velocity was represented in this modified form within the model, the effect of slot velocity on percent reduction continued to be non-significant at the 0.05 level, and the least squares means showed no discernable pattern.

Thus, based on this analysis, EPA's answer to question #1 is as follows: No statistically significant differences were observed in average percent reduction in entrained organisms among different values for either slot velocity or slot width. However, there is some evidence from the available data that percent reduction is greater at a slot width of 0.5 mm compared to larger widths.

11E.5 Model and Results for Question #2 (effects of slot width on untransformed percent)

The ANOVA model to address question #2 was a simpler version of the above model as shown in equation (2). EPA fit this model separately to percent reduction data for eggs only, larvae only, and total organisms. Because slot velocity was not represented in this model, it allowed for data associated with studies in which slot velocity was not reported to be included in the analysis. The equation used in this analysis was:

$$Y_{ik} = \mu + \alpha_i + \epsilon_{ik} \qquad (2)$$

where the notation is the same as above. (Statisticians recognize this model as a classical "one-way" ANOVA model.) Thus, slot velocity is not accounted for in this model. In addition, under this model, EPA determined from preliminary investigations that it was not necessary to take log-transformations of the percent reduction data values in order to satisfy the necessary underlying assumptions of the ANOVA procedures. Therefore, this model features no log transformation.

To determine whether slot width led to statistically significant differences in percent reduction data, EPA performed the following statistical hypothesis test:

- Null hypothesis: the values α_i were each equal to zero (i.e., for each slot width).
- Alternative hypothesis: at least one value α_i was nonzero.

If the significance level of this test was less than 0.05, then EPA concluded that the data were sufficient for rejecting the null hypothesis in favor of the alternative hypothesis, and therefore, that slot width was a significant factor in determining percent reduction in entrainment.

EPA fitted the ANOVA model in Equation (2) separately to percent reduction data for eggs only, larvae only, and total organisms. Exhibit 11E-2 reports the least squares means for percent reduction in entrainment for each model fit, along with 95 percent confidence intervals.

Exhibit 11E-2. Least Squares Means for Percent Reduction in Entrainment and 95 Percent

Confidence Intervals, for Each Encountered Slot Width, Under the ANOVA Model Addressing Question #2

Data Set	Slot Width (mm)	Least Squares Mean (%)	95% Confidence Interval on Least Squares Mean
Total Organisms	0.5	66.7	(41.5, 91.9)
	1.0	38.0	(18.8, 57.3)
	2.0	42.5	(17.2, 67.7)
	3.0	24.2	(-42.6, 91.0)
Eggs Only	0.5	83.6	(54.4, 112.8)
	1.0	21.3	(-10.2, 52.9)
	3.0	27.1	(-50.2, 104.4)
Larvae Only	0.5	63.7	(40.2, 87.2)
	1.0	43.3	(25.3, 61.2)
	2.0	42.5	(19.0, 66.0)
	3.0	16.1	(-46.1, 78.3)

Conclusions made from the information in this table and from the statistical tests for significant slot width effect performed within the ANOVA were as follows:

- Slot width had a significant effect on average percent reduction of eggs (*p*-value = 0.024), for which data were available for three slot widths (i.e., 0.5 mm, 1.0 mm, and 3.0 mm). According to Exhibit 11E-2, the largest average percent reduction in egg entrainment occurred at a slot width of 0.5 mm, and it differed most greatly with percent reduction at 1.0 mm. (Because only one measurement represented a slot width of 3.0 mm, its least squares mean has high uncertainty, and its confidence interval is quite large.)
- Slot width did not have a significant effect on average percent reduction of either total organisms (*p*-value = 0.273) or larvae (*p*-value = 0.337). In both cases, the highest least squares means occurred at a slot width of 0.5 mm, and the smallest occurred at 3.0 mm. (However, the 3.0 mm slot width was limited to a single measurement.) The least squares means at 1.0 mm and 2.0 mm slot widths were similar.
- When considering only larvae entrainment data, EPA refit the ANOVA model to data for only the Chesapeake Bay, Portage River, and Sakkonet River studies, which shared similar experimental designs and which contributed egg entrainment data. In this analysis, slot width was found to have a significant effect on the average percent reduction in entrained larvae (*p*-value = 0.009). Thus, when studies have different sampling designs and protocols, this may contribute to increased variation in the reported entrainment data, and therefore, an increased difficulty in identifying significant differences among slot widths.

Note that when EPA applied a nonparametric form of the ANOVA procedure (using the Kruskal Wallis test to compare results among different slot widths) rather than the parametric form used here, the tests yield the same conclusions as above. The Kruskal

Wallis test does not rely on the assumption that values for percent reduction in entrained organisms (after accounting for slot width effects) originate from a normal distribution.

Thus, based on this analysis, EPA's answer to question #2 is as follows: Statistically significant differences were observed in average percent reduction in entrained organisms among different slot widths for eggs, and as seen in a smaller set of similar studies, for larvae. The greatest difference occurs between 0.5 mm and 1.0 mm slot widths.

11E.6 Future Refinements

For the final rule, if more data are identified, EPA may consider whether additional variables can be used to refine the ANOVA model. Any additional variables should have the following characteristics:

1. The variable is likely to explain variation in the percent reduction of organisms entrained.
2. Each value of the variable should be associated with data for similar screen sizes and slot velocities.

In exploring the entrainment data for the proposal, EPA considered other variables present in the entrainment data set that could be included as predictor variables in the ANOVA model. EPA may consider these variables or others in refining the ANOVA for the final rule. The variables include test condition (e.g., plant, test barge), screen technology, and water body where the test was conducted. Although some of these variables may not be of primary interest, they could explain some degree of variation in the data. Such variables are often called *nuisance* factors. However, from the data available for the proposal, the entrainment data set represents a combination of data from many experiments conducted at different time points and under different conditions. As a result, no observations are available for certain combinations of treatment conditions. This leads to some confounding in the effects of certain variables. For this reason and the lack of data for some variables, EPA could not identify additional variables in the current data set that would provide more predictive ability to the above ANOVA models which EPA developed for the proposed rule.

Appendix F to Chapter 11: Generalized Linear Models for Percent Reduction in Entrained Organisms

11F.0 Introduction

This appendix presents the results of a statistical analysis in which generalized linear models (GLM) were applied to data collected from several studies (and at several different facilities) that measured entrainment of organisms through fine mesh screens placed on the intakes to cooling water intake structures. The objective of applying GLM was to evaluate whether the slot width and/or slot velocity have a statistically significant impact on the entrainment of organisms through the screens. Section 11.3 of Chapter 11 describes the entrainment data that were used in the analyses presented in this appendix. The appendix provides a general overview of GLM, presents two types of models, and summarizes EPA's conclusions.

11F.1 General Overview of GLM

Generalized linear models are statistical methods that explain the relationship between a response variable and a set of predictors. They can be used to address the same types of questions as analysis of variance (ANOVA) methods. However, unlike ANOVA methods, GLMs can be used to make inferences about the model when the data follow a distribution other than the normal distribution. GLMs model a transformation of the mean (called the *link* function) as a linear combination of the factors under investigation. For the entrainment data, EPA considered two types of GLMs: Poisson regression and logistic regression.

11F.2 Poisson Regression

A Poisson regression is often used to model count data. Thus, this model would be appropriate to apply to the number of entrained organisms. The natural logarithm is the standard link function used for Poisson regression. Since the density of organisms in front of the screen is likely to affect the number of organisms entrained, EPA included that variable as a covariate in the model. The Poisson regression model was as follows:

$$\log(Y_{ijk}) = \alpha_i + \beta V_j + \gamma \log(D_k) + \epsilon_{ijk}, \qquad (1)$$

where Y_{ijk} is the number (per unit volume of water, or *density*) of entrained organisms associated with the k^{th} study that utilized the i^{th} slot width and j^{th} slot velocity, α_i is a constant amount that is associated with the i^{th} slot width, β and γ are slope factors, V_j is the j^{th} slot velocity, D_k is the density of organisms measured in front of the screen for the k^{th} study (representing organisms having the potential for being entrained), and ϵ_{ijk} is random error left unexplained by the model.

Note that the form of model (1) is very similar to the ANOVA model considered in Appendix E. If the parameter γ equals 1 and if we subtract the term $\log(D_k)$ from both sides of the model, we obtain the following:

$$\log(Y_{ijk} / D_k) = \alpha_i + \beta V_j + \epsilon_{ijk}. \tag{2}$$

In model (2), the response is the natural logarithm of the relative size of the behind-screen density and the density in front of the screen. This value is similar to natural logarithm of the percent reduction, which in this case would equal $\log(1 - Y_{ijk} / D_k)$. Thus, applying ANOVA methods to model (2) would produce similar results to those obtained in our previous analyses. The distinction of fitting model (1) is that we focus on entrainment density, we assume that these data follow a Poisson distribution, and we allow for the possibility that the parameter γ could deviate from 1.

EPA fit the Poisson regression model to the data set that included observations for organisms in the egg stage of development only, the data set that included observations for organisms in the larval (non-egg) stage of development only, and the data set that included observations for all types of organisms (egg and non-egg). In this analysis, EPA excluded observations from St. Johns River, because the entrainment data at this site were reported as absolute numbers rather than as a density per unit volume of water. EPA excluded the observation from Big Bend, because preliminary fits of the model suggested that this observation was an outlier. EPA excluded the 1983 Chalk Point study that used a screen width of 3 mm because that was the only study that tested that particular mesh size. Slot velocities for the 1982 Chalk Point studies, which were missing for previous analyses, were assumed to be 1.0 feet per second, based on information that EPA obtained from recent site visits.

Based on the results of fitting model (1) to available data, EPA reached the following conclusions:

- Both screen width and slot velocity were highly significant at explaining the number of eggs entrained (screen width p-value < 0.0001, slot velocity p-value = 0.0002).
- Screen width was not significant at explaining the number of non-eggs entrained (p-value = 0.5484) or the number of total organisms entrained (p-value = 0.3413). Slot velocity was not significant at explaining the number of non-eggs entrained (p-value = 0.7889) or the number of total organisms entrained (p-value = 0.6916).
- The logarithm of the density of organisms in front of the screen was significant for all three data sets (eggs only, non-eggs, and total organisms). The point estimate of the slope parameter γ was close to 1 in all cases, ranging from 0.94 (all organisms) to 1.59 (eggs only). This suggests that the fitted model (1) is reasonably close to model (2).

11F.3 Logistic Regression

EPA also investigated the logistic regression model, a GLM that is appropriate when the response variable is a percentage. In this model, EPA assumes that the number of potentially entrained organisms equals the density of organisms measured in front of the screen. The number of entrained organisms then follows a binomial distribution, where the outcome is either entrained or not entrained. The standard link function in logistic regression is the logit function. If *p* is a proportion between 0 and 1, then the logit function is defined as follows:

$$\text{logit}(p) = \log\left(\frac{p}{1-p}\right)$$

The logistic regression model was as follows:

$$\text{logit}(Y_{ijk}) = \alpha_i + \beta V_j + \epsilon_{ijk}, \qquad (3)$$

where Y_{ijk} is the density of entrained organisms divided by the density of organisms measured in front of the screen for the k^{th} study that utilized the i^{th} slot width and j^{th} slot velocity, and the remaining model terms are as defined in model (1).

EPA fit the logistic regression model (3) to the same data used to fit the Poisson regression model (1). The fit of the logistic regression model confirmed the conclusions reached from the fitted Poisson regression. Specifically, EPA concluded the following:

- Both screen width and slot velocity were highly significant at explaining the number of eggs entrained (screen width p-value = 0.0003, slot velocity p-value = 0.0049).
- Screen width was not significant at explaining the number of non-eggs entrained (p-value = 0.4493) or the number of total organisms entrained (*p*-value = 0.2550). Slot velocity was not significant at explaining the number of non-eggs entrained (*p*-value = 0.8322) or the number of total organisms entrained (*p*-value = 0.7720).

11F.4 Summary

In summary, the results of fitting GLMs to the entrainment data suggest that both slot width and slot velocity could significantly explain variation in the number or proportion of *eggs* entrained. However, they do not appear to be significant for either total organisms or organisms in the *larval* (non-egg) stage of life.

While EPA has not fully evaluated which of the above GLMs is most appropriate to analyze the available data, a cursory review of the log likelihood statistics suggests that logistic regression provides a better fit than Poisson regression. However, these statistics were not adjusted for the different number of parameters in each model, and each method has its own set of assumptions which may or may not be reasonable given the conditions of the experiments. For the final rule, EPA will further assess the validity of these assumptions using the data and understanding of what conditions affect entrainment from biological and engineering perspectives.

Chapter 12: Analysis of Uncertainty

12.0 Introduction

Any scientific analysis contains some degree of uncertainty. Data used to develop the analysis may have inherent flaws, assumptions may not be entirely accurate, or outside factors may unexpectedly influence the outcome. In many cases, uncertainty can be reduced by conducting parallel analyses or verifying conclusions via alternate pathways or data sources. This chapter presents EPA's efforts to identify sources of uncertainty, evaluate how those uncertainties might affect the analyses, and consequently minimize the effects of uncertainty associated with its analyses.

12.1 Uncertainty in Technical Analysis of Impingement Mortality

12.1.1 Technology in Place and Related Model Facility Data

The detailed technical questionnaires were conducted more than 10 years prior to this rule proposal. Changes may have occurred at individual facilities that would affect the cost and reductions analyses such as number of intakes, intake flow, operational status, and current technology in place. (EPA did collect more current financial information to update and revise the economic analysis; see EBA for more information). Based on site visits and discussions with industry, EPA believes the technical data is still sufficiently representative of industry operations and can be used to estimate national level costs and reductions of various regulatory approaches. However, some facilities have installed impingement and entrainment technologies as a result of the Phase II, state policies, or other local requirements. As a result, the costs and reductions of the technologies considered in this proposal are potentially overstated.

12.1.2 Costs of Additional Impingement Mortality Controls

The economic analysis presented in the EBA contains estimated compliance costs for impingement mortality technologies and, for some options, entrainment mortality technologies. One uncertainty EPA identified in basing compliance costs on the industry detailed technical questionnaire is how many coastal or estuarine facilities already use barrier nets or some equivalent-performing technology for reducing shellfish impingement mortality. EPA's option 1 would also require a fish handling and return system for all facilities with traveling screens, including those facilities with an actual intake screen velocity of less than 0.5 feet per second (fps). EPA's detailed technical data pre-dates the 2004 Phase II rule, and likely underestimates the number of facilities already employing modified traveling screens with a fish return, or an equivalent performing technology. In a sensitivity analysis, EPA estimated total rule costs assuming zero facilities had technologies to meet either of these requirements. These costs are presented below.

Barrier Net Costs

The proposed rule requires that all facilities located on oceans, tidal rivers and estuaries minimize the impingement of shellfish. EPA estimated costs for this requirement by assigning barrier nets to those facilities that do not already have barrier nets or an equivalent-performing technology. EPA's technical data does not provide sufficient detail to determine which facilities already employ a technology that would meet the requirement. Therefore, EPA's initial cost estimates exclude facilities that met the 0.5 fps intake velocity threshold and that are located on an ocean or estuary from being assigned additional costs for a barrier net. If EPA were to assume the entire universe of facilities (in oceans and estuaries) would need barrier nets, the manufacturing sector as a whole would be assigned an additional $100,000 and electric generators as a whole would be assigned an additional $4,010,000. Therefore the upper bound estimate of total rule costs including this requirement would increase option 1 costs by less than 1 percent.

Fish Handling and Return System Costs

The proposed rule requires that all facilities meet a minimum threshold of impingement mortality or by meeting a 0.5 fps design intake velocity threshold. In addition, the proposed rule requires fish return and handling for all traveling screens, and a requirement to eliminate entrapment of fish and shellfish. Facilities that were found to be compliant with the velocity threshold were initially assigned no further compliance costs, even though some fraction of facilities meeting the maximum intake velocity requirements use traveling screens. EPA estimated the costs assuming all of these facilities would need to install new fish handling and return systems assuming all of these facilities employed existing traveling screen (a reasonable assumption given the predominance of traveling screen use; see Chapter 4 for more information). However, EPA does not have current data on the number of traveling screens that would be deemed "modified" screens, such as Ristroph screens or post-Fletcher modifications. For example, EPA does not have data on the number of large power plants that have already modified their intakes as a result of the 2004 Phase II rule. As a result of this uncertainty, EPA conducted a sensitivity analysis on total costs by revising estimated costs to include fish handling and return systems (as well as new modified Ristroph screens[1]) to all facilities employing conventional traveling screens that were deemed to have met the 0.5 fps threshold.[2] In other words, EPA assumed zero facilities have modified screens with a fish return. Under this conservative assumption, EPA estimates the manufacturing sector as a whole would be assigned an additional $12.3 million and electric generators as a whole would be assigned an additional $50.7 million. Therefore, EPA believes the upper bound estimate of total rule costs including this requirement would increase by approximately 13 percent. Facilities that have modified screens but do not have a fish return system would incur considerably less costs, and facilities that already have a fish return would incur no incremental costs as a result of this requirement. This is further

[1] Technology module 1 was assigned; it includes both the screen replacement costs and costs for a new fish handling and return system.

[2] No additional costs would be assigned to facilities that met the velocity threshold with: modified Ristroph screens, an offshore intake location (velocity cap or wedgewire), perforated pipe, filter bed, or porous dike.

likely a conservative estimate of costs for this requirement because the proposed rule does not preclude the use of different technologies to meet the requirements; for example, dual-flow screens and WIP screens would likely meet the rule requirements for fish return and avoidance of entrapment because these screens have no carry-over, and where these technologies are feasible vendor data and pilot studies suggest such technologies are less costly than a retrofit of existing traveling screens; see Chapter 6 for more information.

12.1.3 Intake Flows for Studies Used to Develop Impingement Mortality Standards

EPA identified 6 technology studies that best represent the efficacy of Ristroph-type coarse mesh traveling screens. (See Chapter 11 for more information on the derivation of the impingement mortality standards.) To enable the development of performance standards, EPA reviewed documentation to verify the intake flows that correspond to the study periods in these documents. None of the studies were completely clear in describing the test conditions, including the intake flows withdrawn during testing. As such, EPA needed to evaluate the flow rates during the test conditions. EPA reviewed the studies and other supporting documentation (including summary reports, primary studies, and information from industry surveys) to determine the design intake flow (DIF) of the cooling water intake structures (CWIS) tested. The results are presented in Exhibit 12-1 below.

EPA is reasonably confident that the DIFs for the Dunkirk and Huntley studies are correct, because the design capacity is explicitly stated for the study screens at each facility. (Whether the screens operated at the DIF for the entire study period is unknown; EPA assumed they were.) Based on the detailed questionnaires and other available information, EPA assigned a CWIS-specific DIF to the Arthur Kill and Salem studies. The DIF is comparable to the DIF identified in site visits and other facility reports. EPA attempted to contact representatives at both facilities to confirm these assumptions. Subsequent communication efforts were not successful with either facility.

All further uncertainty analysis associated with the statistical analysis of the IM limits is addressed in Chapter 11.

12.2 Uncertainty in Technical Analysis of Entrainment Mortality

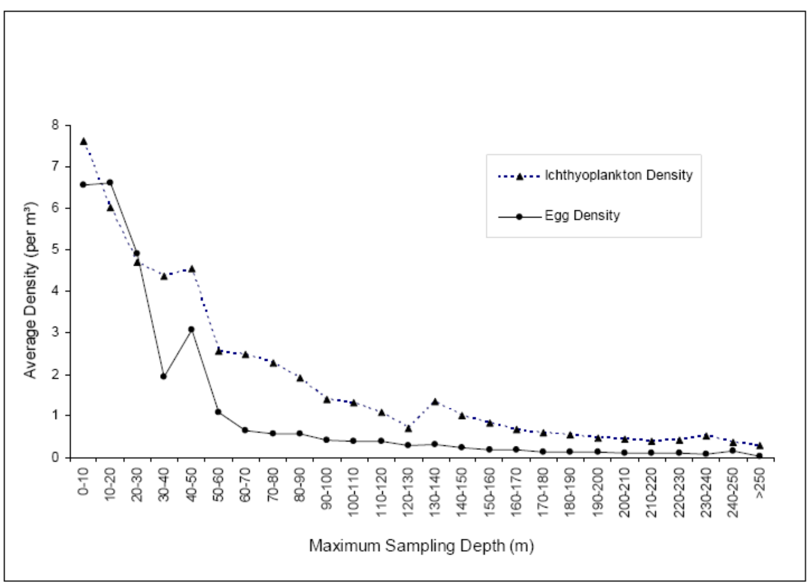
12.2.1 Intake Location

The ability of a facility to locate an intake structure to significantly reduce entrainment, and to a lesser extent impingement mortality, depends on waterbody and species found at that site. Of particular interest is the relationship of ichthyoplankton density to water depth as a potential technology for reducing I&E mortality. EPA used a Southeast Area Monitoring and Assessment Program (SEAMAP) database to characterize ichthyoplankton (fish eggs and larvae) presence, composition, and density within the Gulf (see DCN 9-5200; FDMS ID EPA-HQ-OW-2004-0002-1956). A plot of average ichthyoplankton densities against depth at 10 meter intervals (see Exhibit 12-2 below) shows general trends were similar between egg and larval fish densities. The densities of both declined most rapidly

Exhibit 12-1. Intake Flows During Screen Performance Testing

Facility Name	Generating Units/CWISs	DIF for Test CWIS Screens	Notes	Data Source(s)
Arthur Kill	Unit 20	87 MGD	Each unit contains 4 screens; only one of the four screens was upgraded for the study. No information provided on unit operation during study; assume that the flow through the upgraded test screen was 0.25 the maximum flow for the unit (347.9 MGD – provided in study), or 87 MGD.	EPRI 2007
	Unit 30	85 MGD	Each unit contains 4 screens; only one of the four screens was upgraded for each study. No information provided on unit operation during study; assume that the flow through the upgraded test screen was 0.25 the maximum flow for the unit (339.3 MGD – provided in study), or 85 MGD.	EPRI 2007
Dunkirk	Screenhouse #1, including Units 1 and 2	92.2 MGD	Modifications were made to one of three existing screens. No information provided on unit operation during study; assume flow through the test screen at maximum capacity. 92.2 MGD specified as prototype study *screen* capacity.	Beak Consultants, Inc., 2000 (DCN 5-4327)
Huntley	Units 67 and 68	82.8 MGD	All (4 existing) screens replaced at Units 67 and 68 with 5 Ristroph-types screens. No information provided on unit operation during study; assume flow through the test screen at maximum capacity. 82.8 MGD specified as prototype study *screen* capacity.	Beak Consultants, Inc., 2000 (DCN 5-4325)
Salem	Unit 1 (1995 study)	266.4 MGD	No information provided on unit operation during study; assume flow through the test screen at maximum capacity. 266.4 MGD specified as Unit 1 design flow rate; 1995 study looked only at performance of Unit 1 screens.	Ronafalvy, Cheesman, and Matejek, 2000 (DCN 5-4333)
	Units 1 and 2 (1997-1998 study)	532.8 MGD	No information provided on unit operation during study; assume flow through the test screen at maximum capacity. 266.4 MGD specified as flow rate at each unit; 1997-1998 study looked at performance of screens at both Unit 1 and Unit 2 for a total DIF of 532.8 MGD.	Ronafalvy, Cheesman, and Matejek, 2000 (DCN 5-4333)

Exhibit 12-2. Average Densities (N/m3) of eggs and ichthyoplankton sampled at a given maximum depth intervals in the Gulf of Mexico



from 0 to 60 meters in depth. As depth increased past 60 meters, the decline in ichthyoplankton and egg densities was less pronounced. This is consistent with the understanding that the euphotic zone (zone light available for photosynthesis) does not extend beyond the first 100 meters (328 feet) of depth.

The findings of the SEAMAP analysis for the Gulf of Mexico are generally supported by the cited papers from the Pacific and British coasts and the data from the Gulf of Maine, i.e., that ichthyoplankton densities increase as depth and distance from shore decrease, and that abundance is greatest at depths less than 100 meters. These data did not show consistent or in many cases even a high level of performance as a result of intake location. Further, as a result of these analyses, EPA has determined only intakes far offshore in the ocean or Great Lakes could achieve such distances and depths, therefore the technology is not even available for most facilities. Still other facility data shows that substantial decreases in density are not observed even far offshore. Therefore, EPA did not further consider intake location as a candidate technology for national standards. However, EPA anticipates for some facilities, an intermediate distance/depth/density where an order of magnitude decrease in density would occur. EPA intends to collect and review additional source water characterization and density data, and will reassess intake location as a possible technology.

12.2.2 Space Constraints

Chapter 10 discusses EPA's approach to estimating the number of facilities that would face space constraints (as well as constraints for noise and tower plume). At some facility sites, EPA believes retrofitting to closed-cycle cooling is extremely difficult or perhaps infeasible due to a lack of space for the cooling tower. Space constraints, in particular water-front acres, may preclude expanding an existing intake structure such as to reduce intake velocity by adding intake bays or due to fine mesh installations. In the majority of cases, EPA found dense urban locations simply have no space available on the site to locate a cooling tower of sufficient size. In many cases the surrounding land is occupied, making it impossible (or prohibitively expensive) to acquire additional land. EPA did not assess the costs of additional land purchases in its analysis, because EPA does not have adequate data on which to predict the number of facilities with space constraints, their locations, and the availability and costs of neighboring land.

Based on site visits, permits, and other reports, EPA assumed an upper bound of one in four, or 25 percent, of facilities would face space constraints. EPA based this assumption on the observation that approximately 95 percent of the 47 sites with a ratio of 160 acres per 1000 megawatt (MW) and above would have sufficient acreage to retrofit mechanical draft cooling towers. For the 25 observed sites with a ratio less than 160 acres per 1000 MW, as many as 20 percent of the facilities would likely be space constrained.

Another GIS-based approach EPA analyzed (instead of the population density method presented in Chapter 10) was to use a data layer from the National Atlas that identified "urban" areas. Similar to the population density approach, this data layer would identify areas that are likely to have high densities of populated space and would be the most likely to face significant challenges in siting a retrofit cooling tower.

The urban GIS layer identified a similar profile for land availability. For example, it identified approximately 30 percent of facilities as located in an urban area (as examined by the number of facilities, percentage of total flow, and percentage of total cost).[3] Electric generators were identified as urban slightly less often and manufacturers were identified slightly more often. Small businesses were much less likely to be identified as urban.

The primary drawback of this data was that it was not clear how the urban identification had been designated. Given the similarities in the two approaches and their projected outcomes, EPA opted to use the population density approach, as it provides a better defined and more reliable algorithm.

EPRI reported at least 6 percent of sites evaluated were deemed "infeasible" on the basis that no space was available on which to locate a cooling tower. (See DCN 10-6951.) While EPA does not have access to the facility level data, and is therefore unable to confirm the infeasibility analysis, EPRI's report supports EPA's assertion that there is significant uncertainty around space constraints for facilities to install closed-cycle cooling.

12.2.3 Development of Cooling Tower Costs

In the Phase I and 2004 Phase II rules, EPA used a cost estimation approach that it developed to calculate estimated costs for closed-cycle cooling. This approach was derived from cost modules that specify the necessary activities, materials, and contingencies that comprise the total cost.

In 2007, EPRI provided a new cost estimation tool to EPA. The EPRI tool calculated costs based on documentation for over 50 closed-cycle retrofits and detailed feasibility studies. EPA also used cooling tower engineering assessments conducted for California as part of the Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling. These detailed assessments were conducted on 19 existing coastal plants. Maulbetsch and others have documented cooling tower assessments and presented such findings in symposiums and proceedings; for example see "Issues Associated with Retrofitting Coastal Power Plants" (DCN 10-6955) and "Water Conserving Cooling Status and Needs" Energy-Water Needs" (DCN 10-6953).

Exhibit 12-2 provides a comparison of the cooling tower compliance costs derived using the EPRI Tower Calculation Worksheet to compliance costs derived using the EPA Methodology used in 2004 Phase II for an option where cooling towers were retrofitted to facilities on estuaries and oceans. The costs are for a 350 MW facility with a cooling water flow of 200,000 gallons per minute (gpm) (288 million gallons per day [MGD]). The 2004 EPA costs are adjusted to 2007 dollars. It is assumed that the costs shown contain comparable structural components although it is not known whether the EPRI costs include condenser upgrades so this element of the 2004 EPA costs is shown

[3] EPA also examined the universe of facilities by waterbody type, state, cooling system type, capacity utilization, fuel type, and manufacturing sector. In each case, there were no significant trends that would affect the broader assumption that approximately 30 percent of facilities are in an urban location.

separately (not all cooling tower retrofits require condenser upgrades therefore EPA's costs would not apply condenser upgrade costs to all facilities). The 2004 EPA costs shown do not include any intake modification costs. EPA operations and maintenance (O&M) costs are for gross O&M meaning they do not include reductions for baseline technology O&M such as once through pumping energy costs. Therefore EPA's O&M are potentially overstated.

Exhibit 12-3 shows that the two costing methodologies produce similar results. While the 2004 EPA non-nuclear and nuclear facility capital costs are comparable to the EPRI "easy" and "average" costs, the EPA's O&M cost are higher for nuclear facilities. The highest and lowest total annualized costs (based on 20-year service life and discount rate of 5 percent) cover a similar span for both methodologies especially if condenser upgrades are included. Thus, use of either method should produce comparable national costs.

Exhibit 12-3. Cost Comparison for a 350 MW Plant with Cooling Flow of 200,000 gpm (288 MGD)

	Tower Type	Capital Costs - Tower and Piping	Condenser Upgrade[1]	O&M	Tower Electricity Usage (Pumps & Fans)	O&M Total[2]	Annualized Capital Not Including Condenser Upgrade[3]	Annualized Condenser Upgrade	Total Annualized Cost Not Including Condenser Upgrade	Annual Heat Rate Penalty[4]
EPA Phase II	Redwood Tower	$27,000,000	$5,200,000	Included in O&M Total	Included in O&M Total	$2,900,000	$2,200,000	$400,000	$5,100,000	?
	Redwood Tower - Nuclear	$49,000,000	$9,400,000	Included in O&M Total	Included in O&M Total	$4,200,000	$3,900,000	$800,000	$8,100,000	?
EPRI Costs	Easy	$32,000,000	-	$260,000	$2,600,000	$2,860,000	$2,600,000	-	$5,460,000	$1,040,000
	Average	$53,000,000	-	$260,000	$2,600,000	$2,860,000	$4,200,000	-	$7,060,000	$1,040,000
	Difficult	$83,000,000	-	$260,000	$2,600,000	$2,860,000	$6,600,000	-	$9,460,000	$1,040,000

[1] EPA did not include full condenser upgrade costs at all facilities. Not sure If EPRI included them

[2] O&M shown does not include deduction for baseline O&M pumping energy

[3] Annualized Capital Cost Factor (20 yr at 5%) = 0.08

[4] Heat rate penalty not included in O&M total or Total Annualized Cost

The advantages of using the EPRI costing approach include:

- It can produce a range of capital costs (i.e., the ability to use easy, average and difficult settings);
- The underlying data is based on actual retrofits, and is likely a more robust representation of costs;
- The EPRI worksheet can be readily modified to generate facility costs while the EPA method is more complex and would require considerable spreadsheet development;
- Input variables can be readily generated; and
- The methodology generates all costs including the energy penalty costs.

12.3 Uncertainty in Benefits of I&E Controls

12.3.1 Reductions in Impingement and Entrainment by Region

EPA's analysis of reductions used 96 studies across the seven EPA Benefits Regions (see the EEBA for further information). There are four major kinds of uncertainty that may lead to imprecision and bias in EPA's I&E mortality analysis: data, structural, statistical, and engineering uncertainty. These are discussed in detail in section 1.1 of the EEBA. In response to these potential limitations, EPA conducted a sensitivity analysis exploring the extent to which baseline impingement and entrainment (I&E), and therefore the corresponding potential reductions in I&E attributable to installation of compliance technology, changes as a result of combining or isolating studies in the various benefits regions. The studies I and E losses on a per unit flow (MGD) basis are presented in terms of Age-1 Equivalents in Exhibit 12-4.

Exhibit 12-4. Impingement and Entrainment Losses Per Unit Flow

Region	Studies	AIF	Average Study I loss in A1E per MGD	Average Study E loss in A1E per MGD	I losses in A1E per MGD	E losses in A1E per MGD
(Freshwater Regions)						
Inland (all)	44	139,178			4,457	1,924
Great Lakes	11	19,047			2,489	569
subtotal	55	158,225	4,063	1,653		
(Marine Regions)						
California Coastal	18	12,300			514	23,242
Mid-Atlantic	12	28,165			4,532	33,697
North Atlantic	6	7,037			113	11,919
Gulf of Mexico	3	13,246			8,073	9,722
South Atlantic	2	7,462			7,064	735
subtotal	41	68,210	2,504	22,558		
Total for all regions	96	226,435			4,249	7,648

It appears impingement dominates the total A1E in freshwater systems, and entrainment dominates the marine regions. Due to the limited number of studies in certain regions, EPA next combined studies in those regions and recalculated the national baseline I&E. Due to most studies being conducted on waterbodies in the inland region, EPA also combined all studies by salinity, i.e., a freshwater region and a marine region. Finally, EPA combined all studies into one national region. In each case, the weight of the study (based on the actual flows reported in each study) was kept the same. In all scenarios, EPA found the change in baseline I&E increased as shown Exhibit 12-5.

Exhibit 12-5. Changes in Baseline Impingement and Entrainment

Method of combining studies without changing the weight of each study	National baseline I (A1E)	National baseline E (A1E)	National baseline I&E combined (A1E)	% change in national baseline over current approach
7 regions (current approach)	9.49E+08	1.52E+09	2.47E+09	- - -
5 regions: CA, MA, INL, GL, GoM	1.01E+09	2.21E+09	3.23E+09	131
2 regions, AIF wtd avg	8.56E+08	1.86E+09	2.71E+09	110
all regions total value	1.01E+09	1.82E+09	2.83E+09	115
2 regions, freshwater and marine, study average	8.56E+08	1.86E+09	2.72E+09	110
6 regions (GoM and SA combined)	9.56E+08	1.58E+09	2.54E+09	103
5 regions (GoM + SA, NA+MA combined)	1.00E+09	1.80E+09	2.81E+09	114

This uncertainty analysis suggests potential bias is accentuated when combining studies from different waterbodies. In particular, the extremely small number of studies in the Gulf of Mexico and the South Atlantic regions, and the significantly lower I&E attributed to those regions, is highlighted. Studies in other waterbodies show higher I&E baseline estimates, suggesting the national baseline could be as much as one-third higher than the currently used approach to regional benefits analysis. Further, there is considerable variability observed in I, E, and I&E combined (as measured in A1E). To reduce the uncertainty, EPA intends to collect additional studies in all regions, solicit data in the proposed rule, and revise the baseline I&E calculations accordingly.

12.3.2 Air Emissions Associated with Closed-Cycle

Fossil-fueled facilities may need to burn additional fuel (thereby emitting additional CO_2, SO_2, NO_X, and Hg) for two reasons: 1) to compensate for energy required to operate cooling towers, and 2) slightly lower generating efficiency attributed to higher turbine back pressure. In general, EPA expects national level emissions may increase in the short term,[4] but decrease over the long term as facilities upgrade the oldest units by replacing condensers and boilers. U.S. fleet efficiency will likely increase over the long term, resulting in lower base emissions on a per watt basis, and the turbine back pressure penalty will be further reduced resulting in lower incremental emissions.

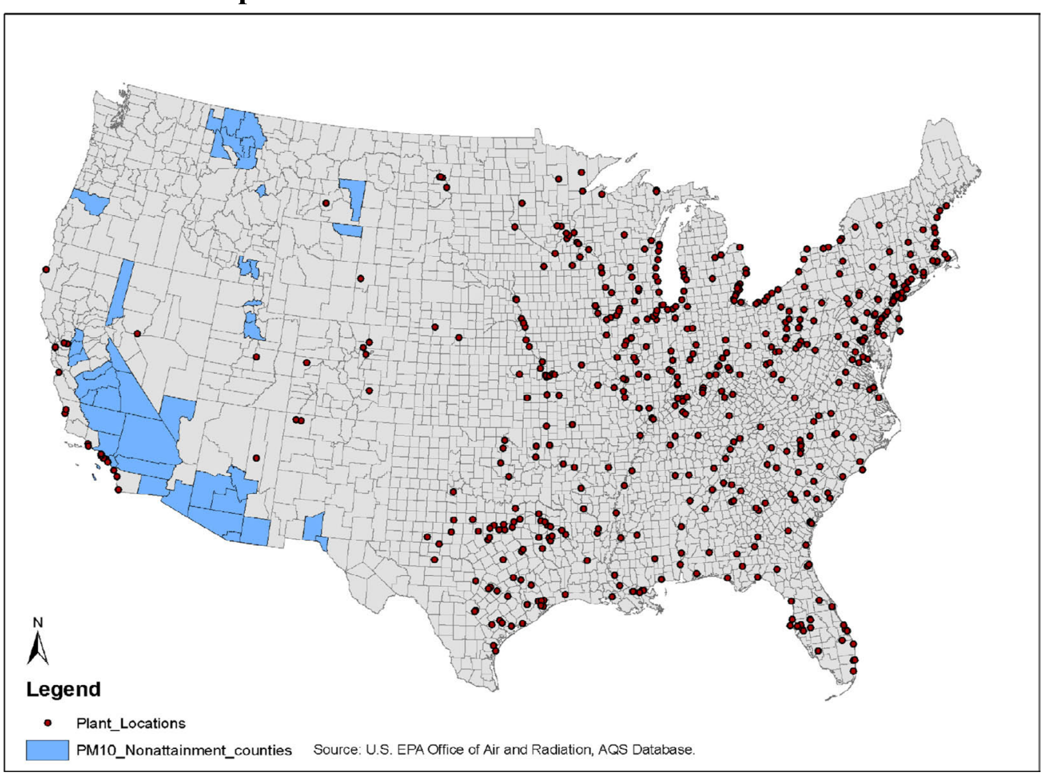
EPA's projected emissions due to cooling tower energy penalties include several sources of uncertainty. EPA's economic analysis of a cooling towers based rule indicates that some units and a few facilities may close as a result of the proposed rule. The IPM modeling used in EPA's economic analysis indicates any closures of generating units are generally comprised of the oldest and least efficient (and therefore the highest emitting) units, resulting in a potential reduction in total air emissions as a result of these closures;

[4] In its comments on the Phase II rule (see DCN 6-5049, authors 316bEFR.211 and 316bEFR.214), the Department of Energy (DOE) predicts energy penalties ranging from 2.4 to 4.0 percent for conversion to wet cooling towers by Phase II facilities, i.e., electric generators with a DIF of greater than 50 MGD. DOE applied these penalties to case study regions and projected less than 1 percent emissions increases.

see the EBA for more information on this specific assessment. Additional capacity brought online to replace these facility closures will be more efficient units. In addition, the current emissions rate calculations do not reflect full implementation of the most recent air rules. For example, the 2010 Air Transport Rule and other state and EPA actions would reduce power plant SO_2 emissions by 71 percent, and NO_x emissions by 52 percent. The mercury rule would require utilities to install controls to reduce mercury emissions by 29 percent. Since the actual emissions data used in EPA's analysis does not reflect full implementation of these air rules, and since in some cases technologies to reduce emissions have yet to be installed, both the baseline and any potential increase in emissions are overstated. Finally, the latest tower fill materials and other cooling tower technology improvements provide increases in cooling capacity. In some cases cooling towers provide cooling water at lower temperatures than available from the source water, resulting in lower turbine back pressure in the summer when maximum power generation is desired.

EPA's emissions estimates also include emissions (drift) from the cooling towers themselves. Drift consists of water droplets exiting the cooling tower. Drift can result in formation of particulate matter (primarily PM_{10}) when the droplets evaporate before hitting the ground. Current cooling tower designs minimize drift to less than 0.1 percent of the circulation flow. Sustained winds and high humidity must be present for drift to reach distances of several hundred feet, therefore most power plants will not have any adverse impacts due to drift. The options considered include costs for drift eliminators – additional technology installed on the top of the cooling tower to further reduce drift to 0.0005 percent of the circulating flow. EPA has reviewed non-attainment areas for PM_{10} and has found many power plants in these areas are using dry cooling, which avoids any issues with drift.

Exhibit 12-6. Map of Non-Attainment Areas for PM10



Chapter 10 discusses the methodology to estimate incremental increases in such air pollutant emissions from retrofitting cooling towers. The approach used a generic modeling of particulate matter emissions from the cooling towers, but more site-specific analyses often use air quality modeling method AP-42. For example, Chapter 8 of EPA's "Emission Estimation Protocol for Petroleum Refineries" specifies ranked approaches to estimating losses from cooling towers. Methodology Rank 5 for cooling towers uses the total liquid drift emission factor given in AP-42 (U.S. EPA, 1995) of 1.7 lb of drift per 1,000 gallons of water (lb/103 gal) for induced draft cooling towers and the total dissolved solids (TDS) weight fraction to estimate PM-10 emissions. This is a conservative PM-10 emission factor in that it assumes that all TDS are in the PM-10 size range. Peer review of EPA's Office of Air Quality has further identified the method AP-42 frequently overestimates emissions.[5] The site-specific TDS fraction in the cooling water should be used when available, the site-specific TDS fraction can be estimated from the TDS of the makeup water and the cycles of concentration ratio (ratio of the measured parameter for the cooling tower water such as conductivity, calcium, chlorides, or phosphate, to the measured parameter for the makeup water), when these data are available. The following two examples of PM-10 emissions estimates calculations (DCN 10-6899) provide an additional method by which EPA can quantify an upper bound of PM emissions from cooling towers.

In addition to the uncertainty over annual baseline emissions generated and the uncertainty over incremental increases in emissions, there is uncertainty over the environmental impacts of emissions. Four of the 15 largest users of cooling water obtain cooling water from a freshwater source; more than half of all existing facilities withdraw water from an inland fresh water river, stream, or lake. The potential for drift formation is highest where cooling water withdrawals are obtained from a saltwater environment. Further, sustained winds and high humidity must be present for drift to reach distances of several hundred feet. A review of EPA's technical questionnaires shows that 10 of the 15 largest users of cooling water (representing more than 12 percent of the total national potential withdraws) are nuclear facilities. Nuclear facilities tend to have setbacks, security perimeters, and other boundaries that are significantly distant from the generating facility that drift is unlikely to land beyond the facility property lines. However, due to the uncertainty of these site-specific factors, EPA is unable to conclude that drift will not result in an environmental impact.

[5] See http://www.epa.gov/ttn/chief/efpac/protocol/refinery_emissions_protocol_vpeer_review.pdf.

Example 8-6: Calculation for Methodology Rank 5 for Cooling Towers

Given: For PM-10 emissions from a cooling tower with a water recirculation rate of 25,000 gal/min, that is servicing a heat exchanger cooling a gasoline stream, and that is in service all year. Using the default average TDS weight fraction of 0.0206 (or 20,600 ppmw), the following equation (Eq. 8-9) should be used to calculate the annual emissions of PM-10, *EPM10*:

$$E_{PM10} = 1.7 \frac{lb\,drift}{10^3\,gal} * 0.0206 \frac{lb\,TDS}{lb\,drift} 25{,}000 \frac{gal}{\min} * 60 \frac{\min}{hr} * 8{,}760 \frac{hr}{yr} * \frac{1\,ton}{2000\,lb} = 230.\frac{ton\ PM-10}{yr}$$

Example 8-7: Calculation for Annual Emissions from Cooling Towers

Given: For PM-10 emissions from a cooling tower with a water recirculation rate of 25,000 gal/min and that is sampled monthly for TDS. Using the site-specific TDS fraction and the operating hours between measurements, equation (Eq. 8-9) should be used to calculate the annual emissions of PM-10, E_{PM10}.

1 Date	2 TDS Concentration (ppmw)	3 Hours	4 Emissions (ton/month)
Jan 10 (startup Jan 1)	360	96	0.044
February 4	520	600	0.398
March 4	780	672	0.668
April 4	1,100	720	1.01
May 4	1,260	720	1.16
June 4	2,300	744	2.18
July 4	3,500	720	3.21
August 4	5,500	744	5.22
September 4	4,600	744	4.36
October 4	1,700	720	1.56
November 4	2,100	744	1.99
December (shutdown Dec 1 - not operating in December)	(2,100 - Use value from previous month)	(648)	1.73
Total		7,872	24 ton/yr

12.4 References

Electric Power Research Institute (EPRI). 2007. Fish Protection at Cooling Water Intakes: A Technical Reference Manual.

U.S. EPA (Environmental Protection Agency). 1995. Compilation of Air Pollutant Emission Factors. Volume 1: Stationary Point and Area Sources. AP-42, Fifth Edition. Office of Air Quality Planning and Standards, Research Triangle Park, NC.