2. General Background

1.0 Federal Regulatory History

The Federal Water Pollution Control Act Amendments, enacted in 1972 and amended in 1977 (commonly known as the Clean Water Act [CWA]), seek to "restore and maintain the chemical, physical, and biological integrity of the nation's waters" 33 U.S.C. 251(a). Impacts associated with the operation of cooling water intake structures are addressed in CWA Section 316(b), which reads, in its entirety, as follows:

> Any standard established pursuant to section 301 or section 306 of this 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.

Authority for implementing Section 316(b) resides with EPA and is addressed through the issuance of National Pollutant Discharge Elimination System (NPDES) permits. States may assume this responsibility if they implement an approved permitting program. California received authorization to implement its water quality permitting program in 1989 and currently administers NPDES permits through the actions of the State Water Resources Control Board (SWRCB) and Regional Water Quality Control Boards (RWQCBs) throughout the state. EPA retains the authority to establish the minimum standards that are to be met through the implementation of an NPDES permit, although authorized states may adopt conditions that exceed any federal requirements.

1.1 1977 Draft Guidance

In 1976 EPA published a final rule implementing Section 316(b). Following a lawsuit filed by a group of utility companies, the Court of Appeals for the Fourth Circuit remanded the rule citing EPA's failure to comply with the Administrative Procedures Act by not properly publicizing the rule's supporting documentation. EPA later withdrew most of the final rule. During the implementation phase of the 1976 rule, however, EPA published a draft guidance document titled *Draft Guidance Document for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment.* This document would serve as the basis for implementation of Section 316(b) in subsequent years by regional and state permitting authorities.

The draft guidance outlined an approach for collecting information that would support any determinations made by the permitting authority but did not establish a national technology-based standard for best technology available (BTA), as required by the CWA (USEPA 1977). Following the remand of the 1976 rule, compliance with Section 316(b) varied from state to state and region to region, with many permitting authorities evaluating facility performance based on site-specific criteria. California, through the SWRCB and RWQCBs, continued to implement Section 316(b) on a case-by-case basis in lieu of national standards.

1.2 CONSENT DECREE

In 1993 a group of environmental organizations, led by Hudson Riverkeeper, filed suit against EPA, claiming its failure to establish national technology-based standards violated the CWA. In the plaintiff's view, the case-by-case, site-specific approach that existed following the remand of the 1976 rule created an inconsistent application of the CWA by ignoring the mandate to minimize adverse impacts to a level based on the performance of the best performing technology. In 1995 EPA entered into a consent decree with Riverkeeper and other environmental plaintiffs that established a framework for the development and promulgation of national technology-based standards that would implement Section 316(b).

Subsequent amendments to the consent decree established a phased approach for implementation. Phase I would address new steam electric and manufacturing facilities. Phase II was reserved for large, existing steam electric facilities (those with a design capacity greater than 50 mgd), while Phase III would address all manufacturing facilities with a capacity greater than 2 mgd and steam electric facilities not covered by Phase II.

1.3 PHASE I

EPA issued the Phase I rule in 2001 and implemented a two-track compliance approach for new facilities. Track I restricts the facility's intake flow to a level commensurate with a closed-cycle cooling system and limits the through-screen intake velocity to 0.5 feet per second. Track II allows a facility to demonstrate it can achieve impingement mortality and entrainment reductions comparable to those achieved with closed-cycle cooling by using other technologies, including restoration.

A subsequent lawsuit by environmental and industry petitioners challenged several components of the Phase I rule. The Court of Appeals for the Second Circuit, on February 3, 2004, upheld nearly all the provisions of Phase I with the exception of restoration. The court held that restoration was incompatible with the expressed intent of the statute, which requires "that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." Restoration in this context was deemed an action taken to mitigate the effects of an adverse impact, not one to minimize the impact in the first place. Use of restoration as a compliance option was barred as a compliance alternative under Phase I (*Riverkeeper, Inc. et al. v. U.S. EPA,* 358 F.3d 174 [2d Cir 2004]).

1.4 PHASE II

EPA issued the Phase II rule for large (50 mgd capacity or greater) existing steam electric facilities in 2004. The Phase II rule established performance standards for reductions in impingement mortality (80–95 percent) and entrainment (60–90 percent) over a baseline value. These standards were developed based on the performance of different technologies at existing facilities but are presented as ranges to allow for the biological variability between different locations and other site-specific factors that would make a single numeric limitation difficult to evaluate (USEPA 2004). Facilities with an annual capacity utilization rate under 15 percent, based on a 5-year average, would not be required to meet the rule's entrainment performance standard. An individual unit at a facility that operated below the 15 percent limit would similarly be exempt, provided it did not share an intake structure with other units that together exceeded the threshold.

Phase II required a facility to demonstrate compliance with these standards by choosing one of the following five alternatives:

1. Demonstrate that the facility has reduced cooling water flow to levels commensurate with wet recirculating systems or reduced cooling water intake velocity to 0.5 feet per second or less (for impingement only).

2. Demonstrate that the existing design and construction technologies, operational measures, and/or restoration measures meet the performance standards established by the regulations.

3. Demonstrate that the facility has selected design and construction technologies, operational measures, and/or restoration measures that will, in combination with any existing design and construction technologies, operational measures, and/or restoration measures, meet the performance standards.

4. Demonstrate that the facility has installed and properly operates and maintains an approved technology.

5. Demonstrate that a site-specific determination of best technology available is appropriate through the use of a cost-cost or cost-benefit test.

As in Phase I, industry and environmental petitioners sued EPA over the requirements of the Phase II rule. The Court of Appeals for the Second Circuit, on January 25, 2007, remanded several key components of the rule as either unsupported by EPA's analysis or contradictory to established procedures and the intent of the CWA (Riverkeeper, Inc. et al. v. U.S. Environmental Protection Agency, No. 04-6692-ag[L] [2nd Cir, January 25, 2007]). In response to the Second Circuit's ruling, EPA suspended implementation of the Phase II rule on March 20, 2007, and directed permitting authorities to base permitting conditions for Section 316(b) on best professional judgment (BPJ) (Grumbles 2007).[1] The principal elements of the Second Circuit decision are the following:

1. **BTA Determination.** The court found that EPA had improperly used a cost-benefit methodology to support the final BTA analysis, noting that the cost-benefit approach "compares the costs and benefits of various ends, and chooses the end with the best net benefits." This approach does not comply with the Section 316(b) requirement to develop a technology-based standard and instead relies on a cost-driven analysis that weighs "the desirability of reducing adverse environmental impacts in light of the cost of doing so." Cost

[1] As of the publication of this study, EPA has not formally withdrawn the Phase II rule, noting that future litigation may be possible.

may be used as a consideration in the final BTA determination, but it may not serve as the principal basis for that decision.

The court also found that, when considering cost in relation to BTA assessments, EPA must first determine the best-performing technology and then evaluate whether its cost can be "reasonably borne" by industry, thus making it "available" to the permitted community. In doing so, EPA must consider only the best-performing facilities and not an average performance level across a range of facilities. Only after making this initial assessment can EPA consider other factors, such as whether different technologies can achieve essentially the same results but at a lower cost. This "cost-effectiveness" approach allows EPA, or the permitting authority, to weigh any incremental benefits that may be achieved by one technology over another and determine whether the added cost is justified by the increased benefits. Cost-effectiveness, the court notes, is different from cost-benefit in that it determines "which means will be used to reach a specified level of benefit that has already been established," rather than influencing the initial selection of the standard.

2. **Performance Standards as Ranges**. In Phase II, EPA established performance standards for impingement mortality and entrainment reductions expressed as broad ranges, noting that ranges were necessary to address the variable characteristics that may affect the performance of a technology. A single numeric limitation was considered impractical in light of these differences. The court did not disagree with EPA's use of performance standards as ranges, but noted the omission of any requirement for a facility to maximize its performance under the standard. As written, the Phase II rule could be interpreted to allow a facility to meet the lower end of the performance standards and be considered compliant with the rule's requirements even if a greater degree of performance could be achieved.

3. **Restoration.** The Phase II rule included restoration as a compliance option. EPA argued that the considerations for existing facilities and the more limited technology options available to them were different from the Phase I rule. The court did not agree and rejected EPA's argument, stating the use of restoration was incompatible with the CWA.

All facilities evaluated in this study are considered Phase II facilities, i.e., they have intake capacities greater than 50 mgd, among other qualifying characteristics. EPA, however, has not indicated how it intends to resolve the issues raised in the Second Circuit decision (the court did not remand the rule in its entirety). Future regulatory efforts by EPA may redefine what constitutes a "Phase II" facility.

1.5 PHASE III

EPA issued the Phase III rule on June 1, 2006. Phase III established categorical requirements for new offshore oil and gas extraction facilities with design intake capacities greater than 2 mgd and that withdraw at least 25 percent of the water exclusively for cooling purposes. EPA did not establish uniform national standards for the remaining Phase III facilities (manufacturers and small steam electric facilities). Instead, Phase III continues the implementation of all statutory requirements through the NPDES program on a BPJ basis.

As of the publication of this study, the Phase III rule remains in litigation.

2.0 PREVIOUS RETROFIT ANALYSES

Other studies have developed cost estimates of cooling system retrofits (from once-through to closed-cycle cooling) to try and identify a reasonably certain correlation between plant-specific factors, such as generating capacity, fuel type, and circulating water flow, and the total cost of the new system. A common weakness of these analyses becomes evident when attempting to apply these cost estimates to actual facilities: the numerous site-specific factors that must be evaluated when attempting to retrofit an existing facility greatly influence the final cost and feasibility assessment. Applying unit-based costs such as $/gpm or $/kWh can lead to widely varying estimates that may underestimate or overestimate the true cost. Figure 2–1compares the capital cost estimates developed by other generic studies with this study's individual estimate for California's fossil fuel coastal power plants.[2] These costs only reflect the installation of the cooling towers and all other civil, mechanical, and electrical components; energy penalty, operations and maintenance (O&M), and shutdown losses are not included.

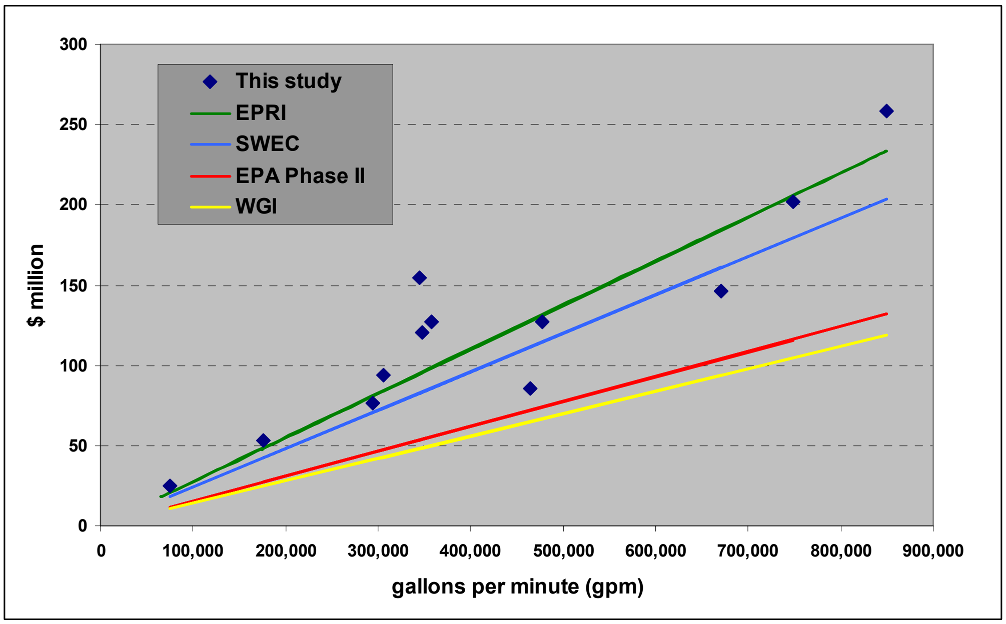

Figure 2–1. Capital Cost Comparison for Fossil Fuel Plants

2.1 STONE AND WEBSTER ENGINEERING CORPORATION

Stone and Webster Engineering Corporation (SWEC) prepared a retrofit cost estimate in a report to the Utility Water Act Group (UWAG)3 in 2002 during the development of the Phase II rule (Yasi 2002). The estimates were based on detailed cost estimates previously conducted for six

[2] All cost values in this chapter have been adjusted to 2007 dollars, except where indicated.

[3] The Utility Water Act Group (UWAG) is an association of 205 electric utilities and four national trade associations of electric utilities: Edison Electric Institute, National Rural Electric Cooperative Association, American Public Power Association, and Nuclear Energy Institute. UWAG frequently represents the interests of the electric power industry in the legislative and regulatory development processes related to the Clean Water Act.

unidentified facilities and extrapolated to the 1,041 units that comprise the Phase II universe. The reference facilities consist of one coal-fired plant located on a freshwater river, while the others (two coal, two nuclear, and one oil) all use marine or brackish waters for cooling. No natural gas facilities were part of the initial data set.

Reference data were compiled into four categories—materials, equipment, labor, and indirect costs—that provided the basis for extrapolated costs. Estimates for all units were then scaled from the reference facility considered to be most similar in terms of size, fuel, and cooling water type, and adjusted for regional differences in labor costs. The circulating water flow rate served as the comparative variable used to correlate costs between the evaluated units and reference data set. Summary data are provided in Table 2–1. The lower cost for Facility 5 is explained by the lower overall effort required to upgrade the existing system in order to accommodate the new closed-cycle cooling system.

Table 2–1. SWEC Reference Facility Costs

Facility	Fuel type	Water body type	Capacity (MW)	Cooling flow (gpm)	Nominal cost ($)	Cost ($/gpm)
1	Coal	Estuary	250	174,627	41,760,000	239
2	Coal	Estuary	620	279,403	66,120,000	237
3	Oil	Estuary	440	259,701	55,680,000	214
4	Nuclear	Marine	863	570,448	140,360,000	246
5	Nuclear	Marine	1,137	895,522	146,160,000	163

2.2 WASHINGTON GROUP INTERNATIONAL

Washington Group International (WGI) developed closed-cycle cooling retrofit estimates for each Phase II unit based on general information regarding the steam cycle and unit size collected from an industry database. Facilities were grouped according to their generating system, steam conditions, and unit size. Other values, such as the thermal load rejected to the condenser and total flow rate, were calculated using heat balance and heat exchange equations and an assumed condenser temperature rise of 12° F. No other site-specific criteria describing the facility were included in the development of the cost estimate.

Cost information was obtained directly from cooling tower vendors for saltwater and freshwater applications with different size and flow specifications. Other elements, such as pumping capacity, additional civil and structural works, and treatment systems, were estimated based on contractor experience and BPJ. The total distance of supply and return piping was estimated based on an assumed maximum distance between the condensers and the cooling towers of 500 feet (for a total of 1,000 feet). WGI included project multipliers to account for indirect and contingent costs such as management, profit, start-up, and engineering. Final costs for the sample facilities in each group were then normalized to a dollar per gpm value and scaled to each unit based on the calculated circulating water flow rate (WGI 2001).

Final costs ranged from $110 to $140 per gpm in saltwater applications.

2.3 EPRI

EPRI developed a closed-cycle cooling retrofit cost estimate during the Phase II rule development in support of public comments submitted by UWAG to EPA. EPRI developed its estimate using cost data obtained directly from facilities and through a literature search of previous studies (EPRI 2002). Information was compiled for 50 representative facilities (unidentified) and categorized by generating capacity, fuel type, and water body type. The cost estimates provided by each facility or obtained from other studies were normalized to account for the level of detail included in each cost estimate and adjusted to current year dollars (2002). Where it could be determined that the provided estimate only included capital costs, EPRI increased the project total value by adding 40 percent of the direct cost to account for “ancillary costs” (engineering, management, and contingencies).

Reference cost estimates were grouped according to the scope of the retrofit and classified as either a “minimum modifications” or “re-optimized” retrofit. The minimum modifications approach leaves most elements of the cooling system unchanged and incorporates a wet cooling tower into the existing system together with other necessary components and upgrades (e.g., pumps, treatment systems, and additional piping).

Re-optimized systems, however, expand the scope of the retrofit primarily by modifying the surface condenser to maintain its design performance with lower flow rates and higher condenser rise temperatures that are part of an optimized cooling tower. This is not always an easy, or inexpensive, undertaking, as EPRI notes:

> [Condenser modification] would be accomplished by changing the tube side from one-pass to two-pass in order to maintain the water velocity in the tubes at an acceptably high level. This in turn requires substantial rearrangement of the inlet and outlet headers and piping and often considerable demolition (and subsequent rebuilding) of the turbine building walls in order to gain access to the condenser for the modifications. (EPRI 2002)

An optimized system will have lower performance penalties and operating costs (fan and pump capacity) but can add significantly to the initial capital cost. EPRI considers the re-optimized approach generally more applicable to baseload facilities with long remaining operational lives over which the increased capital cost can be amortized and notes that there are limited data for this type of re-optimization. Most of the cost data used in its analysis is based on the “minimum modifications” approach.[4]

Cost estimates ranged from $165/gpm to $425/gpm depending on the degree of difficulty associated with the retrofit. Costs reflect a 7 percent increase to account for saltwater applications (EPRI 2007).

2.4 EPA PHASE I AND PHASE II RULES

EPA evaluated the cost of wet cooling tower retrofits in support of the Phase II rule using a model-based approach expanded from the development of costs for new facilities in Phase I

[4] Two of the 50 reference facilities provided data for a re-optimized system, but are not identified in the report.

(USEPA 2001; USEPA 2002). As with other studies, EPA did not assume any major modifications to the condenser except those required to allow the system to function within its design parameters. The new cooling tower would be inserted into the cooling water loop without changing the circulating water flow rate or basic characteristics of the condenser.

New facility costs are developed using a base cooling tower construction cost, in $/gpm, and adjusting upward for various facility and design elements, such as tower material, size, and location. EPA established four base cost estimates depending on the circulating water flow (greater or less than 10,000 gpm) and the design approach temperature (5° F or 10° F). This value was then modified to account for the base tower material (fiber reinforced plastic [FRP], concrete, redwood, Douglas fir) and the type of fill material (splash or film). An installation cost factor accounted for all civil and structural projects as well as management, engineering, profit, and contingencies. Finally, an adjustment was made to account for regional labor and material cost differences. Table 2–2 summarizes the Phase I cost factors that are comparable to the materials evaluated in this study.

Table 2–2. Phase I Cost Factors

Design element	Cost factor
FRP construction	1.1
Splash fill	1.1
Installation	1.8
Regional adjustment (California)	1.081

Beginning with a base capital cost of $35/gpm (capacity greater than 10,000 gpm and 10° F approach temperature) results in a California new facility cooling tower estimate of $82.40/gpm.

In the Phase II rule, EPA developed additional cost factors to address the complexities and logistical obstacles that would be expected when building wet cooling towers at an existing facility. These elements build upon the new facility cost factors and are summarized in Table 2–3.

Table 2–3. Phase II Cost Factors

Design element	Cost factor
Capital cost adjustment	1.25
Retrofit factor	1.2 (low) or 1.3 (high)
Contingency	1.1
Unknowns	1.05

These retrofit cost factors, together with the modified base cost for a new facility, results in an existing facility cost estimate ranging from $143 to $155/gpm, depending on the retrofit factor used.

3.0 IMPINGEMENT MORTALITY AND ENTRAINMENT CONTROLS

Numerous technologies have been developed over the last several decades that attempt to minimize either impingement mortality or entrainment, or both. This section summarizes the basic characteristics of the more widely used technologies, including their advantages and limitations, effectiveness, and general considerations for use at California's coastal facilities. This summary is not an exhaustive review. Instead, it reviews other technology resources to provide context for the larger discussion in this study. The following resources offer a more comprehensive analysis of the different technologies, including performance and cost, and provide examples of onsite evaluations:

EPA (U.S. Environmental Protection Agency). February 12, 2004. *Technical Development Document for the Final Section 316(b) Phase II Existing Facilities Rule*. EPA 821-R-04-007.

EPRI. 1999. *Fish Protection at Cooling Water Intakes: Status Report.* TR-114013.

The most commonly used technologies discussed in this chapter are generally categorized as follows:

- Physical Barriers: traveling screens; cylindrical wedgewire screens (including fine mesh); nets; aquatic filter barriers
- Collection Systems: modified traveling screens with fish returns
- Behavioral Barriers: velocity caps
- Flow Reduction: closed-cycle cooling; variable speed pumps
- Operational Modifications: intake relocation; seasonal operation

While many of these methods have been employed successfully and can achieve the level of impact reduction contained in the California Ocean Protection Council (OPC) resolution, actual reductions vary from site to site depending on many factors. The key to maximizing a technology's potential effectiveness lies in the evaluation of the mix of physical *and* biological characteristics that are unique to each location, and subsequently optimizing its design and installation with respect to those parameters. Ongoing monitoring and system modifications are often necessary to ensure that the desired reduction is achieved consistently following installation.

This study, therefore, limited detailed evaluation to technologies whose impact reductions can be reasonably assumed when certain physical and logistical requirements are met. In addition, greater emphasis is placed on the ability of a technology to reduce entrainment impacts rather than impingement. While impingement mortality remains a concern at most, if not all, of California's coastal facilities, entrainment impacts are common to all facilities and are thought to have a greater adverse impact on aquatic habitats, especially those located in more productive waters.

Most technology options that reduce entrainment can often be configured to reduce impingement mortality as well. Fine-mesh traveling screens, for example, are typically designed with the same collection and return system that also serves as an impingement mortality control.[5] Likewise, aquatic filtration barriers (AFBs) will reduce both impingement and entrainment if they can be maintained properly. The same cannot be said for many impingement controls, such as barrier nets, velocity caps, or behavioral barriers, which cannot be configured to reduce entrainment.

Many facilities with once-through cooling systems employ some type of primary screening device to prevent larger debris from being drawn into the facility cooling system and damaging sensitive equipment. Vertical traveling screens are the most common screening technology used at California's coastal facilities. Traveling screens, as their name implies, consist of mesh panels fixed on a continuous loop that rotate through the water column and remove large objects from the intake forebay. Most often configured in a vertical orientation with slot sizes ranging from 3/8 inch to 1/2 inch, traveling screens typically rotate on a predetermined time cycle or based on a maximum pressure differential between the upstream and downstream faces of the screen panels. High-pressure sprays are used to remove debris from the screen, which is then disposed of in a landfill or returned to the source water. These screening systems are not designed to distinguish between debris and impinged fish and, due to their large slot sizes, do not offer any protection against entrainment.

3.1 BARRIER NETS

Fish barrier nets are constructed of wide-mesh fabric panels and configured to completely encircle the cooling water intake structure inlet from the bottom of the water column to the surface. The relatively large slot sizes (1/2 inch) combined with the larger overall area of the net reduce impingement mortality by preventing physical contact with the main intake structure and by maintaining a low through-net velocity (typically 0.2 feet per second [fps] or less), which prevents organisms from being drawn against the net. Fish barrier nets have been deployed most successfully in locations where seasonal migrations create high impingement events, and their use can be limited to these same periods. Seasonal use avoids damage that may be caused by winter icing or high waves. Impingement mortality reductions have exceeded 90 percent at some locations (USEPA 2004).

Barrier nets are not considered for further evaluation in this study because their use at most California facilities is infeasible and they offer no protection against entrainment impacts. Most of the intake structures in this study are located either directly on the Pacific Ocean at shoreline or submerged a considerable distance offshore. To date, there are no facilities that have deployed a barrier net in a submerged configuration or for a shoreline intake located directly on the ocean. The conditions that would be expected at these locations, particularly during winter storms, present significant challenges to the deployment of a barrier net, especially one that would be required year round. At other facilities, where intakes are located within harbors or estuaries, the large overall size of a barrier net will likely conflict with other uses of the water body, such as shipping, boating, swimming, or recreational and commercial fishing.

[5] This is by no means a guaranteed result. A 1985 test evaluation of fine-mesh screens at Brayton Point Station in Massachusetts produced measurable entrainment reductions but significantly increased the impingement mortality of bay anchovy (LMS 1987).

3.2 AQUATIC FILTRATION BARRIERS

Aquatic filtration barriers (AFBs) are fabric panels constructed of small-pore (< 20 microns) materials and deployed in front of an intake structure much like a barrier net. The small openings in the fabric allow water to pass through while screening out most organisms, including those that are susceptible to entrainment. The small openings reduce the through-fabric flow rate to a maximum of 10 gpm per ft^2, as opposed to 25–27 gpm per ft^2 for barrier nets. At a given facility, an AFB will be approximately 2.5 times larger than a barrier net and require a larger open area for placement. The smaller openings are also more susceptible to fouling and clogging by sediment or debris and require a more active maintenance effort to minimize performance losses. An AFB deployed in marine or brackish waters, where clogging and fouling is more of a concern than in a freshwater environment, would likely operate below its design maximum and further increase the initial size of the system required to reliably provide sufficient water to the facility.

To date there has been only one deployment of an AFB at a facility with a large intake volume comparable with the facilities in this study.[6] The Lovett Generating Station, located on the Hudson River in New York, with an intake capacity of 391 mgd, has conducted a comparative evaluation of a seasonally-deployed AFB between one protected and one unprotected intake in different configurations since 1995. Impingement reductions have been substantial, with observed reductions of 90 percent or better. Entrainment has consistently been reduced by 80 percent, compared to the unprotected intake that serves as the baseline (LMS 2000). Wave overtopping and screen fouling present the greatest challenges to maintaining the system at its optimal level of performance.

AFBs are not considered for further evaluation in this study due to the lack of data for deployments at large facilities and the significant logistical challenges that must be overcome to ensure successful installation. If local conditions can be met, AFBs would be expected to reduce impingement and entrainment to levels comparable with reductions observed at Lovett. As with barrier nets, however, there have been no evaluations of AFBs under conditions that approximate those encountered along the Pacific coast. With their greater overall size and higher susceptibility to performance degradation from fouling or clogging, AFBs are more limited in their potential deployment than barrier nets.[7]

3.3 FINE-MESH CYLINDRICAL WEDGEWIRE SCREENS

Fine-mesh cylindrical wedgewire screens reduce impingement by maintaining a low through-screen velocity (0.5 fps), which allows larger organisms to escape the intake current. Entrainment is reduced through the use of screen mesh with slot sizes small enough to prevent eggs and larvae from passing through.[8] The phenomenon of hydrodynamics resulting from the cylindrical shape of the screen aids in the removal of small "entrainable" organisms that become caught against the screen. The low through-screen velocity is quickly dissipated and allows organisms to escape the

[6] An AFB evaluation was proposed for Contra Costa Power Plant but halted due to maintenance difficulties (CEC 2005).
[7] In its Proposal for Information Collection, El Segundo Generating Station proposed a pilot study of a submerged AFB configuration. The current status of this project is unknown (El Segundo 2005).
[8] Screens with slot sizes ranging from 1 to 2 mm are generally considered to be "fine mesh," although the effective size in each installation must be determined based on the target species in the affected water body.

influence of the system, provided there is a sufficient ambient current present to carry freed objects away from the screen (Weisberg et al. 1984). Organisms that are impinged against the screens are released through the action of a periodic airburst cleaning system and carried away by the ambient current.

Alden Research Laboratories, in coordination with EPRI, conducted laboratory evaluations of the effectiveness of fine-mesh cylindrical wedgewire screens using screens with different slot sizes and through-screen velocities. Reductions approached 100 percent for impingement and 90 percent for entrainment, depending on the specific design conditions (Amaral et al. 2003). These reductions compare favorably to results from facilities that have deployed or tested fine-mesh cylindrical wedgewire screens for entrainment reductions (Seminole: 99 percent; Logan: 90 percent) (EPRI 1999). Using these results and other data, EPA determined that fine-mesh cylindrical wedgewire screens used at certain freshwater river facilities with sufficient ambient current and a through-screen velocity of 0.5 fps or less could meet BTA requirements under Section 316(b). This determination was not extended to facilities in other water body types, such as estuaries and oceans, due to the lack of available information about such deployments, although their use may be determined on a case-by-case basis.

Despite the expanding use of fine-mesh cylindrical wedgewire screens in marine and brackish waters, current data remains insufficient to determine their effectiveness with reasonable certainty at many of California's facilities, most of which are situated on the Pacific Ocean and would require placement offshore along the seabed. Existing applications are located in water bodies with known ambient currents that are unidirectional and allow the screens to be oriented in line with the current, which aids in fish avoidance and removal of small organisms and debris from the screens. The near-shore currents found at coastal facilities are less easily predicted and can slacken or change direction along with the tide, potentially impacting the ability of the screens to remain free of debris and impinged organisms. Without a consistent current, screens may quickly clog and impact the performance of the facility. The distance from shore that would be required (2,000 feet or more) further complicates the use of wedgewire screens because the ability to maintain sufficient air pressure for the airburst cleaning system decreases substantially at those distances, and they cannot be assured to function at all times (Someah 2007).

This study evaluates fine-mesh cylindrical wedgewire screens for Pittsburg and Contra Costa, both of which are located on the Sacramento/San Joaquin Delta, where sufficient ambient currents are more likely to be present. The actual deployment of this technology would require more careful consideration of the various species (and their life stages) that would be protected by the screens.

A portion of the cost estimate developed for these facilities is based on the methodology prepared by EPA for the Phase II rule and scaled to 2007 dollars. Initial capital costs have been revised with updated estimates from cylindrical wedgewire screen vendors. The reason for this update is largely due to the increases in the cost of materials used in construction that have outpaced inflation, particularly for the preferred material for saltwater and brackish environments: 316-stainless steel. Costs are developed from vendor estimates for fine-mesh screens (1.4-mm slot size) based on the total flow required for each facility. At this mesh size, the initial capital cost of the screens ranges from $6.30 to $7.40/gpm depending on the overall length of each screen and the total number of screens required (GLV 2007). This cost includes the airburst system (except piping to the screens) and installation but does not allow for any changes or additions to the circulating water pipes or pump capacity that may be needed. These additional elements, if necessary, and the increased O&M costs, are scaled from the Phase II estimates (USEPA 2004) and other data used in the development of this report.

3.4 MODIFIED TRAVELING SCREENS (RISTROPH SCREENS)

Vertical traveling screens, such as those at most of California's facilities, can be modified to capture and remove fish that are impinged against the screens and return them to the source water body without inducing serious injury or mortality. The term "Ristroph screens" refers to a particular modification where individual screen panels are fitted with water-filled buckets that collect fish temporarily. As the screens rotate, the buckets empty into a return trough or pipeline that is flushed with water to carry the captured fish back to the source. A low-pressure spray is employed to gently remove any organisms that remain impinged on the screens and send them to the return trough, followed by a high-pressure spray to remove other debris. The critical design elements of this system include the screens' rotation speed, the material and shape of the collection buckets, and the method of return to the water body. Ristroph screens designed to reduce impingement mortality are relatively easy to install and do not involve substantial modification to the existing intake structure. The principal new component is usually the fish return system.

Modified traveling screens have been shown to reduce impingement by up to 90 percent or more (USEPA 2004; EPRI 1999). Common to most of these applications is the need to tailor the final design and operation of the system to the unique mix of species and hydrodynamic conditions at each facility. Factors ranging from the screen and collection bucket material to the speed at which the screens are rotated can directly affect the overall effectiveness, which may vary from species to species. Hardier species may exhibit higher latent survival rates than smaller, more fragile species.

These systems can be fitted with fine-mesh panels to reduce the entrainment of eggs and larvae as well. Screen slot sizes typically need to be within the range of 1–2 mm in order to be effective as an entrainment reduction measure, although the size used at a particular location is dependent on the target species. With a smaller open area per square foot than standard screens, fine-mesh screens require a larger overall intake structure in order to maintain desirable intake velocities. The need to expand the intake structure to accommodate the new screens may result in a temporary shutdown.

Entrainment reductions can also range as high as 90 percent or more when fine-mesh panels are used in conjunction with a return system. What is less understood, however, is the viability of eggs and larvae following their impingement against a fine-mesh screen and their return to the water body. Few studies have been conducted that evaluate viability, primarily because of the smaller number of facilities that have adopted fine-mesh traveling screens.[9] Screened organisms,

[9] Big Bend Power Plant in Tampa Bay conducted a viability analysis that showed that latent survival rates for eggs and larvae impinged against the fine-mesh screen and returned to the water were comparable to the control sample (EPRI 1999).

although they have been prevented from being entrained through a cooling water system, may suffer serious injury or mortality, which effectively results in the same adverse impact.[10]

It is unclear how this uncertainty can be reconciled with the OPC resolution's benchmark of reducing entrainment *impacts* rather than simply reducing the number of organisms that are entrained in the first place. For this reason, and the site-specific nature of their performance, fine-mesh traveling screens are not evaluated further in this study.

3.5 VELOCITY CAPS

Offshore intakes may be fitted with a device know as a velocity cap, which is a physical barrier placed over the top of an intake pipe rising vertically from the sea floor. Water is drawn into the pipe through openings placed on the sides of the cap, which converts what had been a vertical current to a horizontal one. Motile fishes are less likely to react to dramatic changes in vertical currents, but exhibit a more consistent flight response when the changes are sensed in the horizontal current, thus preventing their capture by the intake system (ASCE 1982). Velocity caps are classified as an impingement reduction technology because they function by discouraging "impingeable" fishes from entering the system. Velocity caps offer no reduction in the rate of entrainment.

Ormond Beach, Scattergood, El Segundo, Redondo Beach, Huntington Beach, and San Onofre currently employ offshore intakes with velocity caps for their cooling systems. While the impingement reductions can be substantial, performance may vary unexpectedly. Studies at Huntington Beach and El Segundo have shown impingement reductions ranging as high as 90 percent (Musalli et al. 1980). San Onofre operates two separate intake structures that are essentially mirror images of each other. The intakes for Units 2 and 3 are located offshore with velocity caps in relative proximity to one another at similar depths and bathymetry. Impingement data for 2003, however, showed more than 2.5 million fish impinged at Unit 3, a rate nearly 2.5 times that for Unit 2 (SCE 2005).[11]

Velocity caps are not considered for further evaluation in this study due to their inability to address entrainment and the need for site-specific biological information. All of California's facilities that currently operate submerged offshore intakes already use velocity caps. Modification of the remaining facilities would also involve the relocation of the intake to deeper waters.

3.6 CLOSED-CYCLE COOLING

Options and considerations for closed-cycle cooling are discussed in more detail in Chapter 4.

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[10] The Phase II performance standards expressly require an entrainment *reduction* rather than an entrainment *impact reduction.*

[11] The intake structure at San Onofre also incorporates guiding vanes and a fish elevator to capture and return any fish that have been drawn past the velocity cap. The citation summarizing the disparity in impingement rates does not offer any information describing the role played by the velocity cap or return system. The species abundance was relatively similar for each intake (SCE 2005).

3.7 VARIABLE FREQUENCY DRIVES

A variable frequency drive (VFD) (similar to variable speed pumps [VSPs]) allows a facility to lower the cooling water withdrawal rate by reducing the electrical load to the pump motor. The pump speed can be tailored to suit the cooling water demands at a certain time or under certain conditions. VFDs can throttle a pump's flow rate more precisely according to operating conditions, but must operate at a minimum flow rate in order to maintain sufficient head and prevent damage to the pump from cavitation. Depending on the initial design specifications, VFDs can achieve flow reductions ranging from 20 to 50 percent of their maximum capacity (Treddinick 2006).

Actual flow reductions with a VFD vary throughout the year depending on seasonal conditions and facility operations. At their maximum efficiency, VFDs enable a facility to withdraw the same volume of water as conventional circulating water pumps, thereby negating any potential benefit. Baseload units would not be ideal candidates for this technology, since they operate in the upper range of their load capacity for significant portions of the year. Units that are designated for peak or intermittent dispatch are more likely to accrue benefits from this method of flow reduction. In these situations, the use of VFDs must be evaluated against the operational profile of that facility and any seasonal variations in the makeup or abundance of affected species in the water body.

A facility that employs VFDs may be able to reduce its intake flow by 40 percent on an annual basis, but may operate at its maximum capacity during the most critical periods of the year, i.e., during spawning or migration seasons. An annual flow reduction might be a suitable metric if the potential for impact is equally distributed throughout the year. This method skews the actual benefit, however, if 80 percent of the potential annual impact occurs within a short time period that also corresponds to maximum pump operation.

At Contra Costa Power Plant, for example, VFDs are installed on the circulating water pumps for Units 6 and 7. From May 1 to July 15, which overlaps with periods of striped bass larval abundance, operating procedures call for the VFDs to operate at 50 percent capacity until the unit is generating a 172 MW load. Above that threshold, the pumps gradually increase the intake flow until they reach 95 percent of the maximum capacity. Depending on the amount of time in operation and the corresponding generating load, VFDs may reduce intake volumes by as little as 5 percent (Mirant Delta 2006).

The inability to determine seasonal variations in the potential use of VFDs excludes them from further consideration in this study.

3.8 INTAKE RELOCATION

Cooling water intakes that are located at an ocean shoreline or within an estuary are thought to have a greater environmental impact due to their presence in more biologically productive areas. Deep offshore locations may avoid or reduce some of these impacts by nature of their location in less sensitive areas. EPA recognized this distinction in the Phase II rule when it defined a baseline facility as one located flush with the shoreline at the surface, but acknowledged the limited data available that support this claim and the need to evaluate each installation on a case-by-case basis (USEPA 2004).

Six of the facilities in this study already utilize a deep offshore intake in conjunction with a velocity cap. Despite the location of these intakes in “less productive” waters, there has been no formal acceptance of their comparative benefit versus intakes located onshore or in estuaries, if any, by the NPDES permitting authorities for these facilities. Various state agencies have also demurred on a consensus opinion regarding the relative effectiveness of offshore intake locations (CCC 2000; SLC 2006; CEC 2005; SWRCB 2006). This study, therefore, does not evaluate intake relocation as a control technology because it must be viewed in conjunction with a site-specific biological assessment.

3.9 SEASONAL OPERATION

Seasonal operation may allow for significant reductions of impingement and entrainment at non-baseload facilities, provided the operational period does not overlap with times of highest impingement and/or entrainment susceptibility in the affected water body. The limitations associated with seasonal operation are similar to the issues concerning the use of VFDs, discussed in Section 3.7.

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