Evaluation of Impingement Mortality Reducing Technologies for Harbor and Haynes Generating Stations

Final Report, July 2014

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ACRONYMS

AFB – aquatic filter barrier

CCRS – closed-cycle recirculating system

CFS – cubic feet per second

CWIS – cooling water intake structure

EPRI – Electric Power Research Institute

FPS – feet per second

GPM – gallons per minute

Harbor – Harbor Generating Station

Haynes – Haynes Generating Station

IMNODA – impingement mortality notice of data availability

LADWP – Los Angeles Department of Water and Power

MGD – million gallons per day

MIS – Modular Inclined Screen

MWh – Megawatt Hour

O&M – operations and maintenance

OTC – once-through cooling

Policy - California Statewide Water Quality Control Policy on “Use of Coastal and Estuarine Waters for Power Plant Cooling” (as amended on July 19, 2011)

PSI – pounds per square inch

SWRCB – California State Water Resources Control Board

TWS – traveling water screen

VFD – variable frequency drives

EXECUTIVE SUMMARY

The Los Angeles Department of Water and Power (LADWP) plans to eliminate the use of once through cooling at both the Harbor and Haynes Generating Stations (Harbor and Haynes) by 2029. The California Statewide Water Quality Control Policy on the "Use of Coastal and Estuarine Waters for Power Plant Cooling", as amended on July 19, 2011 (Policy), Section (2)(C)(4)(b) requires facilities with compliance dates that extends beyond 2022 that LADWP "*conduct a study or studies, singularly or jointly with other facilities, to evaluate new technologies or improve existing technologies to reduce impingement and entrainment.*". Harbor and Haynes have schedules extending beyond 2022.

At the request of LADWP, the Electric Power Research Institute (EPRI) initiated a study in 2013 to evaluate fish protection options that could reduce entrainment mortality and the results of that study are also being provided to the California State Water Resources Control Board (SWRCB). While the SWRCB agreed that it appeared that no practical technology alternatives were available to reduce entrainment, it felt that a similar detailed evaluation should be conducted for impingement mortality reduction technology alternatives in terms of their engineering issues, potential biological performance, and cost. The objective of this report is to provide the results of that analysis. The evaluation is based on fish protection research conducted by EPRI and others since 2002 and focuses on the site-specific engineering considerations for Harbor and Haynes, as well as currently available results of a new two-year impingement study that LADWP initiated in April 2012. LADWP has been funding jointly with other facilities, research to evaluate new fish protection technologies and to improve existing technologies. The evaluation considered all currently available approaches and technologies to reduce impingement mortality, including new technologies and improvements to existing technologies. Results of the analysis are discussed separately for Harbor and Haynes.

Harbor

Current Impingement Levels - New impingement studies were initiated at Harbor in April 2012 and consisted of collecting 24-hour impingement samples every other week. The new study was initiated to document current impingement levels. Estimated annual fish impingement during the one-year impingement study conducted at Harbor in 2006 was 8,851. During the first year of the current study, the estimated annual impingement of fishes at Harbor was 2,315 in year one (a reduction of 73.9%) and 1,735 in year two (a reduction of 80.4%). The most abundant fishes collected (i.e., fish that made up more than 1% of the annual impingement) include Northern Anchovy (53.3%), Round Stingray (23.2%), Shiner Perch (6.7%) and Spotted Kelpfish (3.3%) and together these species made up 86.5% of the total estimated annual impingement.

Technologies Evaluated – One collect and transfer technology (modified traveling water screens [TWS] with a fish return and modular inclined screens [MIS]) and three technologies that would reduce the maximum through-screen intake velocity to not exceed 0.5 feet per second (fps) (cylindrical wedgewire screens, barrier nets and restoring currently retired screens back into operation) were evaluated to reduce impingement mortality with results as follows:

- Modified TWS with a Fish Return System – This screen system could be placed in the existing screen wells for Unit 5 for an estimated annualized capital and O&M cost of approximately $2.9 million. The technology is expected to perform poorly for fragile Northern Anchovy that dominate impingement. In the federal §316(b) final rule, fragile species with survival rates <30%, such as northern anchovy were exempted from meeting monitoring requirement due to poor performance on TWS. Installing modified TWS on Unit 5 is estimated to save 865 fish per year with an estimated cost per fish of $3,338.

- Barrier Nets – Barrier nets could potentially be installed in front of the entrance to the Harbor intake tunnels in Slip 5 for an estimated annualized cost of $899,000. While the capital cost of barrier nets is relatively low it is much more labor intensive due to the need for frequent net changes to control biofouling. The cost estimate does not include the cost of permitting and regulatory approvals for installation in Pier 5. Even more significant is the lost revenue and reliability risk of outages for net maintenance due to safety concerns for work in front of the intake. Due to prior accidents at intakes LADWP no longer allows workers to engage in maintainence in front of its CWISs while the cooling water intake pumps are in operation. Such outages are highly problematic for LADWP as it converts from OTC to dry cooling since the power generation reserve margin will be low as units are converted from OTC to dry cooling. The technology would be expected to have a relatively high level of biological performance (estimated to be 90% effective), saving an estimated 1,825 fish per year with an estimated cost per fish of $493 (primarily Northern Anchovy).

- Cylindrical Wedgewire Screens – Cylindrical wedgewire screens could potentially be installed in front of the Harbor intake tunnel in Slip 5 for an estimated annualized cost of $932,000. This cost estimate does not take into account lost generation during construction related shutdowns (~3 to 4 months). Additionally, the extended outage would be highly problematic due to the low power generation reserve margin that LADWP will experience as it transitions from OTC to dry cooling. These screens would likely eliminate impingement, saving an estimated 2,028 fish annually for an estimated cost per fish of $460 (primarily Northern Anchovy).

- Reducing the Through-Screen Velocity to Not Exceed 0.5 fps by Restoring Now Retired Screens to Operation –The four currently retired screen bays at Harbor could be brought back into service by installing new screens for an estimated annualized cost of $803,000. While biological performance was estimated to be a 75% reduction in impingement it may be significantly less due to entrapment as a result of higher velocities in the intake tunnel leading back to the source waterbody. However, this action could potentially save an estimated 1,521 fish annually for a cost of $528 per fish.

Key Uncertainties Associated with Harbor Cost and Performance Estimates

- Inter-annual variability – If 2006 impingement levels were averaged with the two years of current data the annual impinged estimates would be approximately double and the cost per fish saved would be 52.2% lower.
- The Capital and O&M cost estimates for technologies are + or – 30%.
- The technology cost estimates do not include the cost of pilot studies that would be necessary to better estimate biological performance, design considerations or operation and maintenance costs.
- Both the barrier net option and the cylindrical wedgewire screen option extend out from the intake into the Pier 5 harbor. Key uncertainties for these options are whether or not their deployment in front of the intake would impair boat dockage or the ability of ships to navigate in Pier 5. It would be necessary for these options to undergo review and approval by the Los Angeles Harbor Authority, U.S. Coast Guard and the California Coastal Commission. Additionally there are uncertainties associated with the amount of time that will be required to complete such reviews and obtain approvals and necessary permits. The time frame to accomplish this could extend beyond the end of 2020.
- There is also uncertainty associated with the cost to obtain approvals, permits and associated legal fees and none of these costs have been included in the cost estimate.
- Biological performance of for Modified TWS with a fish return and potential entrapment for barrier nets and restoring retired screens to operation are based on BPJ and would require pilot studies to reduce biological performance uncertainty.

Conclusions

- Impingement levels have declined significantly since 2006 (estimated to be 77.1%).
- Currently estimated annualized costs of fish protection technologies are relatively high (i.e., range from an annualized cost of $899K (a barrier net) to $2.9 million (modified traveling water screens) compared to the cost per fish saved (i.e., ranges from $367)cylindrical wedgewire screens) to $3,345 (modified traveling water screens)) due to the current relatively low level of impingement. An additional planned one year of sampling will verify whether the current low level of impingement continues.
- It is uncertain whether or not the lowest cost option (a barrier net) can be permitted in Slip 5. Further, the need to cease cooling water pump operation and take the unit offline two or more times per week to perform net changes is highly problematic for LADWP due to the low power generation reserve margin as it transitions for OTC to dry cooling. While this option would eliminate impingement the estimated cost is $460 per fish saved or for biomass would equate to $5,839.60 per pound of fish. The fish saved would be primarily northern anchovy, a common forage species with no recreational or commercial value.

The overall result of the evaluation is that none of technologies evaluated, could be deployed for a cost that is not significantly disproportionate to the benefit and the two highest performing options (a barrier net and cylindrical wedgewire screens) many not be allowed due to potential interference with ship navigation in Pier 5). LADWP is committed to eliminating impingement and entrainment mortality through conversion to dry cooling no later than December 31, 2029.

LADWP will also be paying $3 per MGD to compensate for impingement and entrainment losses through fish habitat restoration mitigation. By converting from OTC to dry cooling Harbor will over comply with the OTC Policy. Use of wet closed-cycle cooling is estimated to reduce use of cooling water flow and entrainment by approximately 93%, while dry cooling is 100% effective. Thus after conversion, there will be 7%/year reduction in entrainment compared to use of wet closed-cycle cooling and the benefit is expected to be for a period longer than the interim impingement and entrainment mortality reductions apply.

Haynes

Current Impingement Levels - New impingement studies were initiated at Haynes in April 2012 that consisted of collecting a 24 hour impingement sample at each operating intake every other week. The new study was initiated to document current impingement levels. The annual impingement estimates based on actual cooling water flow declined from 31,226 in 2006, to 11,059 in year one (a reduction of 65%). In year two of the current study Unit 1, which accounts for just under 90% of the impingement, was out of service from the end of August through January of 2014. For the six months when Units 1, 2 and 8 were in operation impingement levels were comparable. LADWP plans to continue impingement sampling for an additional year. The most abundant fishes collected during sampling included Queenfish (86.3%), Northern Anchovy (2.5%), Bay Pipefish (2.3%), Giant Kelpfish (1.2%) and Topsmelt (1.1%) and together these species made up 93.3% of the estimated annual impingement. Impingement at Unit 1 accounted for just under 90% of the total abundance in the new study (year one) followed by Unit 2 (9.3%), Unit 8b (1%), and Unit 8a (<1%).

Technologies Evaluated – Two collect and transfer technologies (modified TWS with a fish return and modular inclined screens [MIS]) and three technologies that would reduce the maximum through-screen intake velocity to not exceed 0.5 fps (cylindrical wedgewire screens, fixed-panel screens at the intake and new expanded intakes) were evaluated to reduce impingement mortality with results as follows:

- Modified TWS with a Fish Return System – Such screens could be placed in the existing screen wells for Unit 8 but the fixed screens for Units 1 and 2 would require modifications to accommodate such screens. The estimated annualized capital and O&M cost to install these screens on Units 1, 2 and 8 is approximately $7.6 million and $4.0 million for only Units 1 and 2 that currently account for approximately 99% of total the annual impingement for Haynes. The technology is expected to perform poorly for fragile juvenile queenfish that dominant impingement. Installing modified TWS on all units is estimated to save 1,655 fish per year and 1,614 fish per year if installed at only Units 1 and 2 resulting in costs of $4,580 and $2,468 per fish respectively.

- MIS – An MIS system could be installed in the Haynes intake channel with a fish friendly pump to return fish back to Alamitos Bay. The estimated annualized capital and O&M cost is estimated to be approximately $1.7million. This technology is expected to perform better than modified TWS saving an estimated 3,889 fish per year for a cost of $443 per fish.

- Cylindrical Wedgewire Screens – Cylindrical wedgewire screens could be installed in the Haynes intake channel. Fish friendly pumps installed in the now retired Units 5 and 6 intakes would be used to create a sweeping flow that would transport fish from the intake channel to the San Gabriel River. This cost does not include the additional cost of lost revenue for each of the four units to be shut down for 4 to 6 months to complete construction. The estimated annualized cost is $6.8 million. Such screens are estimated to save 8,847 impingeable sized fish per year with a cost of $769 per fish. However, this option would double the flow into the intake channel, thereby doubling the number of entrainable sized fish and expose the entrained fish to the thermal discharges of both Haynes and the Alamitos Generating Station in the San Gabriel River.

- Fixed-Panel Screens at the Entrance to the Intake Channel – It may be possible to install fixed-panel screens at the entrance to the intake channel in the Long Beach Marina. The estimated annualized cost for such screens is $1.2 million and an estimated 9,953 fish would be saved per year for a cost of $123 per fish. LADWP does not own the property that would have to be used to operate and maintain such screens and this option would require modifications to three piers and reduce the number of boats that could be docked in the marina. Thus permitting for this option may be difficult and additional costs associated with such permitting that are likely to be significant have not been included in the estimates.

- Install New Intakes of a Size Adequate to Not Exceed 0.5 fps Through-Screen Velocity – The existing intakes for Units 1, 2 and 8 could be replaced with new larger intakes with sufficient screening area to not exceed a 0.5 fps through-screen velocity. The estimated annualized cost for this alternative is approximately $7.1 million for all units and $3.7 million for Units 1 and 2 only. An estimated 9,953 fish per year would be saved (regardless of whether Units 1 and 2 or all three units are upgraded) for an estimated cost of $718 per fish if new intakes were installed at all units and $368 per fish if new intakes were only installed at Units 1 and 2. However, installing such intakes at Units 1 and 2 may simply transfer impingement that is occurring at Units 1 and 2 to Unit 8.

Key Uncertainties Associated with Haynes Cost and Performance Estimates

There are a number of uncertainties associated with the Haynes technology evaluations that are summarized as follows:

- Inter-annual variability – If 2006 impingement levels were averaged with the current estimate the annual impinged estimates would be 37.8% higher and the cost per fish saved would be 37.8% lower.
- Cost estimates for technologies are + or – 30%.
- Technology cost estimates do not include the cost of pilot studies that are necessary to better estimate biological performance, design considerations or operation and maintenance costs have not been included.
- The cost estimates also do not include permitting costs or the cost for the major modifications that would be required in the Long Beach Marina for fixed-panel screens.
- LADWP may not be able to obtain approval from the Long Beach Marina to install and operate fixed-panel screens in the marina. Also not included are the cost of permitting the fixed-panel screens and compensating the Long Beach Marina for significant modifications to operate the screens and the loss of boat docks. Additionally the permitting time frame for

this option could extend longer than the December 31, 2020 date for completing installation of interim technologies.

- The estimated biological performance of for Modified TWS with a fish return and the MIS, entrapment or risk of re-impingement at Haynes or Alamitos for fish returned to Alamitos Bay or potential additional mortality due to the Hayne's and Alamitos's thermal discharges if fish are returned to the San Gabriel River are based on BPJ and would require site-specific studies to reduce uncertainty associated with use of wedgewire screens.
- Haynes will also over comply with the OTC Policy by achieving a 100% reduction in cooling water flow as opposed to 93% on which the California Policy is based. Thus after conversion, there will be 7%/year reduction in entrainment this is expected to be for a period longer than the interim impingement and entrainment mortality reductions apply.

Conclusions for Haynes - Conclusions for Haynes are as follows:

- LADWP has already completed a flow reduction of 50% for Haynes, 45% of which took place after the July 2011 interim Policy condition that went into effect; and the current schedule to convert Units 1 and 2 to dry cooling is scheduled to be completed prior to the requirement for interim impingement further reduction flow by 77%.

- Impingement levels have declined significantly since 2006 and the retirement of Units 5 and 6 may contribute to that trend.

- Currently estimated annualized costs of fish protection technologies are relatively high (i.e., range from an annualized cost of $1.2 to $7.6 million) compared to the cost per fish saved (i.e., ranges from $123 to $4,580) due to the current relatively low level of impingement. The cost per fish saved are conservative since they do not include the cost of pilot studies, a 4 to 6 month outage required for cylindrical wedgewire screens or the cost of approvals and permitting. An additional planned one year of sampling will verify whether the current low level of impingement continues. If the lowest cost option (fixed-panel screens) can be permitted in the Long Beach Marina impingement it may achieve a 90% reduction in impingement mortality for a cost of $123 per fish which equates to $12,505 per pound of fish saved.

As for Harbor, the overall result of the evaluation Haynes is that none of technologies evaluated, could be deployed for a cost that is not significantly disproportionate to the benefit. The lowest cost option, use of fixed panel screens, would be highly problematic due to the major modifications that would be required in the Long Beach Marina that is currently in the process of making renovations. As for Harbor LADWP is committed to eliminating Haynes's impingement and entrainment mortality through conversion to dry cooling no later than December 31, 2029. For Haynes, LADWP will also be paying $3 per MGD to compensate for impingement and entrainment losses through fish habitat restoration mitigation. Also, by converting from OTC to dry cooling Haynes will over comply with the OTC Policy. Use of wet closed-cycle cooling is estimated to reduce use of cooling water flow and entrainment by approximately 93%, while dry cooling is 100% effective. Thus after conversion, there will be 7%/year reduction in entrainment compared to use of wet closed-cycle cooling and the benefit is expected to be for a period longer than the interim impingement and entrainment mortality reductions apply.

CONTENTS

1 INTRODUCTION

The California Statewide Water Quality Control Policy (Policy) on the "Use of Coastal and Estuarine Waters for Power Plant Cooling," as amended (July 19, 2011), requires at Section (2)(C)(4)(b) that LADWP:

"Conduct a study or studies, singularly or jointly with other facilities, to evaluate new technologies or improve existing technologies to reduce impingement and entrainment."

The requirement at Section (2)(C)(4)(b) is only applicable to fossil facilities with compliance dates that extend past December 31, 2022. The requirement applies to the three LADWP facilities that utilize once-through cooling (OTC), the Harbor, Haynes and Scattergood Generating Stations (Harbor, Haynes, and Scattergood). However, since compliance applies on a unit by unit basis, LADWP compliance must be implemented in a carefully planned sequence. LADWP is targeting compliance for Scattergood before the end of 2022 and therefore the requirement is not applicable to that facility. However, this requirement is applicable to Harbor and Haynes which have compliance dates that extend beyond 2022.

The Electric Power Research Institute (EPRI) was requested by LADWP to assist the Department in satisfying this requirement. A study was initiated in the fourth quarter of 2013 to evaluate the engineering feasibility, expected biological performance and cost of alternative fish protection technologies that could reduce both impingement and entrainment mortality, with an emphasis on entrainment reduction. The results of that evaluation were presented to the California State Water Resources Control Board (SWRCB) at a meeting held on November 26, 2013. Those results determined that as a result of site-specific circumstances, available fish protection technologies would generally have poor biological performance, significant engineering issues, permitting issues, and high costs. SWRCB agreed that it did not appear to make sense to further pursue interim entrainment mortality reduction technologies. However, technologies that only reduce impingement mortality should be further evaluated, because additional options are available and may be more cost effective.

The purpose of this report is to discuss the results of an evaluation of impingement mortality reduction technologies for the Harbor and Haynes. As discussed in the entrainment mortality reduction report, LADWP has, in fact, been funding research to evaluate new fish protection technologies and to improve existing technologies, in cooperation with other power companies. This EPRI research program funds research on fish protection topics including studies that specifically Concern on impingement mortality reduction technologies and operational measures, which are applicable to Sections 316(a) and (b) of the Clean Water Act.

The organization of this report, starting with the information in the remainder of this section, is as follows:

- Provides a general overview of the major categories of impingement mortality reduction technologies;

- Summarizes impingement mortality reduction technologies relative to Harbor and Haynes; and
- Identifies potential fish protection technologies for further evaluation for Harbor and Haynes.

Chapter 2 – Provides an estimate of current levels of impingement for Harbor and Haynes.

Chapter 3 – Provides a discussion of results of the Harbor impingement mortality reduction options, their expected performance and uncertainties.

Chapter 4 – Provides a discussion of results of the Haynes impingement mortality reduction options, their expected performance and uncertainties.

Chapter 5 – Provides a summary and conclusions.

Chapter 6 – Provides a list of references used.

1.1 Summary of EPRI Fish Impingement Mortality Reduction Technology Research

The following is a summary of research studies funded by LADWP jointly with other facilities to evaluate new fish protection technologies and/or improve existing technologies:

1. Evaluation of Angled Bar Racks and Louvers for Guiding Fish at Water Intakes, EPRI Technical Report 1005193, EPRI 2001
2. Evaluation of the Effects of Power Plants on Aquatic Communities: Summary of Impingement Survival Studies, (EPRI Technical Report 1007821, EPRI 2003Laboratory Evaluation of Wedgewire Screens for Protecting Early Life Stages of Fish at Cooling Water Intake Structures, EPRI Technical Report 1005339, EPRI 2003
3. Technical Resource Document for Modified Ristroph Traveling Screens: Model Design and Construction Technology and Technology Installation and Operation Plans, EPRI Technical Report 1013308, November 2006
4. Design Considerations and Specifications for Fish Barrier Net Deployment at Cooling Water Intake Structures, EPRI Technical Report 1013309, EPRI October 2006
5. Laboratory Evaluation of Modified Ristroph Traveling Screens for Protecting Fish at Cooling Water Intakes, EPRI Technical Report 1013238, June 2006
6. Latent Impingement Mortality Assessment of the Geiger Multi-disc^{TM} Screening System at the Potomac River Generating Station, EPRI Technical Report 1013065, July 2007 Numeric and Physical Model Study of Fish Barrier Net Designs for Complex Hydraulic Environments, EPRI Technical Report 1016808, November 2008
7. Beaudrey Water Intake Protection (WIP) Screen Pilot-Scale Impingement Survival Scale Study, EPRI Technical Report 1018490, March
8. Evaluation of Continuous Screen Rotation and Fish Survival: Studies at Plant Barry, Mobile River, AL. EPRI Technical Report 1016807, January 2010
9. Evaluation of Factors Affecting Juvenile and Larval Fish Survival in Fish Return Systems at Cooling Water Intakes. EPRI Technical Report 1021372, December 2010

In addition to the specific technology related research summarized above, EPRI developed and periodically updates a fish protection technology manual that discusses all known fish protection technologies and operational measures. The following is a summary of the manual's history:

1. Research Update on Fish Protection Technologies for Water Intakes, EPRI Technical Report 104122, 1994
2. Fish Protection at Cooling Water Intakes: Status Report, EPRI Technical Report 114013, December 1999.
3. Fish Protection at Cooling Water Intake Structures: A Technical Reference Manual. EPRI Technical Report 1014934, December 2007

EPRI is in the process of making another major update to be issued after the EPA issues the Final 316(b) Rule that is scheduled to be issued on May 16, 2014. Additionally EPRI, in conjunction with the American Fisheries Society 2011 Annual Meeting, conducted a symposium on 316(b) that included papers on a variety of 316(b) related topics and included a number of papers on fish protection technologies.

1.2 Overview of Impingement Mortality Reduction Technologies

EPRI, over the last decade, has been conducting research on fish protection technologies for cooling water intake structures (CWIS) on behalf of the electric power generation industry in anticipation of new federal regulations implementing §316(b) of the Clean Water Act. During this period, EPRI has interacted on a regular basis with fish protection technology vendors, conducted field and laboratory studies on alternative fish protection technologies, and conducted workshops and conferences on this subject. The EPRI December, 2013 Haynes and Harbor entrainment reduction evaluation (EPRI, 2013) report reviewed five categories of fish protection technologies for both impingement and entrainment and in this report will review options that exclusively focus on impingement mortality reduction.

There are basically five options to reduce impingement mortality reduction for CWISs that include:

1. Flow Reduction;
2. Exclusion Devices;
3. Collect and Transfer Technologies;
4. Behavioral Devices (includes diversion devices); and
5. Change in Intake Location.

The following sections provide a brief description of each of these options and the potential applicability for Harbor and Haynes:

1.2.1 Flow Reduction

Examples of flow reduction technologies range from use of wet or dry closed-cycle re-circulating systems (CCRSs) to reduced use of existing condenser cooling water pumps, use of variable frequency drives (VFDs) on those pumps to achieve a finer level of adjustment of flow and use of recycled water (e.g., use of grey water from a wastewater treatment facility). A reduction in the amount of cooling water entering a CWIS directly reduces impingement by the combined effect of reducing the amount of water withdrawn from the source waterbody, and therefore the number of impingeable-sized fish entering the cooling water system, in addition to reducing the water velocity passing through the screens, making it easier for fish to escape from the intake hydraulic zone of influence.

In the proposed Federal 316(b) Rule (EPA, 2011) and Impingement Mortality Reduction Notice of Data Availability ((IMNODA) EPA, 2012) the EPA stated they were considering allowing facilities to assume that a reduction in cooling water flow would result in a proportional reduction in impingement.

For flow reduction, the general options for impingement are the same as for entrainment and were discussed in the December, 2013 report and are restated here.

LADWP for Harbor, Haynes and Scattergood has already committed to eliminating use of OTC water through a combination of Unit retirements, repowering and use of dry cooling rather than wet cooling. LADWP also considered use of wastewater for condenser cooling at Scattergood. The option was considered feasible because of its proximity to the City of Los Angeles Hyperion Treatment Plant. However, neither Harbor nor Haynes are near wastewater treatment plants that can provide adequate cooling water on a sufficiently reliable basis to meet the cooling water needs for these facilities, making this option impractical for these facilities. In terms of the other flow reduction options (i.e., reduced cooling water pump use and VFDs), since the California OTC Policy went into effect, Haynes has already achieved a significant flow reduction of 552.9 MGD that includes conversion of Units 5 and 6 to dry cooling. The daily average cooling water flow for Haynes in 1990 was 1,014 MGD (704,000 gpm). In 2002 the replacement of once through cooled Units 3 and 4 to closed-cycle cooled Unit 8 achieved a 46 MGD (32,000 gpm) reduction (4.5%) in design flow. More recently, after the California OTC Policy went into effect, an additional interim flow reduction of 506.9 MGD (320,000 gpm) per day was implemented resulting in an additional flow reduction of 45% resulting in an overall 50% reduction since 1990. Further, the current target date for converting Haynes Units 1 and 2 to dry cooling is 2022 bringing the total flow reduction to 77% and removing Units 1 and 2 from regulation under Section (2)(C)(4)(b) of the California OTC Policy. While the 2022 target date may be achieved, this evaluation assumes it will be the scheduled December 2029 compliance date before the conversion is complete. In terms of further flow reductions for either Harbor or Haynes, the benefit of such reductions, to the extent possible, depend on the ability of those facilities to reduce flow during periods of high entrainment.

Due to LADWP efforts to integrate more renewable energy into the Los Angeles area electric system and current plans to convert to dry cooling, there is a need for flexibility to dispatch these units on a diel and seasonal basis, such that a commitment to fixed reductions at specific times of the day or seasons of peak entrainable life stage abundance is not possible. For the purposes of power system and grid reliability, the Harbor and Haynes units must remain fully functional with full generation capability throughout the year. During periods of high potential entrainment (i.e., summer months) are also periods when these units are most critical to the power system. Therefore this approach will not be given further consideration.

1.2.2 Exclusion Devices and/or Low Intake Velocities

Examples of exclusion devices for impingement mortality reduction include wide-slot (i.e., 9.5 mm) cylindrical wedgewire screens and barrier nets. These technologies are generally designed to have a low maximum through screen velocity (i.e., 0.5 feet per second [fps] or less). Other than use of CCRS, these devices tend to be the best performing fish protection technologies. This class of technologies functions by excluding impingeable-sized organisms from entering the CWIS. Cylindrical wedgewire screens are constructed by wrapping a wedge shaped wire around a support frame resulting in a smooth surface with no mesh. Instead there is a continuous slot from one end of the cylinder to the other. Exclusion is accomplished by use of a combination of a 9.5 mm screen slot size and a low through screen velocity (generally 0.5 fps or less). In terms of the ability of fish to avoid the CWIS, the EPA determined in the now remanded 316(b) Phase II and proposed new rule, that a through screen velocity less than or equal to 0.5 fps is protective and can be used for compliance. The EPA determination of this criterion is supported by EPRI research (EPRI Technical Report 1000731). The results of a literature review of fish swimming speeds at various velocities are shown in Figure 1.1. Of the 536 values gathered during the literature survey, only one value for a small fish was below the 0.5 fps criterion.

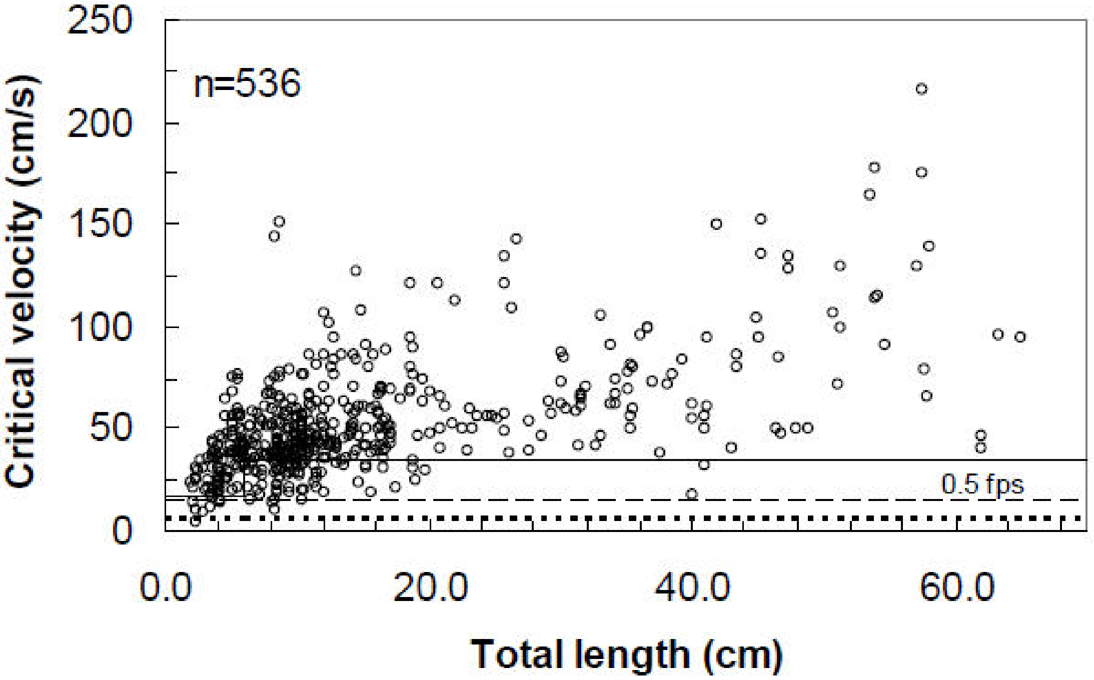

Figure 1.1 – Relationship of fish size (cm) and swimming velocity (cm/s) based on 536 values collected from a literature survey by EPRI (Technical Report 1000731). The dashed line is equivalent to an approach velocity of 0.5 fps. The dotted line is equivalent to the Rule's 0.5 fps maximum through screen design velocity. The solid line represents a threshold proposed by the National Marine Fisheries Service.

The result is that existing TWS that can achieve a through-screen velocity that does not exceed 0.5 fps can achieve the same level of fish protection as cylindrical wedgewire screens or a barrier net. Simply reducing the existing intake velocity can also reduce impingement. The most widely deployed exclusion devices for reducing impingement are barrier nets and wide-slot (9.5 mm) wedgewire screens. For impingement, barrier nets are the equivalent of the aquatic filter barrier (AFB) discussed for entrainment in the December, 2013 report. Barrier nets have a relatively low capital cost that is somewhat offset by a higher operations and maintenance (O&M) cost for most deployments compared to other technologies. This is especially in locations that have severe macro biofouling issues and/or high debris loading that require frequent net changes. There are over a dozen deployments around the U.S. described in EPRI Technical Report 1013309 (EPRI 2006). Barrier nets are generally not practical for use in open oceans and rivers but have been used in estuaries, reservoirs and on the Great Lakes. Barrier nets can also require a relatively large surface area to achieve the low through net water velocity and therefore can be problematic in locations where there are navigation issues or obstructions in front of the CWIS.

There have been improvements in the design of cylindrical wedgewire screens, most notably in methods to control debris accumulation and biofouling. Further, cylindrical wedgewire screens has been successfully deployed and operated in the San Francisco Bay area, with adequate ambient sweeping currents, at the Conoco-Phillips Refinery in Rodeo and the San Francisco Exploratorium. The EPA, in the proposed §316(b) Rule preamble said that these devices were not designated as BTA, since they cannot be used at all facilities. The problem is that these devices must extend into the source waterbody where navigation issues, water depth (i.e., shallow water) and hydraulic forces can make them impractical for use at some facilities.

Due to their high level of performance both the barrier net and wide-slot wedgewire screens are further evaluated in this report. Additionally, modifications of the existing CWIS designs to achieve lower velocities at the intake for both Harbor and Haynes are evaluated.

1.2.3 Collect and Transfer Technologies

Examples of these technologies include modified-Ristroph, Bilfinger, Hydrolox and Beaudrey and other Water Intake Protection (WIP) traveling water screens (TWS). These screens work by using technologies that minimize the damage to fish (“fish-friendly”) that are collected from the intake screens and returned back to the source waterbody to a location that will maximize survival and minimize risk of reimpingement at the CWIS or entrainment in the thermal discharge. Generally, these screens are rotated continuously to minimize the time between finfish collection and return to the source waterbody. The systems typically utilize a low-pressure screen spray wash to remove fish prior to a high-pressure spray wash to remove debris. A positive aspect of these technologies is that it is relatively easy to install them as a replacement for an existing conventional TWS. For that reason, the EPA designated these screens combined with a fish return as BTA in the proposed 316(b) Rule. However, biological performance of these screens is highly variable depending upon the species and size ranges of fish subject to impingement at a facility. There have been a number of new screens developed for use in the U.S. over the last decade (Appendix A). Most of the new screens have advantages in terms of preventing by-pass of debris and organisms and improving overall debris control. EPRI has been conducting laboratory and/or field research on these technologies and results have shown relatively high biological performance for the majority of recreationally important species. However, these laboratory and field trials have focused primarily on freshwater species. At present, there are limited data on the performance of these TWS with the fish species impinged at Haynes and Harbor. At some facilities the difficulty of locating a suitable fish return location in reasonably proximity that avoids the risks of return to the CWIS or the thermal discharge can also be an issue.

The above discussion provides the basis for further evaluation of modified TWS with a fish return for both Harbor and Haynes. The primary focus of the evaluation is engineering issues, potential biological performance and cost relative to the potential reduction in impingement mortality.

1.2.4 Behavioral Devices

Examples of these technologies include use of lights, sound (both high and low frequency), bubble curtains, electric fields and diversion devices such as louvers. This category of technology works by either acting as "scarecrows" (e.g., use of light and sound) to induce fish to move away from the CWIS, using hydraulic forces to guide fish away from the intake (e.g., diversion systems) or using electrical currents to repel fish away from the CWIS. Such devices can be deployed independently or used in combination with other fish protection or exclusion technologies. An advantage of these devices is their relatively low cost and the fact that they can generally be used at almost any CWIS. A disadvantage of these technologies is that they are only effective for certain species that tend to respond to such devices. For example, only species with air bladders (e.g., herring species) tend to respond to sound. It has also been found that in other cases, while there may be an initial response, fish acclimate and no longer respond once they get used to the stimuli.

1.2.5 Change in Intake Location

While not a technology per se, for some waterbodies, locating the intake in an area with lower densities of fish can reduce impingement. This approach was evaluated for reducing entrainment for both Harbor and Haynes and deemed impractical since for both intakes relocating the intake far enough offshore in the ocean to reduce entrainment would result in navigation impairment issues during construction and the cost would be on the same order of magnitude as conversion to closed-cycle cooling (already planned). These same issues are applicable to relocation of the intake for impingement mortality reduction. Further details on intake relocation issues for Harbor and Haynes can be found in the entrainment reduction evaluation report for Harbor and Haynes (EPRI, 2013).

1.3 Identification of Potential Fish Impingement Mortality Reduction Technologies for Further Evaluation for Haynes and Harbor

The locations of Harbor and Haynes in context with their intakes and source waterbodies are provided in Figures 1.2 and 1.3, respectively. Based on the fish protection options summarized, four technologies were selected for further evaluation at Harbor and five were selected for Haynes. For both facilities, two exclusion technologies were selected. Wide-slot (3/8 inch/9.5 mm) cylindrical wedgewire screens were selected for evaluation at both Harbor and Haynes. For Harbor, the second exclusion device selected was a barrier net while for Haynes a fixed panel screen was selected. Barrier nets are generally significantly less expensive than fixed panel screens but due to the Haynes intake entrance in the Long Beach Marina, it is not practical to deploy a barrier net at that location. Modified TWS with a fish return were also evaluated for both facilities since this technology was identified by the EPA as BTA in the proposed federal §316(b) rule and can achieve good performance depending on the species of Concern. Modular inclined screens (MIS), another collect and transfer technology was also selected for Haynes since it can potentially achieve a higher level of biological performance than modified TWS. For both facilities a reduction in intake velocity is also evaluated.

Figure 1.2 – Location of Harbor Generating Station cooling water intake structure

Figure 1.3 – Location of the Haynes Generating Station intake channel and entrance to the cooling water intake structure.

2 SUMMARY OF IMPINGEMENT LEVELS

This chapter summarizes current impingement levels for both Harbor and Haynes. As discussed in the report on the potential interim measures for entrainment, a new two-year impingement study was initiated for both facilities in 2012. Results of the first year of impingement sampling were presented in the prior report and were compared to results from the 2006 study conducted for the Phase II Rule. The information provided in this chapter updates the information with additional data from the second year of sampling and also discusses species of Concern for each facility.

2.1 Harbor

2.1.1 Summary of Impingement Sampling Methods

In anticipation of the federal §316(b) Rule, LADWP initiated an impingement study in April 2012. The new impingement study (new study) differs from the 2006 impingement study in two ways. First, in the original study, each 24-hour impingement survey was comprised of four, 6-hour sampling events (cycles), while in the new study each survey consisted of a single 24-hour cycle. Second, sampling frequency was once per week for one year in 2006 and the sampling frequency during the new study is once every other week for two years.

Sampling methodology, other than the timing and duration mentioned previously, were consistent between the new study and the 2006 study detailed in MBC et al. (2007a). Beginning on April 5, 2012, and nearly every other week thereafter, impingement on the Harbor TWS was monitored. Each survey cycle (six hours in 2006 and 24 hours in the new study) began when the TWS stopped rotating during initial screen clearing. Material that accumulated in the collection basket was discarded. A 0.25 inch diamond mesh rigid basket was temporarily installed into the permanent steel collection basket. Material was allowed to accumulate over the next six (2006 study) or 24 (new study) hours (approximately) as the TWS were operated per normal station operating procedures. The sampling period ended when the TWS stopped rotating at the end of the cycle. All material was washed off the screens and carried to the collection basket in a trough. When all water stopped washing out of the trough, the temporary basket with the accumulated material was removed and the sample processed. Fish were removed, identified to the lowest practicable taxonomic level (species most often), up to 200 individuals of each species were measured to the nearest millimeter of the most appropriate axis (standard length, total length, disc width, carapace length, or carapace width), and weighed by species. If more than 200 individuals per species were impinged, aggregate weights for the first 200 and remaining portion were recorded separately. The total abundance was estimated by dividing the remaining portion's weight by the average weight of the 200 individuals. The disposition of the first 30 individuals of each species were recorded as live, dead, or mutilated during the 2006 study but not in the new study. Data from the new study through 22 January 2014 were used in this analysis. Survey-specific data from both studies was extrapolated to derive an estimated total impinged abundance and biomass by the equation:

$$Estimate = \frac{Survey\ Data}{Cycle\ Flow}\ X\ Analysis\ Flow$$

The cycle flow was the volume of cooling water circulated during the cycle and the analysis flow was the volume of cooling water circulated during the intervening period. In 2006, the analysis flow was the sum of seven days (weekly sampling) while the new study summed over 14 days (biweekly sampling).

2.1.2 Estimated Annual Fish Impingement

Estimated annual impingement during the one-year impingement study conducted at Harbor in 2006 was 8,851 fish weighing 1,317 kg. The estimated annual impingement for year one during the new study (April 2012-March 2013) was 2,315 fish weighing 139 kg (Table 2.1). Complete data (impingement survey results and cooling water volumes) were only available for the first 10 months of year two (April 2013-January 2014), but in these 10 months an estimated 1,730 fish weighing 5.13 kg were impinged. Data were incomplete for February and March 2014, and were therefore unavailable for this analysis. During the first year of the study, a total of five fish were impinged during this two-month period. Preliminary review of the raw data suggests results from the second year are approximately the same and therefore would not appreciably alter the final results or subsequent conclusions. Therefore, the data from year one was substituted for these two months in year two to comprise a full 12-month data set. Averaging the monthly totals for each year resulted in an estimated 2,028 fish weighing 72.35 kg impinged annually.

The impingement abundance in 2006 was over four-times higher than the average across the two years of the new study. While the 2006 estimates are based on 50 sampling events and the new study estimates are based on 24 (year one) and 21 (year two thus far) sampling events, the impingement estimates from both studies were calculated using actual cooling water flows over the designated periods.

In the 2006 study, 25 different species were collected compared to 17 species in year one and 11 thus far in year two. Round Stingray (*Urobatis halleri*) was the dominant species in 2006 and in year one of the new study with 70% and 40% of the estimated totals by number, respectively (Table 2.2). Northern Anchovy (*Engraulis mordax*) made up less than 1% of the estimated impingement in 2006 but accounted for 33% of the estimated totals in year one and 81% in year two of the new study. Five species accounted for 89% of the estimated impinged abundance after summing across the 22 months of data available from the new study. Northern Anchovy ranked first with 53% of the total followed by Round Stingray (23%), Shiner Perch (*Cymatogaster aggregata*, 7%), Spotted Kelpfish (*Gibbonsia elegans*, 3%), and Black Perch (*Embiotoca jacksoni*, 2%).

The estimated annual impingement declined from 8,851 fish in 2006 to an average of 2,028 in the current study (77% fewer fish impinged). The overall cooling water flow during the new study was only 6% (year one) and 5% (year two adjusted to the same 10 months in each year) lower than during the 2006 study. The majority of impingement each year occurred from August to December as shown in Table 2.1 and Figure 2.1. A comparison of Harbor cooling water flow between the 2006 and first and second year of the current study is provided in Figure 2.2 and shows little difference in flows during the two studies. In fact, flows were often higher during the summer and fall months of the new study compared to those during the 2006 study. Thus, the difference between the 2006 estimated impingement and the estimated impingement derived from the new study was likely due primarily to inter-annual variability in fish populations. One recent study reported the 2006 cumulative coastal fish abundance index was 69% higher than the 2000-2010 average (Miller and McGowan 2013).

Harbor does not heat treat the cooling water system so there was no additional mortality associated with heat treatments. Fish impingement at Harbor is among the lowest for California's once-through cooled facilities, which is likely due, in part, to (1) the relatively low approach velocity (i.e., 0.4 fps) at the traveling water screens, and (2) not using heat treatments to control fouling. Differences between the 2006 and 2012-2014 studies most likely represent inter-annual variability due to a variety of factors related to changing ocean conditions (Miller and McGowan 2013) or changes in the harbor complex. Prior analyses of the coastal fish populations suggest the 2006 data were collected during a period of anomalously high fish numbers while the new study is more representative of conditions prevalent since 2000.

Table 2.1 – Estimated monthly abundance and biomass (kg) of fish impinged at Harbor Generating Station for the April 2012-March 2013 (2012-13), April 2013-January 2014 (2013-14), and January-December 2006 (2006) periods. Data from February and March 2013 was used for February and March 2014. The mean abundance or biomass impinged during the 2012-14 studies is included. Please note that the sum of the monthly means differs from averaging the annual totals due to rounding the monthly means.

	Estimated Abundance					Estimated Biomass (kg)			
Month	2012-2013	2013-2014	Mean	2006		2012-2013	2013-2014	Mean	2006
January	20	0	10	246		0.18	0	0.09	17.08
February	5	5*	5	183		0.09	0.09*	0.09	6.28
March	0	0*	0	129		0	0.00*	0	13.35
April	43	0	22	122		1.46	0	0.73	2.03
May	74	70	72	811		1.3	1.38	1.34	12.87
June	108	131	120	626		1.83	0.38	1.11	18.02
July	185	27	106	353		35.61	0.15	17.88	40.13
August	231	84	158	1,334		16.49	2.02	9.25	260.68
September	322	869	596	1,446		9.62	0.59	5.11	279.35
October	997	535	766	1,693		38.68	0.6	19.64	308.36
November	249	0	125	1,478		25.1	0	12.55	285.36
December	81	14	48	430		9.11	0.01	4.56	73.1
Annual Total	2,315	NA	2,028	8,851		139.47	5.31	72.35	1,316.60

*Data substituted from prior year.

Table 2.2 – Estimated abundance and biomass (kg) impinged at Harbor Generating Station, by fish species, for the April 2012-March 2013 (2012-13), April 2013-January 2014 (2013-14), and January-December 2006 (2006) periods. Only species occurring during 2012-14 are presented in the table. * only 10 months of data available during the second year. The annual total for the 2013-14 survey year and mean for the 2012-14 period was taken from the monthly abundance (Table 2.1).

	Estimated Abundance					Estimated Biomass (kg)			
Species	2012-2013	2013-2014	Mean	2006		2012-2013	2013-2014	Mean	2006
Northern Anchovy	756	1,401	1,079	24		0.46	0.76	0.61	0.02
Round Stingray	926	14	470	6,150		133.27	1.56	67.41	1,231.68
Shiner Perch	223	46	135	390		3.1	0.3	1.7	3.36
Spotted Kelpfish	105	29	67	158		0.4	0.13	0.27	1.49
Black Perch	80	10	45	646		0.47	1.3	0.89	18.85
White Croaker	0	89	45	25		0	0.24	0.12	0.2
Giant Kelpfish	30	36	33	192		0.75	0.26	0.51	15.73
Barred Sand Bass	0	51	26	209		0	0.16	0.08	7.51
Yellowfin Goby	14	28	21	163		0.09	0.32	0.21	3.15
Topsmelt	37	0	19	7		0.17	0	0.09	0.2
Chameleon Goby	33	0	17	52		0.1	0	0.05	0.28
Specklefin Midshipman	26	0	13	484		0.03	0	0.02	11.96
Rainbow Seaperch	16	0	8	0		0.12	0	0.06	0
Barred Surfperch	13	0	7	0		0.01	0	0.01	0
Longjaw Mudsucker	0	13	7	7		0	0.07	0.04	0.01
Pacific Sardine	13	0	7	0		0.35	0	0.18	0
Rockpool Blenny	13	0	7	0		0.04	0	0.02	0
White Seaperch	13	0	7	115		0.01	0	0.01	4.12
Yellowchin Sculpin	0	13	7	7		0	0.03	0.02	0.04
Bay Pipefish	12	0	6	20		0.01	0	0.01	0.07
Hornyhead Turbot	5	0	3	34		0.09	0	0.05	3.97
Total all species	2,315	1,735	2,028	8,851		139.47	5.22	72.35	1,316.60
Number of species	17	11		25					

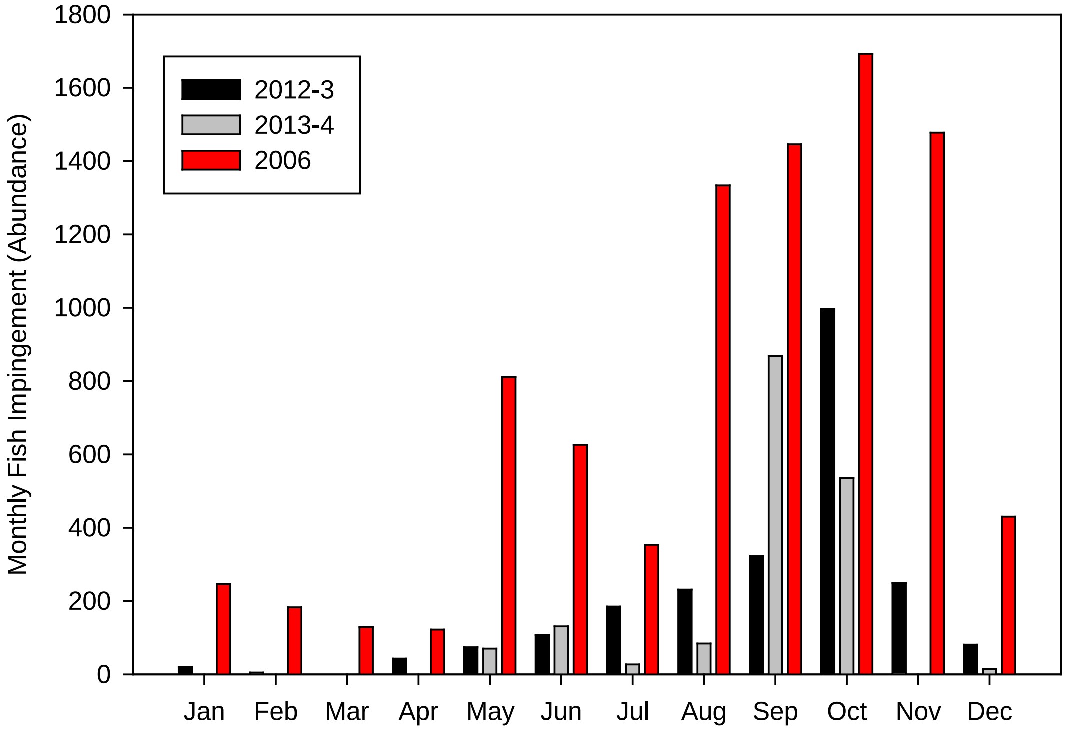

Figure 2.1 - Harbor Generating Station fish impingement during the study periods impingement study.

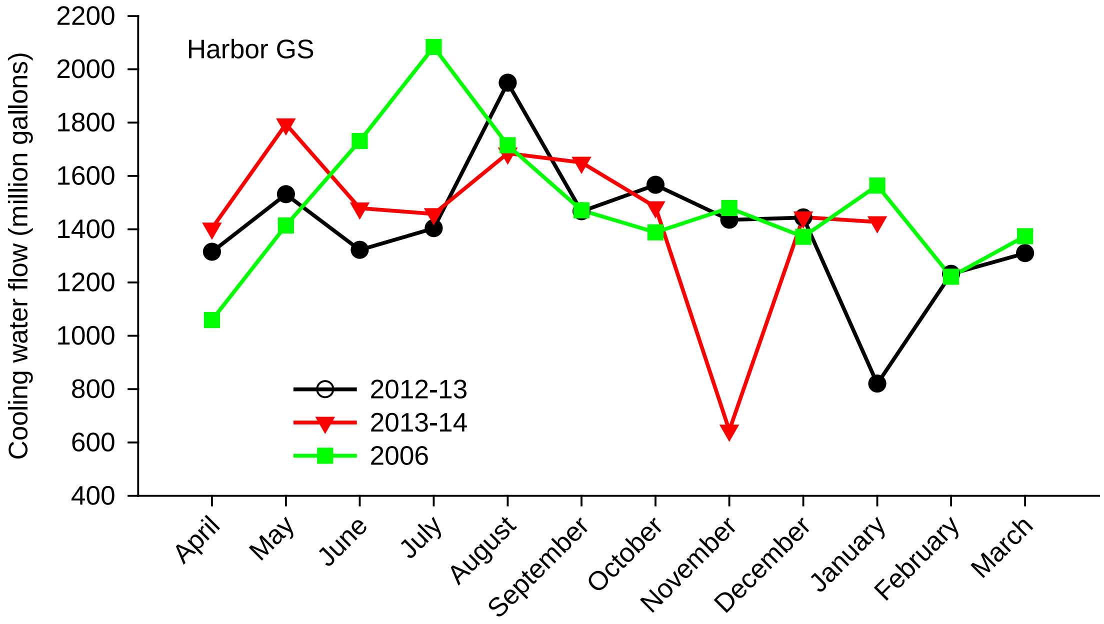

Figure 2.1 – Comparison of Harbor Generation Station actual cooling water volumes (million gallons) circulated during the 2006, April 2012 to March 2013 (2012-13), and April 2013 to January 2014 (2013-14) studies by traveling water screen designation.

2.1.3 Species of Concern

The species of Concern were chosen based on 1) their relative abundance in the new study, 2) relative abundance during the 2006 study, 3) whether or not the species is targeted by a commercial or recreational (or both) fishery, and 4) whether or not the species is protected by regulations due to being threatened, endangered, overfished, or some other consideration. Criteria number four did not apply to any of the fishes collected during the sampling.

Round Stingray - Round Stingray is a common inhabitant of shallow, nearshore waters, bays, and harbors of southern California with peak activity at night (Love 2011). Seasonal spawning aggregations form annually in warm water refuges. Round Stingrays reach a maximum disc width of 310 mm. Female Round Stingrays give birth to live young measuring 65-80 mm disc width (Hale and Lowe 2008). No coastal population estimates are available, but their common occurrence throughout the Los Angeles County area suggests the population is healthy. Like nearly all species, Round Stingray abundance was reduced in the new study in comparison with the 2006 study. No clear explanation is available for the difference as their migratory behavior and lack of source water population estimates over time undermine any attempt to place this difference into context. We again revisit the published information demonstrating that 2006 was a year when the local fish stocks, in general, were more abundant than usual (Miller and McGowan 2013).

Northern Anchovy - Northern Anchovy is a common inhabitant of the coastal southern California waters. Northern Anchovy routinely undergoes dramatic changes in ambient abundance primarily in response to oceanographic conditions (Love 2011). Large schools of Northern Anchovy can be found throughout harbors, bays, and the coastal waters along the west coast of the United States and Canada where they support one of the largest commercial fisheries in the area. This schooling behavior sometimes leads to large impingement numbers (biomass) when the school encounters an active intake structure. Northern Anchovy can reach 248 mm total length, although most individuals collected during sampling measured 80-120 mm total length, corresponding to individuals less than three years old (Parrish et al. 1985). Only 24 individuals were estimated to be impinged in 2006 with an increase to 756 in year one and 1,401 in year two. Despite the increasing abundance, the estimated annual impingement biomass was low with the average Northern Anchovy weighing one gram, or less.

Shiner Perch - One of the common members of the surfperch family of fishes, Shiner Perch occurs in many habitats from soft bottom to rocky reefs and harbor environments (Love 2011). Shiner Perch are not considered a prized or particularly economically valuable fishery (recreational or commercial) with individuals occasionally taken by recreational anglers fishing from man-made structures (piers, breakwaters, etc.). When abundant, Shiner Perch form large aggregations that can result in high impingement when the aggregations occur near an operating intake structure. Shiner Perch reach a maximum size of 203 mm total length, although most impinged individuals range from 80-120 mm total length, or generally two years old or less. Nearly all surfperch in southern California have declined from their pre-1985 abundances, including Shiner Perch. To date, research has consistently found oceanographic changes as the most likely cause of this decline (Holbrook et al. 1997; Brooks et al. 2002; Miller and McGowan 2013). Estimated impingement in both years of the new study was lower than was reported for 2006, but this was especially true of year two when less than 50 Shiner Perch were estimated to be impinged, or more than eight times fewer individuals in 2013-14 than in 2006. While 12 months were surveyed in 2006 as compared to the 10 months of monitoring in year two, it is highly unlikely that these two months account for this difference. The more recent results of the new study indicate high inter-annual variability with a nearly five-fold difference between the annual abundance estimates. Variable recruitment is the leading cause of the variation observed in the impingement estimates.

Spotted Kelpfish - Spotted Kelpfish are common to high-relief habitat (kelp, pilings, rocky reefs, etc.) in southern California, but they rarely occur in large, dense aggregations (Love 2011). Instead, these cryptic fishes often occur as solitary individuals or in association with a few others dependent on the availability of suitable habitat to hide in. Spotted Kelpfish reach a maximum length of 160 mm standard length. No commercial or recreational fishery targets Spotted Kelpfish. Likewise, little research has been published regarding Spotted Kelpfish population dynamics. As with Shiner Perch, Spotted Kelpfish are planktivorous fishes commonly associated with marine algae. Their abundance in the impingement sampling was highest in 2006 of the three years of study, although their abundance during year one was similar to that in 2006. A considerable decline in impingement abundance was observed in year two. No reasonable information regarding this change in abundance is available other than a response to an environmental parameter(s).

Black Perch - Like the Shiner Perch, Black Perch is a common member of the surfperch family of fishes in southern California that lives near high-relief habitat like reefs, kelp, and pilings, although older individuals can be found over sand on occasion (Love 2011). Black Perch reach 390 mm total length. Impinged individuals range in ages from young-of-the-year to several years old (Froeschke 2007). Black Perch, like all southern California Surfperch, declined in abundance across the Southern California Bight in response to oceanographic changes (Holbrook et al. 1997). In 2006, the estimated annual impingement was 646 individuals, while an estimated 90 were impinged during the 22 months of the new study, or less than one-sixth of the 2006 abundance. No explanation for this difference is available other than the general patterns in coastal fish abundance detailed previously.

2.2 Haynes

2.2.1 Summary of Impingement Sampling Methods

In anticipation of the new federal §316(b) Rule LADWP initiated a new impingement study in April, 2012. The new impingement study (new study) differs from the 2006 impingement study in two ways. First, in the original study each 24-hour survey was comprised of four, 6-hour sampling events (cycles) at the Unit 8 TWS. Difficulties in operating the vertical slide screens at Units 1 and 2 prevented the six-hour cycles at Units 1 and 2; each survey covered a single 24-hour period at those units. The new study used a single 24-hour sampling event at all three units. Second, sampling frequency was once per week for one year in 2006 and the sampling frequency for the new study is once every other week for two years.

Sampling methodology, other than the frequency of the surveys and duration of each sampling event mentioned previously, were consistent between the new study and the 2006 study detailed in MBC et al. (2007b). Beginning on 10 April, 2012, and nearly every other week thereafter, impingement sampling on the Haynes screens (TWS and vertical slide screens) was conducted.

The screen structure for each operating unit was monitored individually, but all units were monitored on the same day. The pumps for Unit 8 withdraw through the screen structure that once serviced Units 3 and 4. These same designations were used in the initial study (Units 3 and 4). Each survey cycle (six hour in 2006 and 24 hour in the new study) began when the screens were placed back into position (Units 1 and 2) or stopped rotating (Units 3 and 4) during initial screen clearing. Material that accumulated in the collection basket was discarded. A 6.4 mm (0.25 inch) diamond mesh rigid basket was temporarily installed into each permanent steel collection basket. Material was allowed to accumulate over the next six (2006 study) or 24 (new study) hours (approximately) as the screens were operated per normal station operating procedures. The sampling period ended when the screens were cleaned at the end of the cycle. All material was washed off the screens and carried to the collection basket in a trough. When all water stopped washing out of the trough, the temporary basket with the accumulated material was removed and the sample processed. Fish and shellfish were removed, identified to the lowest practicable taxonomic level (species most often), up to 200 individuals of each species measured to the nearest millimeter of the most appropriate axis (standard length, total length, disc width, carapace length, or carapace width), and weighed by species. If more than 200 individuals per species were impinged, aggregate weights for the first 200 and remaining portion were recorded separately. The total abundance was estimated by dividing the remaining portion's weight by the average weight of the 200 individuals. The disposition of the first 30 individuals of each species were recorded as live, dead, or mutilated during the 2006 study but not in the new study. Data from the new study through 28 January 2014 were used in this analysis. Survey-specific data from both studies were extrapolated to derive an estimated total impinged abundance and biomass by the equation:

$$Estimate = \frac{Survey\ Data}{Cycle\ Flow}\ X\ Analysis\ Flow$$

The cycle flow was the volume of cooling water circulated during the cycle and the analysis flow was the volume of cooling water circulated during the intervening period. In 2006, the analysis flow was the sum of seven days (weekly sampling) while the new study summed over 14 days (biweekly sampling).

2.2.2 Estimated Annual Fish Impingement

The estimated annual impingement during a one-year impingement study conducted at Haynes in 2006 was 31,226 finfish for Units 1, 2, and 8, and 53,442 finfish for all units combined (i.e., including the now retired Units 5 and 6). Unit 8 went into service after the retirement of Units 3 and 4, but the TWS for Units 3 and 4 are currently used for Unit 8. The TWS are designated as 8a (formerly Unit 3) and 8b (formerly Unit 4). All analyses presented herein exclude data from Units 5 and 6. The 2006 estimates are based on 50 sampling events and the new study estimates are based on 22 sampling events in both years for the new study (April 2012–March 2013 and April 2013–January 2014). Year two of the new study, as of the time this report was prepared, encompassed only 10 months. The additional impingement abundance and biomass from these two months will likely result in minimal change to the annual estimate. The estimates from the sampling in February in both year one and 2006 were the lowest month of the year while March was also amongst the lowest in each year. There are no indications that impingement in February and March 2014 will be substantially different than during the prior two years.

Impingement estimates from both studies were calculated using actual cooling water volumes over the one year, or nearly one year, periods. In the 2006 study, 40 different species were collected compared to 27 species in the new study's first year and 16 during the second 10 months. The impingement estimates (Table 2.3) declined from 27,009 in 2006, to 11,059 in year one (59.05% fewer fish impinged). A direct comparison is not possible for year two since Unit 1 was offline from September 2013 through January 2014 and as noted, the second year only includes 10 months of data rather than a full year. Since in year two there are only six months (half the year) when Units 1, 2 and 8 were all in operation and some of those months tend to be months of higher impingement. Thus average impingement was not estimated for the combined first and second year of the current study. However for the six months when all three units were in operation the impingement levels in the second year of the current study were comparable to the first year indicating that lower levels of impingement are continuing compared to the prior 2006 study.

Impingement at Unit 1 accounted for almost 90% of the total impingement for the new study (year one) followed by Unit 2 (9.3%), Unit 8b (1%), and Unit 8a (0.1%). The highest impingement levels in 2006 occurred from mid-June through October (Figure 2.3). Figure 2.4 shows a comparison of flows for Units 1, 2, 8a and 8b. The overall cooling water flow during the new study was quite similar to the 2006 study with the exception of periods when a unit was offline for maintenance and there was no cooling water flow. Therefore, since flows were relatively similar for the two study periods the most likely cause of the difference in fish impingement is inter-annual variability in fish abundance.

Queenfish (*Seriphus politus*) ranked first in all three years of surveys making up 61% of the total estimated impingement in 2006 and 87% and 84% in years one and two, respectively, of the new study (Table 2.4). A substantial difference in abundance occurred between Queenfish and the second most abundant fish in each year of study. Northern Anchovy ranked third in 2006 after Topsmelt (*Atherinops affinis*) and second in each year of the new study.

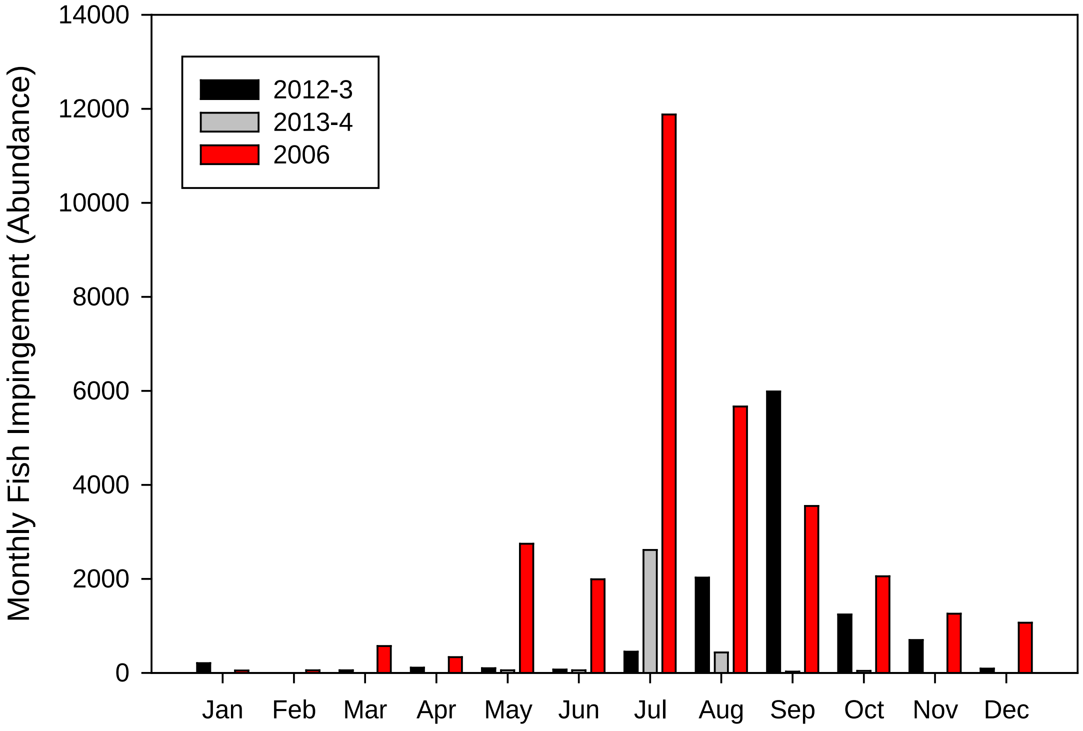

Figure 2.3 – Haynes Generating Station estimated monthly fish impingement during three study periods: January–December 2006, April 2012 to March 2013 (2012-13), and April 2013 to January 2014 (2013-14) .

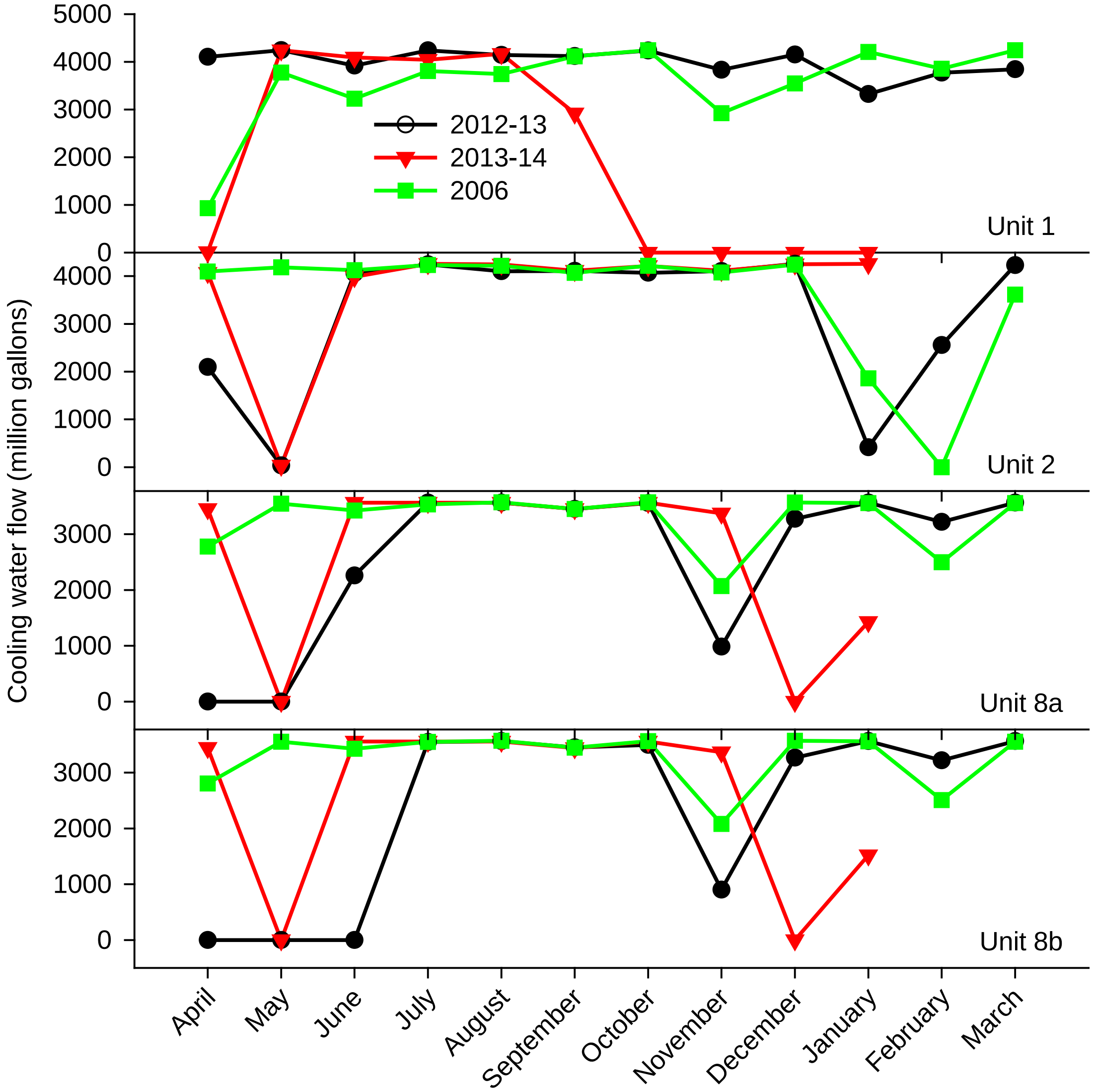

Figure 2.4 – Comparison of Haynes Generation Station actual cooling water volumes (million gallons) circulated during the 2006, April 2012 to March 2013 (2012-13), and April 2013 to January 2014 (2013-14) studies by traveling water screen designation.

Table 2.3 – Estimated monthly abundance and biomass (kg) of fish impinged at Haynes Generating Station for the April 2012-March 2013 (2012-13), April 2013-January 2014 (2013-14), and January-December 2006 (2006) periods. February and March 2013 were not sampled. The mean abundance for biomass impinged during the 2012-14 studies is included.

	Estimated Abundance				Estimated Biomass (kg)		
Month	2012-2013	2013-2014	2006		2012-2013	2013-2014	2006
January	207	0*	49		0.1	0	0.87
February	14	NS	55		0.01	NS	4.42
March	56	NS	570		3.02	NS	1.82
April	112	15	336		0.89	0.09	2.57
May	98	56	2,746		9.47	14.9	21.53
June	70	55	1,991		5.31	0.14	8.26
July	451	2,616	11,880		1.06	18.02	13.63
August	2,028	434	5,666		2.61	1.5	7.42
September	5,987	8*	3,551		10.14	4.83*	15.82
October	1,244	42*	2,055		10.48	0.16*	7.91
November	700	0*	1,259		0.97	0.00*	5.22
December	92	0*	1,068		0.3	0.00*	3.68
Annual Total	**11,059**	NA	**31,226**		**44.36**	**NA**	**93.15**

*Unit 1 out of service and no Unit 1 flow.

Table 2.4 – Estimated abundance and biomass (kg) impinged at Haynes Generating Station, by fish species, for the April 2012-March 2013 (2012-13), April 2013-January 2014 (2013-14), and January-December 2006 (2006) periods. Only species occurring during the 2012-14 are presented in the table. During 2013/2014 only 10 months of data available during the second year and Unit 1 was out of operaton from the end of August through January of 2014.

	Estimated Abundance				Estimated Biomass (kg)		
Species	2012-2013	2013-2014	2006		2012-2013	2013-2014	2006
Queenfish	**9,629**	**2,719**	**18,895**		**8.32**	**0.86**	**12.17**
Northern Anchovy	**221**	**143**	**1,775**		**0.43**	**0.42**	**2.63**
Bay Pipefish	**268**	**54**	**1,399**		**0.19**	**0.09**	**1.15**
Giant Kelpfish	**155**	**14**	**39**		**1.31**	**1.04**	**0.45**
Topsmelt	**96**	**55**	**3,196**		**0.48**	**0.13**	**7.52**
Kelp Pipefish	**87**	**16**	**7**		**0.08**	**0.02**	**0.01**
Rockpool Blenny	**59**	**42**	**10**		**0.2**	**0.33**	**0.06**
California Grunion	**97**	**0**	**208**		**0.34**	**0**	**0.26**
Black Perch	**43**	**28**	**57**		**5.19**	**14.7**	**0.91**
Round Stingray	**28**	**42**	**128**		**9.35**	**6.6**	**14.59**

Slough Anchovy	**60**	**0**	**336**		**0.11**	**0**	**0.77**
Specklefin Midshipman	**42**	**14**	**336**		**0.06**	**10.27**	**28.59**
Reef Finspot	**14**	**30**	**7**		**0.01**	**0.11**	**0.03**
Longjaw Mudsucker	**35**	**0**	**50**		**0.06**	**0**	**0.05**
Snubnose Pipefish	**29**	**0**	**0**		**0.03**	**0**	**0**
Spotted Kelpfish	**29**	**0**	**92**		**0.42**	**0**	**0.93**
Barcheek Pipefish	**28**	**0**	**0**		**0.02**	**0**	**0**
Diamond Turbot	**14**	**14**	**63**		**0.03**	**4.02**	**0.58**
California Clingfish	**0**	**16**	**22**		**0**	**0.06**	**0.03**
Spotted Sand Bass	**0**	**15**	**0**		**0**	**0.09**	**0**
Bat Ray	**14**	**0**	**0**		**2.97**	**0**	**0**
Bay Blenny	**14**	**0**	**0**		**0.06**	**0**	**0**
Bay Goby	**14**	**0**	**0**		**0.01**	**0**	**0**
Grass Rockfish	**0**	**14**	**0**		**0**	**0.06**	**0**
Jacksmelt	**14**	**0**	**21**		**0.11**	**0**	**2.49**
Pacific Staghorn Sculpin	**14**	**0**	**320**		**0.11**	**0**	**6.62**
Plainfin Midshipman	**0**	**14**	**13**		**0**	**0.81**	**1.63**
Thornback	**14**	**0**	**0**		**9.45**	**0**	**0**
Barred Sand Bass	**13**	**0**	**0**		**0.17**	**0**	**0**
White Seaperch	**28**	**16**	**35**		**4.85**	**0.03**	**0.2**
Total all species	**11,059**	**NA**	**31,226**		**44.36**	**42.67**	**93.15**
Number of species	**26**	**NA**	**40**				

The analysis also indicates that there has been a significant reduction in impingement, since September, 2013. This is likely due primarily to the shutdown of Unit 1 that impinges the majority of the fish. However, Unit 6 was retired on August 25, 2013 and Unit 5 was retired on August 27, 2013 and the resulting 45% reduction of flow into the intake channel may also have contributed to the 85% reduction in impingement. At this point it is not clear on the extent to which the unit retirements are a contributor to the impingement reduction. However, LADWP plans to continue the impingement study for a third year to determine if the current trend in lower impingement continues.

Table 2.5 – Comparison of impingement at the Haynes Generating Station for the five months after Unit 1 went off line and Units 5 and 6 were retired.

Month	April 2012 - March 2013	April 2013 - March 2014
April	112	15
May	98	56
June	70	55
July	451	2,616
August	2,028	434
September	**5,987**	**28**

October	**1,244**	**42**
November	**700**	**0**
December	**92**	**0**
January	**207**	**0**
Total Impingement for Overlapping months after Unit 5 and 6 pump retired	**8,230**	**70**

2.2.3 Species of Concern

The species of Concern were chosen on the same basis used for Harbor and the criteria included 1) their relative abundance in the new study, 2) relative abundance during the 2006 study, 3) whether or not the species is targeted by a commercial or recreational (or both) fishery, and 4) whether or not the species is protected by regulations due to being threatened, endangered, overfished, or some other consideration. Criteria number four did not apply to any of the fishes collected during the sampling. Four species were selected and included Queenfish, Northern Anchovy, Topsmelt and Bay Pipefish. Northern Anchovy were described for Harbor and the other three species are discussed below.

Queenfish – Queenfish, a common fish in southern California that was consistently the most abundant fish collected in nearshore fish surveys, has declined across the region in recent years (Miller, et al. 2009, Love 2011, Miller, et al. 2011, Miller and McGowan 2013). Although Queenfish range in size up to 305 mm total length, most Queenfish collected during impingement sampling at Haynes Generating Station were 100 mm or less. Fish of this size range are likely young-of-the-year, or individuals born within the last 12 months (Miller et al. 2009). Queenfish abundances in southern California recently peaked in 2007 before declining, consistent with Queenfish impingement at Haynes (Miller et al. 2011). The relatively high abundance in 2006, especially of young-of-the-year, influenced the population levels in 2007. Results from the new study, rather than the 2006 study, were likely more representative of the current abundances of Queenfish.

Topsmelt - Topsmelt is a nearshore species common to bays and harbors. Ranging in size up to 388 mm total length, Topsmelt generally remain near the surface, especially the younger aged individuals (Love 2011). During mating season they will dive to the bottom to spawn in vegetation where their eggs can attach (Love 2011). The preference for bays and harbors exposes Topsmelt to wide variations in salinity and temperature, which they appear to have evolved to survive. Impingement during the new study likely represents baseline conditions better than the 2006 data as Topsmelt populations were elevated in 2006 based on the source data used in the analysis by Miller and McGowan (2013).Bay Pipefish - Bay Pipefish (*Syngnathus leptorhynchus*) are a common inhabitant of nearshore coastal environments, and are commonly found amongst submerged aquatic vegetation (Love 2011). As with most species examined here, Bay Pipefish impingement in the new study was lower than in 2006. Causes behind the relative decline are unclear as pipefish (all species) numbers have generally increased in recent years across the Southern California Bight in coastal monitoring studies such as the trawl sampling at the San Gabriel River Mouth (MBC 2014).

3 HARBOR IMPINGEMENT MORTALITY REDUCTION EVALUATION

3.1 Introduction

Based on EPRI impingement mortality reduction technologies research, site visit and facility information provided by LADWP, EPRI has identified the following four technologies for more detailed evaluation for Harbor:

- Modified traveling water screens with a fish return
- Wide-slot (9.5 mm) cylindrical wedgewire screens
- Barrier net
- A reduction in intake velocity

Site-specific designs were developed for each of the listed technologies. The evaluation describes the general deployment, installation and operation of the selected technology and includes appraisal level capital, O&M, and component replacement costs.

There is some uncertainty in the ability of the selected technologies to be effective under the hydraulic, biofouling, and debris conditions found at Harbor. Information on site-specific pilot studies, including a preliminary layout, study design, and costs were included to address any engineering uncertainties.

3.2 Engineering Evaluation of Impingement Mortality Reduction Technology Options

Each of the four impingement mortality reduction technology options for Harbor is discussed in terms of:

- a description of the proposed engineering design and issues relative to construction and/or operation;
- expected biological performance;
- necessary studies to confirm performance, feasibility and/or estimated cost;
- estimated cost for construction, O&M and pilot studies; and
- the estimated cost relative to the reduction in impingement mortality.

Two classes of technologies are available to reduce impingement mortality at Harbor, exclusion devices/velocity reduction, and collection and transfer. These technologies were described in Sections 1.2.2 and 1.2.3 respectively. As discussed in Section 1.2.2 of the introduction, the EPA determined that an intake with a maximum through-screen velocity of 0.5 fps was highly protective of fish and qualified as BTA for impingement under the now remanded §316(b) Phase II Rule as well as an impingement mortality compliance alternative in the §316(b) proposed rule. Two options to achieve an intake velocity reduction to not exceed a 0.5 fps are discussed for Harbor and include use of cylindrical wedgewire screens and a barrier net. The EPA also determined that a modified TWS with a fish return was BTA, since it could be deployed at almost any facility.

3.2.1 Modified Traveling Water Screens with a Fish Return

Currently there are a number of different modified TWS on the market that include:

- Modified Ristroph,
- Beaudrey WIP,
- Bilfinger Multi-disc, and
- Hydrolox

EPRI has conducted laboratory research on each of these screens as well as field studies on modified-Ristroph, Hydrolox and Beaudrey WIP and has a field study in progress for Hydrolox. A more detailed discussion of these screen types is provided in Appendix A. While these screens vary significantly in terms of their debris handling capability and maintenance issues, in general their overall fish protection performance is similar. For the purpose of this evaluation a modified-Ristroph screen system was selected, since this has been the most commonly used screen for fish protection and is the one analyzed by the EPA for their determination that a modified TWS with a fish return is BTA for impingement mortality reduction.

3.2.1.1 Description of Engineering Design

Coarse-mesh modified TWS with fish protection features and a fish return could be installed in the existing Harbor screen house. With this option, screens would only be installed in the four currently operating screen bays. The velocity approaching the new screens would be less than 0.5 fps at a design flow of 167.1 cubic feet per second (cfs) and a low water level of El. -1.7 ft. The new screens would include a 0.25 by 0.5 inch smooth-top mesh and each screen basket would have a fish bucket to hold collected organisms in about 2 inches of water while they are lifted to the fish recovery system. A low-pressure spray (~10 pounds per square inch [psi]) would be used to gently remove the fish from the fish holding buckets and into a fish return trough. A high-pressure wash (>80 psi) would then flush the remaining debris into a debris trough. The fish and debris troughs would combine into a single fish and debris trough that would run through the east intake pipe (Figure 3.1). This combined return would exit through the east wall of the intake structure, and discharge in Slip 5 approximately 120 ft northeast of the CWIS (Figure 3.1). A second, redundant fish return was included in the design to address anticipated biofouling. One fish return would be used during operation while the second fish return would be allowed to dry, desiccating attached biofouling organisms for ease of removal. Operations would be switched periodically, so that one fish return would be dried for cleaning.

Figure 3.1 – Fish-friendly modified traveling water screen retrofit option for Harbor

The existing TWS would be removed in order to install the new fish-friendly modified TWS. The new TWS would be the same width as the existing screens (6.2 ft) and designed to fit into the existing screen slots. Prior to installing the new screens, the existing screen guides and supports should be evaluated to determine their condition and if they are compatible with the new screens. The existing electrical service at Harbor should be sufficient to handle the electrical needs of a modified TWS retrofit.

Depending on existing screen wash pressures and flows, new high- and low-pressure screen wash pumps and supplemental fish return pumps may be required. New screen wash pumps were assumed for costing purposes. Additional construction efforts include the connection of the new spray wash system and installation of the fish return system. New screen controls located in a water tight enclosure were included as part of the design. The new controls would be connected to the overall station control system allowing the condition of the screens to be monitored and controlled remotely. Any new control system should be designed to allow the screen rotation speed to adjust automatically based on debris loading. No changes will be needed to the circulating water pumps.

Removal of the existing screens, installation of the new screens, and completion of mechanical and electrical work would require about 2 weeks per screen (8 weeks total). The new fish and debris return would be built simultaneously to the installation of the screens. Timing the installation of the new screens and fish and debris return to coincide with scheduled maintenance outages would eliminate any additional shutdowns. The capital cost of installing the new screens is estimated to be $7,066,000.

Except for frequency, the annual O&M requirements for fish-friendly modified TWS are very similar to what is required for standard TWS. Continuous operation of the screens and the auxiliary and screen wash pumps would require approximately 2,444 MWh, per year. Continuous screen operations increases the stress and wear on screen components, requiring increased man-hours to inspect, maintain, and repair the screens. It was assumed that screens would be inspected daily with a thorough inspection and lubrication conducted at least annually. These maintenance tasks are expected to require 1,780 man-hours per year. It was also assumed that the screens would require a complete overhaul or replacement every three years. The actual maintenance schedule at Harbor should be based on operating experience with the existing screens and adjusted with increased experience using the new screens.

The fish and debris return systems should be regularly inspected to ensure that they are operating as designed. An annual inspection by divers or remote cameras would be necessary to provide a thorough inspection of the return lines. Regular switching between the two return lines should reduce biofouling. If fouling or debris plugging of the return lines becomes an issue, pigging or plunging of the lines can be used to remove any attached debris. These efforts will require approximately 653 man-hours, or more, per year depending on the number of times the return lines need to be cleaned.

3.2.1.1 Description of Engineering Design

Two source of information were considered in making BPJ estimates of biological performance for modified TWS with a fish return. They were a study conducted to estimate performance on such screens using information in the literature and a memo prepared by MBC biologists based on direct observations and literature for west coast species of Concern (Appendix B)

3.2.1.1.1 EPRI Analysis

EPRI reviewed available impingement survival reports from more than 35 steam-electric power plants and included data from several different screen types (EPRI 2003). Based on the review, families of fish were divided into three groups based on their potential for survival: high survival potential (~71-100%), intermediate survival potential (~31-70%), and low survival potential (~0-30%). Based on this categorization, one species would have low potential for survival (Northern Anchovy), two species would have intermediate potential for survival (Shiner Perch and Black Perch), and one species would have high potential for survival (Round Stingray). Based on this study the species of Concern for Harbor are rated as:

Round Stingray – High Survival
Northern Anchovy – Low Survival
Shiner Perch - Intermediate Survival

Spotted Kelpfish - Unknown
Black Perch - Intermediate Survival

3.2.1.1.2 MBC Memo

A copy of the MBC memo is provided as Appendix B and the results for Harbor species of Concern are:

Round Stingray – 18 of 54 impinged specimens placed in holding tanks survived 144 hours (end of test).
Northern Anchovy – No live specimens were collected off the TWS, however, some survival has been reported in the literature.
Shiner Perch – One study reported 60% survival while a second said a very low percentage survived impingement but those that did survive had a 100% survival rate after 96 hours following transport back to the source waterbody.
Spotted Kelpfish – Habitat preference suggests poor survival
Black Perch – Some 30 individuals out of 175 impinged specimens were placed in a holding tank and had a 90% survival rate after 144 hours.

Based on the two sources of information a BPJ impingement survival estimate for finfish was made for Harbor assuming modified TWS were installed as described in Section 3.2.1.1 (Table 3.1). For the species of Concern that make up 88.5% of the annual impingement, it is estimated that a 41% reduction in impingement mortality can potentially be achieved. This amounts to a total of 749 species of Concern saved annually. For the remaining 228 non-species of Concern it is assumed that 42.7% or 865 fish will survive for the purpose of the cost versus performance comparison based on the current average annual impingement. If a three year average that included the 2006 data the estimated survival might be double that number. A pilot study to reduce the uncertainty of these estimates is discussed in Section 3.2.1.3.

Table 3.1 – Estimated impingement survival if modified TWS with a fish return was installed at the Harbor Generating Station.

Species	Current Avg. Annual Impingement	Estimated % Survival	Estimated # of Fish Surviving with Modified Screens
Round Stingray	**470**	**70%**	**329**
Northern Anchovy	**1,079**	**30%**	**324**
Shiner Perch	**135**	**40%**	**54**
Spotted Kelpfish	**67**	**15%**	**10**
Black Perch	**45**	**70%**	**32**
Total Species of Concern	**1,796**		**749**
Total Non-Species of Concern	**232**	**50%**	**116***
Total Impingement	**2,028**		
Estimated Total Survival			**865**

*Assumes a survival rate of 50% for the 232 non-species of Concern.

3.2.1.2 Uncertainties and Pilot Studies

3.2.1.2.1 Biological Performance Study

There is uncertainty around the estimated survival rates presented in the previous section and the best means to reduce that uncertainty would be to conduct an impingement survival study using a test screen. A description of the methods and cost for such a study are provided in Appendix B. The study would require measuring survival at different points in the collection and transfer process and would include the following:

1. Impingement sampling to collect fish for testing off the TWS and evaluate impingement survival;
2. Impingement sampling at the point of return of fish to the source waterbody to allow quantification of fish survival following transport; and
3. Latent mortality study to evaluate survival after 96 hours.

A pilot study would require the purchase of one new modified traveling water screen for testing for an estimated to be $764,000, while the cost to perform the biological evaluation of screen performance is estimated to be $291,000. The basis for the screen evaluation cost estimate for Harbor is provided in Appendix B. The combined cost of the test screen and biological sampling is $1,055,000.

3.2.1.2.2 Fish Return Optimization

Fish survival can be adversely affected if the fish return system is not properly designed or the discharge is not properly located. BPJ was used in selecting the best location to return fish to the source waterbody. However, because the discharge point is within Slip 5, re-impingement could be an issue. Studies may be required to better locate the fish return discharge. One approach would be to release dead, dyed fish at the discharge location, and monitor the fish return trough to document any re-impingement. Costs for this type of study could be up to $130,000. Alternatively, a numeric computational fluid dynamics (CFD)] model could be used to estimate the probability of re-impingement (see below), or radio tags could be attached to fish released following impingement to track their movement.

A hydraulic analysis of the fish return would be needed prior to construction to ensure the water depths and velocities are sufficient to safely transport fish and debris back to Slip 5. This analysis is needed for both return options. A one-dimensional hydraulic model should be sufficient to accurately model the fish return. This type of study is expected to cost between $5,000 and $15,000 depending on the complexity of the model and number of iterations needed to achieve the desired flow conditions.

3.2.1.2.3 Hydraulic/Physical Modeling

As referenced above, a CFD model could be developed to optimize the fish return location. In addition, any screen replacement can have a direct effect on intake hydraulics (e.g., head loss, vortices) and circulating water pump performance (i.e., pump submergence). This is not expected to be an issue if the screens are replaced in-kind (i.e., through-flow to through-flow), but may be needed if an out-of-kind replacement is used (i.e., through-flow to dual-flow, center-flow, WIP, MultiDisc). An assessment of effects using a CFD or physical model may be required if any potential hydraulic issues are identified. Costs for these types of studies are very site-specific and are expected to range from $70,000 to $130,000 for a CFD model and $50,000 to $250,000 for a detailed physical model of the intake.

3.2.1.2.4 Structural Evaluation for the Fish Return

A structural analysis of the east intake tunnel would be needed to verify that the tunnel can be modified to accommodate the new fish return lines. At a minimum, a visual inspection of the intake tunnel should be conducted to identify any structural deficiencies that would prevent the fish return lines from being sufficiently anchored to the bottom of the intake pipe. This is expected to take two divers 2 days plus an additional day to review their findings.

3.2.2 Not Exceeding 0.5 fps Intake Velocity Using Cylindrical Wedgewire Screens

There are a number of facilities around the U.S. that currently make use of cylindrical wedgewire screens for cooling water intakes and the technology that was discussed in Section 1.2.2. A slot size of 3/8 inch (9.5 mm) would be used, since the Concern is solely on reducing impingement mortality. This slot size has a greater open area than narrow-slow screens used to reduce both impingement and entrainment; therefore fewer, smaller modules are needed to achieve the desired 0.5 fps maximum through slot velocity. Because of the larger openings some of the issues discussed in the interim entrainment reduction technology evaluation for Harbor are less problematic if the technology is being used solely for impingement mortality reduction. However, uncertainties remain and are discussed in Section 3.2.2.3.

3.2.2.1 Description of Engineering Design

The Harbor CWIS is located along the northwest corner of Slip 5 within the Inner Los Angeles Harbor. At this location, tidal fluctuations and the intake withdrawal are the primary source of currents. The magnitude of these currents within Slip 5 are not known; but, a recent sediment transport study (Tetra Tech 2010) indicated that within the east basin channel the tidal currents are weak (i.e., on the order of 2 cm/sec (0.07 fps) or less across the tidal cycle). These tidal currents are an order-of-magnitude less than the through-slot velocity and are not expected to be strong enough to transport fish and debris away from the screens. Without sufficient bypass flow, debris could impinge on the screens. The lack of sufficient sweeping flow would also reduce the effectiveness of the automatic, screen cleaning system. Because of this shortcoming, the proposed wide-slot cylindrical wedgewire layout includes the ability to remove the screens for manual cleaning.

The proposed wide-slot wedgewire design uses four (4), T-60 (5-ft diameter) screens to filter the Harbor circulating water. The screens would have a slot size of 3/8 inch (9.5 mm) that meets the definition for impingement in the EPA’s §316(b) proposed rule. Only three (3) screens are needed to accommodate the total flow, but the additional screen allows one screen to be taken offline for maintenance without exceeding a 0.5 fps through-slot velocity. The screens would be mounted on slide gates flanged to fit a bulkhead wall constructed in front of the existing intake, as shown on Figure 3.2. The bulkhead wall would support a work platform and house the air-backwash system.

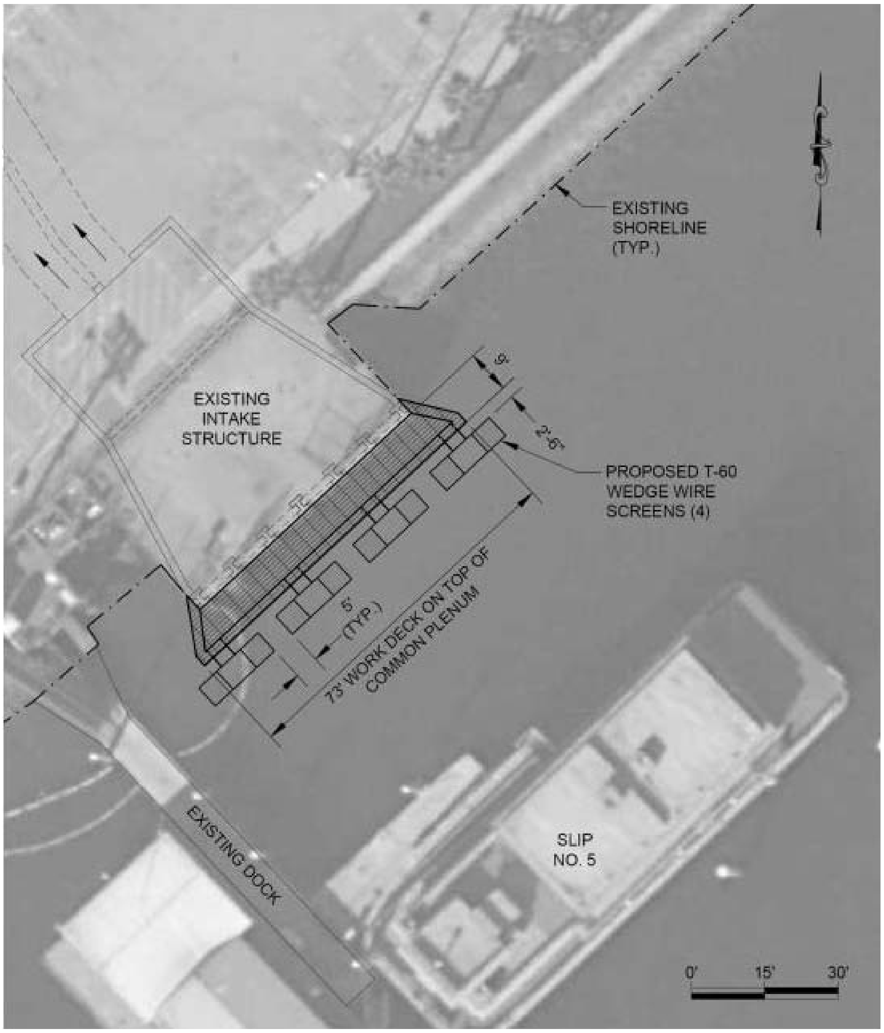

Figure 3.2 – Wide-slot wedgewire screens at Harbor

Each 5 ft diameter, T-shaped screen would have an overall length of approximately 16.5 ft. Two screen sections would be located on each side of a solid T section. The screens would be constructed of a copper-nickel alloy to reduce biofouling growth. The wire used to make the screen mesh has a V-shaped profile with a 0.089-inch wide face. A 42-inch diameter outlet pipe would be located in the middle of the T section. The outlet pipes would be flanged to fit track-mounted slide gates, allowing the screens to be lifted to the work deck. The slide gates would create a tight seal between the screens and the bulkhead wall.

Remotely-operated emergency bypass gates incorporated into the bulkhead would allow flow to bypass the screens if they become obstructed by debris or experience other malfunctions. The existing bar racks and TWS will remain in place to screen any debris that may enter the intake if the screens are bypassed in an emergency.

The air-backwash system, including air compressors, air receivers, and control system would be housed on the work deck. A high-pressure spray wash system (including a high-pressure pump) would also be integrated into the work deck. Mechanical winches, one per screen, installed on the work deck would lift the screens to the work deck for supplemental cleaning. Power for the air-backwash cleaning system, high-pressure wash and the screen lifting winches would be supplied by the Harbor in-house power system.

Head loss through the screens should not exceed one foot (assuming clean screens). Except for the slightly lower water level at the circulating water pumps, flow patterns approaching the circulating water pumps would not change.

Installation of the new wedgewire screen array and construction of the bulkhead wall is expected to take approximately 1 year. The bulkhead would be constructed in two parts, with a cofferdam surrounding the active construction area. This will allow Harborto remain operational during most of the construction period. The circulating water pumps at Harbor may need to be taken off-line during the installation of the cofferdams and during the final tie-in and inspection. This shut down is expected to take 3 to 4 months. Once the bulkhead wall is complete the air-backwash, spray wash, and screen lifting system can be installed. The final step would be the installation of the wedgewire screens. No modifications would be needed to the existing TWS and circulating water pumps. The total capital cost for this installation is expected to be $4,001,000.

The primary cleaning method would be an automatic air-backwash system. However, the air-backwash frequency cannot be determined without a better understanding of the debris loading rate. Each screen could also be raised and manually cleaned with the high-pressure spray wash system to remove attached biofouling and to inspect the screen. It was assumed that the air-backwash system would be operated once daily requiring 18.3 MWh and about 730 man-hours per year to monitor, operate, and maintain the air supply equipment. Monthly manual cleanings were assumed for costing. These cleaning are expected to take approximately 720 man-hours and require 0.5 MWh annually. In addition, an annual diver inspection to remove any debris that may have accumulated around the screens was included. Each inspection is expected to take a 3-person dive crew approximately two days.

Maintenance on the TWS would be reduced from existing O&M procedures because the wedgewire screens would remove much of the debris currently impinging on the TWS. Maintenance on the TWS would still be needed and should include sufficient inspection, lubrication, and operation to ensure that the screens are fully functional in the event they are needed.

3.2.2.2 Expected Biological Performance

As discussed in Section 1.2.2 and shown in Figure 1.1 a through screen velocity not to exceed 0.5 fps is highly protective of impingeable-sized fish. It is reasonable to assume that achieving this velocity with cylindrical wedgewire screens would virtually eliminate impingement mortality.

3.2.2.3 Uncertainties and Pilot Studies

There are a number of uncertainties associated with this option. The cylindrical wedgewire screens would extend out from the intake into the Pier 5 harbor. An important uncertainty is whether or not their deployment in front of the intake would impair boat dockage or the ability of ships to navigate in Pier 5. It would be necessary for this option to undergo review and approval by the Los Angeles Harbor Authority, U.S. Coast Guard and the California Coastal Commission to obtain necessary approvals and permits and there is a question as to whether or not approval would be granted. Additionally there are uncertainties associated with the amount of time that will be required to complete such reviews and obtain approvals and necessary permits. The time frame required to accomplish this could extend beyond the end of 2020.

While biological performance is not an issue for cylindrical wedgewire screens, potential operational issues would warrant further study.

3.2.2.3.1 Wide-slot (9.5 mm) Cylindrical Wedgewire Screen Pilot Study

Prior to installing cylindrical wedgewire screens, a pilot study would be necessary to verify that the screens can be maintained in a clean condition under normal operating conditions. Some of the uncertainties associated with installing these screens at Harbor include, but are not limited to, debris accumulation and biofouling. The pilot study could be conducted using small test screens located near the existing intake where hydraulic, sediment, and debris conditions are similar to the proposed deployment location. The duration of the study would be dictated by seasonal changes in the quantity and type of debris experienced at Harbor. Head loss across the test screens would be the primary indicator of screen cleanliness. The head loss should be measured for the screens under a clean condition (baseline condition) and then monitored during the study. Underwater videography or photographs of the screens could be taken to determine the debris and biofouling type, the effect on head loss, and the effectiveness of the screen cleaning system. Other parameters including water temperature, air temperature, turbidity, wind direction/ magnitude, current direction/magnitude and commercial boat traffic within Slip 5 could be included as part of the pilot study. The costs to conduct this study could range from $80,000 to $612,000 depending on the design of the test rig(s), testing duration, and number of parameters measured.

The assumption at the low end of the range (i.e., $80,000) is that a single small cylindrical screen unit would be deployed with a pump of sufficient size to generate flow through the screen that would simulate flow with a full-sized screen. The data provided from such a study would reduce uncertainty as to the time intervals between cleanings. However, for that cost, the screen would be cleaned manually and provide no data on the frequency or effectiveness of an air burst or other system (mechanical) to remove debris and biofouling. The high end cost (i.e., $612,000) assumes that a larger screen and pump would be deployed along with a debris and biofouling control system (i.e., air burst cleaning system). Sampling would take place over the course of a year and would require divers or the ability to remove screens from the water for observation. Such a study would provide the information necessary to reduce the risk that wedgewire screens could not be operated and maintained in compliance with the regulatory requirements of Compliance Alternative 2 as well as the need for and cost of manually cleaning.

3.2.2.3.2 Hydraulic/Physical Modeling

Hydraulic model studies (numeric and/or physical) are recommended to balance the flow through the screens and determine if there is any impact to circulating water pump operations. The cost for these studies could range from about \$20,000 for a simple two-dimensional numeric study to about \$200,000 for both three-dimensional numeric and physical models.

3.2.3 Not Exceeding 0.5 fps Intake Velocity Using a Barrier Net

As discussed in Section 1.2.2 barrier nets have been used effectively to reduce impingement at over a dozen facilities in estuaries, reservoirs and on the Great Lakes and have been demonstrated to reduce impingement mortality on the order of 80-90% (EPRI 2006). For facilities where it is practical to deploy them they are generally the lowest cost option. However, their maintenance cost is generally high due to the need for net changes to remove debris. At the Harbor intake and other marine and estuarine environments the frequency of net changes is usually driven by the need to control debris and biofouling.

3.2.3.1 Description of Engineering Design

A coarse-mesh barrier net installed in Slip 5 directly in front of the Harbor CWIS could be used to reduce impingement at Harbor. Barrier nets are designed for a 0.2 fps approach velocity or less in this report to ensure a through-screen velocity of less than 0.5 fps and allow for some biofouling and debris accumulation. A net with an effective area of about 836 ft^2 at the low water level would be needed to achieve this velocity. Assuming a 19.3 ft water depth in front of the intake bays, the net would have to be approximately 43 ft long. The Harbor CWIS withdraws water from the bottom 10 ft of the water column requiring the barrier net to be placed some distance in front of the CWIS. For this evaluation, the barrier net was placed 20 ft in front of the CWIS as shown on Figure 3.3. At this location, the effective area of the net would be approximately 1,500 ft^2 at the design low water level, assuming that only a 10 ft effective water depth on the sides of the net. With these assumptions the net approach velocity would be approximately 0.1 fps.

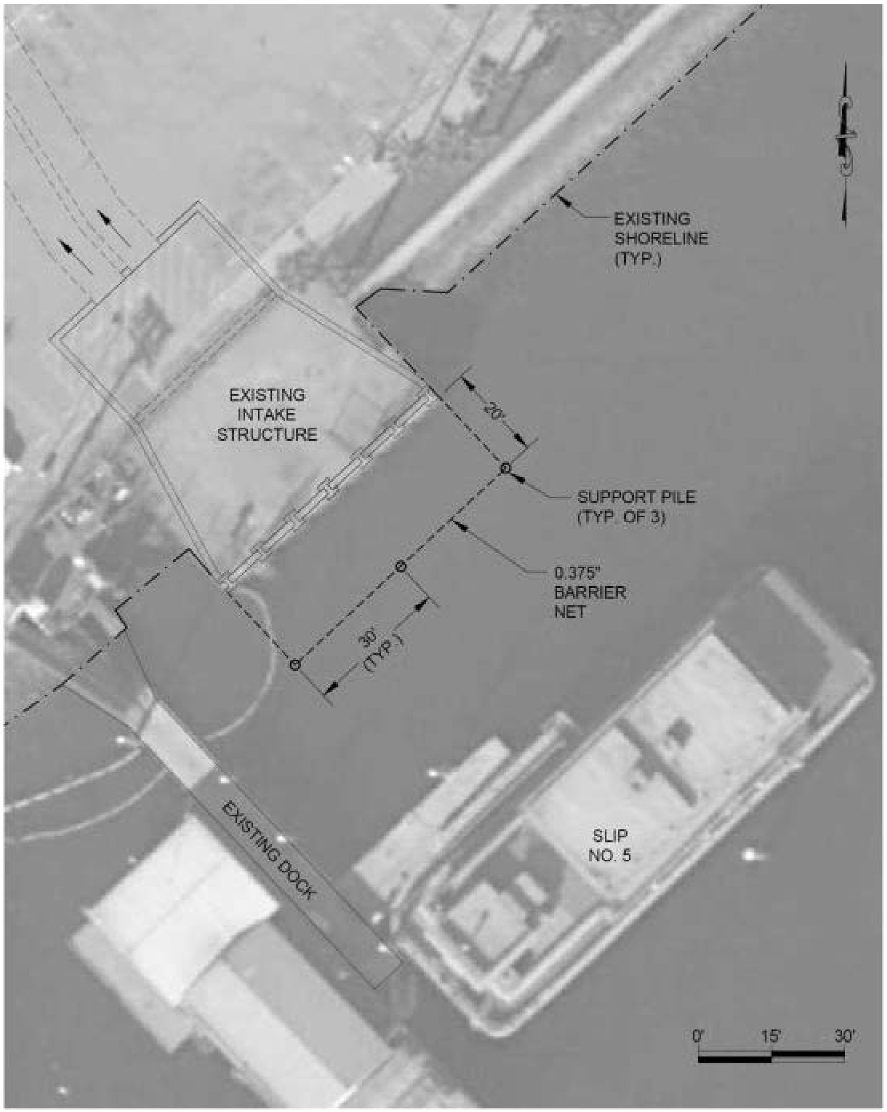

Figure 3.3 – Barrier net for Harbor

The net would be made out of 1/4 inch (6.4 mm) square mesh. This mesh was selected to allow the material to stretch without expanding beyond a 3/8 inch (9.5 mm) opening. The net would be supported by piles, floats, and anchors. Floats would be used to prevent the top of the net from submerging. Piles would be positioned at the corners and center of the net.

The net would be constructed out of a single, 120 ft long section and fabricated to match the water depth at the specific installation position. An additional 10 ft wide strip of netting would be incorporated into the bottom of the net to limit any gaps that fish can pass under. The extra 20 ft of net length would allow the net to shift and stretch while reducing stress on the supports and net materials. An anchor chain along the bottom and floatation billets along the top would be incorporated into each net panel. The panels would then be framed with rope to transfer forces to the piles, floatation billets, and anchor chain. Quick disconnect chain links would be used to join the net panels to the pile supports. Top and bottom anchor lines would run between the piles and attach to the net panels where they connect.

It was assumed that the net would be removed and replaced with a clean net every four days. The basis for the four days is frequency of cleaning at the barrier net at the Chalk Point Generating Station on the Chesapeake Bay (in operation in excess of twenty years) which requires changes twice per week to control biofouling during the summer. In the absence of site-specific data it is believed that the marine fouling in the Pacific will be more severe than estuarine fouling on the east coast. Pilot studies to reduce net changing frequency uncertainty are discussed in Section 3.2.3.3. Two nets would be needed to accommodate this cleaning schedule. Each net replacement would take a 4-man crew working on two workboats approximately 1 day. Once removed the dirty net would be cleaned. Annually net maintenance would require 2,944 man-hours. In addition to regular maintenance, divers may be needed to aid in removal of the net if it becomes stuck. Six diver events were added as a contingency to the total net O&M cost.

Installation of the net and support system would not impact station operations. The piles would be installed using barge mounted rigs and cranes. Once the support system is in place, the net would be installed. The first net installation would take about 1 week. Installation is expected to cost approximately $475,000.

In the event of severe debris loading, the top of the net would submerge to minimize damage to the nets and support system and to ensure that there is sufficient water available for station operation. Depending on the local conditions, replacement of the net panels may be required as frequently as every year. For costing purposes it was assumed that both nets would be replaced every 3 years.

The net would not eliminate the need to operate the existing TWS. When the net is in place, the screens would have to be ready to operate in the event of overtopping or net failure due to severe blockage of the net material. Maintenance requirements for the circulating water pumps would not change with this option.

3.2.3.2 Expected Biological Performance

Over a dozen current barrier net deployments have been demonstrated to provide a high level of performance on the order of 80 to 90%. However, the performance does not generally achieve the same level of protection as cylindrical wedgewire screens due to two factors:

1. Net Changes – Maintaining barrier nets requires changing the net(s) periodically to control debris buildup and biofouling. There is some opportunity for fish to get behind the net during net changes. Procedures can be developed to reduce this risk but the risk cannot be eliminated.

2. Entrapment – A potential issue raised in the Proposed Rule is fish entrapment. For some facilities, such as the Chalk Point Generating Station in Maryland, small Atlantic Menhaden can get through the net and grow to a size where they cannot escape from the

net. There were impingement incidents in the fall until the operations were changed to lower the net in the fall to allow the menhaden to escape from behind the net. There is some risk of entrapment at Harbor, however, this is minimal since the area between the net and the TWS is relatively small, compared to Chalk Point. Additionally, if this is an issue it is simple to design a solution for fish to escape.

For the purpose of this evaluation it is assumed performance of a barrier net would be a 90% reduction in impingement mortality.

3.2.3.3 Uncertainties and Pilot Studies

Similar to cylindrical wedgewire screens a barrier net would extend even further out from the intake into the Pier 5 harbor. Therefore the uncertainty is whether or not a barrier net deployment in front of the intake would impair boat dockage or the ability of ships to navigate in Pier 5 is also a significant concern. It would also be necessary for this option to undergo review and approval by the Los Angeles Harbor Authority, U.S. Coast Guard and the California Coastal Commission to obtain necessary approvals and permits and there is a question as to whether or not approval would be granted. Additionally, there are uncertainties associated with the amount of time that will be required to complete such reviews and obtain approvals and necessary permits. The time frame required to accomplish this could also extend beyond the end of 2020.

While barrier nets have used in other parts of the U.S. in freshwater and estuaries, none have ever been used on the west coast or in a marine environment. It is therefore especially important to verify that a barrier net would be practical and not interfere with Harbor operations prior to deployment.

A barrier net pilot study is recommended at Harbor due to the potential for biofouling and debris buildup. A full-scale study is preferred because it would allow the actual debris and bio-fouling loading rates on the net to be determined for refining a net maintenance schedule and provide information on the net support system and the effectiveness of the bottom seal. However, a limited study with several sections of netting may be more practicable. The study would require divers to inspect the net and a maintenance crew to remove and clean the net. Water temperature, air temperature, turbidity, wind direction/magnitude, navigation and other environmental parameters can be measured as part of the study. Costs to conduct a biofouling/debris control pilot study are provided in Appendix C. The total estimated cost for this study is $123,900.

3.2.4 Reducing the Traveling Water Screen Approach Velocity

As an alternative to expanding the intake surface area with cylindrical wedgewire screens or a barrier net, there is also an opportunity to reduce the through screen velocity at Harbor by increasing the number of TWS used for Unit 5.

3.2.4.1 Description of Engineering Design

The Harbor screen house was originally designed to provide cooling water for five units. Since Unit 5 is the only unit that currently withdraws water through the CWIS, there is additional screening area available to reduce the through-screen velocity to less than 0.5 fps without major structural or operational changes.

Under current operations only one circulating water pump is used during normal operation, with the second pump held on reserve for use if there are problems with the unit (e.g. vacuum problems). Based on one-pump operation and flow through four screen bays, the through-screen velocity is estimated to be approximately 0.4 fps. With all six bays in use the through-screen velocity would be reduced to less than 0.3 fps under one pump operation.

With two pumps operating the through-screen velocity at Harbor is approximately 0.8 fps through four bays and just over 0.5 fps with six operational bays. Reducing the through-screen velocity to 0.5 fps with six bays in service would require a 7% flow reduction (155 cfs) or the installation of screens with a minimum total open area of 63%. This level of flow reduction is based on clean screens. The level of flow reduction needed to meet the 0.5 fps criterion with and without 15% of the screen area blocked is shown on Table 3.2.

Table 3.2 – Flow reduction scenarios for harbor

Number of Operating Pumps	Flow (cfs)	Number of Screen Bays	Through Screen Velocity (fps)	Percent Flow Reduction to Meet 0.5 fps Criterion	Reduced Flow (cfs)
1	83.6	4	0.4	NA	NA
		6	0.27	NA	NA
2	167.1	6	0.54	7%	154.7
		4	0.81	38%	103.1

Reducing the through-screen velocity at Harbor would not change the velocity at the entrance to the intake tunnels. This may lead to the entrapment of organisms within the CWIS. LADWP may have to install modified TWS with a fish return to return any entrapped organisms back to the source waterbody. These screens and fish return would be the same as the screens detailed in Section 3.2.1.1. For cost estimating purposes it was assumed that four new screens would be installed alongside the two existing screens. Standard screens without a fish return were assumed because they are not required to meet the 0.5 fps velocity criterion. Installation of the new screens, along with replacing the existing screen lifting crane is estimated to cost $2,800,000. O&M on the screens is based on the operation of the existing screens and would require approximately $120,000 per year in labor and 93 MWh.

3.2.4.2 Expected Biological Performance

As discussed in Section 1.2.2 and shown in Figure 1.1, not exceeding a velocity of 0.5 fps is highly protective of fish and would virtually eliminate impingement of fish at the TWS. However, velocities in the intake tunnel leading from the Los Angeles Harbor to the plenum in front of the TWS would still exceed this velocity (1.7 fps with two pumps operating and 0.8 with one pump operating) and could result in fish entrapment. This is a potentially significant issue for the two dominant impinged species. Small northern anchovy, while able to handle the low velocity in the area in front of the screens, may not be able to return to the source waterbody. While the larger Round Stingrays should be able to handle the current velocities but for some reason they end up being impinged and that may not change even with the lower velocities. Entrapped fish would likely be lost to the fishery and ultimately end up being impinged. For the cost-biological performance comparison the assumed level of biological performance is 75%. This is considered highly conservative since it is unlikely based on the current impingement levels and velocities that entrapped fish near the screens could escape to return to the source waterbody. While the design includes fish friendly screens with a fish return, as noted in Table 3.1 for northern anchovy, the dominant impinged species, survival is expected to be <30%.

3.2.4.3 Uncertainties and Pilot Studies

The two operating circulating water pumps are located in the eastern half of the screen house. Because of their location, more water may be withdrawn through the easternmost screen bays than the western bays. Hydraulic model studies (numeric and/or physical) are recommended to balance the flow through the screens, and to determine methods to balance the flow if needed. Cost for these studies could range from about $20,000 for a simple two-dimensional numeric study to about $200,000 for both three-dimensional numeric and physical models. If the results of this study indicate that unbalanced flow through the screens then the circulating water pumps may need to be moved or replaced with several smaller pumps to provide an even flow distribution.

3.3 Evaluation of Cost and Performance

This section provides the capital, O&M, component replacement cost as well as the annualized cost for comparison to the expected performance. Costs are discussed in Section 3.3.1, while the comparison of cost to performance is discussed in Section 3.3.2.

3.3.1 Cost of Impingement Mortality Reduction Technologies

Costs, based on the conceptual designs, were estimated using Alden’s cost database of detailed site-specific cost estimates. These costs were adjusted for identifiable differences in project sizes and operations. Due to their generalized nature, these appraisal-level cost estimates are intended to allow a valid comparison of the cost differences between alternatives and should be sufficient for preliminary budgeting and decision making. The preliminary design costs provided herein have a confidence interval of +/- 30%.

O&M costs were based on preliminary estimates of the labor and power requirements of each technology. O&M efforts were monetized using a labor cost of $46.20 per hour, that reflects the cost for a skilled worker, and a replacement power cost of $35.00/MWh. Component replacement costs were estimated by dividing the direct technology cost by the estimated service life. As with the capital costs, the O&M and replacement costs are preliminary in nature and would have to be refined based on detailed assessment of each technology and the results of any engineering pilot studies.

Costs for each technology were annualized to allow them to be compared to their annual benefits. The total annual costs include the capital costs annualized over the life of the project, annual O&M costs, and the costs to repair or replace component as they wear out. The capital costs were annualized over a 10 year period (2020 to 2029) using a7% discount rate. A 10 year amortization period was used because any new technology is not expected to be installed until 2020 and by 2029 Harbor will use dry cooling and the screens will no longer be needed. Costs, including the annualized costs associated with each technology evaluated for Harbor, are presented in Table 3.3.

Table 3.3 – Harbor Alternative technology cost summary

Technology	Capital Cost	O&M Cost	Component Replacement	Annualized Cost
Coarse Mesh Modified Traveling Water Screens	**$7,066,000**	**$168,000**	**$1,713,000**	**$2,887,000**
Wide-slot Cylindrical Wedgewire Screens	**$4,001,000**	**$71,000**	**$291,000**	**$932,000**
Barrier Net	**$475,000**	**$716,000**	**$115,000**	**$899,000**
Reduced Screen Approach Velocity	**$2,800,000**	**$124,000**	**$280,000**	**$803,000**

In addition to the technology costs, LADWP may incur pilot study costs to determine if the technology would be practical and/or to verify its performance. These studies were discussed in the uncertainties section for each of the technologies evaluated and are summarized in Table 3.4. Additionally, the costs do not consider the costs of approvals, permitting and legal fees that would be incurred for the barrier net and cylindrical wedgewire screen options that extend out from the intake into Pier 5 and for the barrier net the lost revenue as a result of outages necessary to change the net to control biofouling and debris loading.

Table 3.4 – Estimated costs of Harbor pilot studies necessary to evaluate the feasibility, O&M or biological performance of the technologies evaluated.

Pilot Studies	Modified Screens	Cylindrical Wedgewire Screens	Barrier Net	Velocity Reduction
Biological Performance Study	**$1,055,000**	**NA**	**NA**	**NA**
Fish Return Optimization Study	**$130,000 to $145,000**	**NA**	**NA**	**NA**
Biofouling/Debris Control	**NA**	**$80,000 to $612,000**	**$123,900**	**NA**
Hydraulic/Physical Modeling	**Optional**	**$20,000 - $200,000**	**NA**	**$20,000 to $200,000**

3.3.2 Comparison of Cost to Expected Performance

For each technology evaluated a BPJ estimate of performance was provided. There is uncertainty associated with the estimates and for some technologies studies to better estimate the expected biological performance would be required (see Table 3.4). In the absence of more detailed information the current BPJ estimates are compared to estimated technology costs in Table 3.5.

Table 3.5 – Comparison of the annualized cost of evaluated impingement mortality reduction technologies to the number of fish projected to be saved based on current impingement levels at the Haynes Generating Station

Technology	Estimated Annualized Cost ($)	Estimated Number of Fish Saved	Estimated Cost Per Fish Saved ($)
Coarse Mesh Modified Traveling Water Screens	**$2,887,000**	**865**	**$3,338**
Wide-slot Cylindrical Wedgewire Screens	**$932,000**	**2028**	**$460(1)**
Barrier Net	**$899,000**	**1825 (2)**	**$493**
Reduced Screen Velocity to Not Exceed 0.5 fps	**$803,000**	**1521 (3)**	**$528**

(1) Equates to $5,839/pound of fish saved (current biomass estimate is 72.4 Kg/year = 159.6 lb/year)
(2) Barrier net and reduced intake velocity assumed to be 90% effective

(3) Estimated biological performance of 0.5 fps through screen velocity is 75% reduction in impingement mortality

The expected cost per fish saved ranges from $3,338/fish for modified TWS with a fish return to $367/fish for wide-slot cylindrical wedgewire screens based on the current levels of impingement. If average impingement mortality was based on a three year average that included the two current years of sampling and 2006 impingement values for Units 1, 2 and 8 the cost per fish values would decrease by about half (i.e., 52.2%) and range from $1,594/fish to $175/fish. The cost per fish estimates are considered highly conservative since they do not include the additional costs of pilot studies, lost revenue for the barrier net option and the cost of permits and approvals for the barrier net and cylindrical wedgewire screens.

4 HAYNES IMPINGEMENT MORTALITY REDUCTION EVALUATION

4.1 Introduction

This chapter considers the issues, including technical (i.e., engineering) feasibility, costs, biological efficacy and potential studies associated with reducing impingement mortality at Haynes. Based on EPRI impingement mortality reduction technologies research, site visit and facility information provided by LADWP, EPRI has identified five technology options for more detailed evaluation for Haynes.

- Fish-friendly modified TWS with a fish return;
- Modular inclined screens in the intake channel;
- Wide-slot cylindrical wedgewire screens;
- Fixed-panel screens in front of the intake; and
- Reducing the screen approach velocity.

Designs were developed for each of the listed technologies for use at Haynes. The evaluation describes the general deployment, installation and operation of each technology and includes appraisal level capital, O&M, and component replacement costs.

There is some uncertainty in the ability of the selected technologies to be effective under the hydraulic, biofouling, and debris conditions found at Haynes. Information on site-specific pilot studies, including a preliminary layout, study design, and cost were included to address any engineering uncertainties.

4.2 Engineering Evaluation of Impingement Mortality Reduction Technology Options

The following information is provided for each of the five impingement mortality reduction technology options for Haynes:

- a description of the proposed engineering design and issues relative to construction and/or operation;
- expected biological performance;
- necessary studies to confirm performance, feasibility and/or estimated cost; and
- estimated cost for construction, operation and maintenance (O&M) and pilot studies.

Each of the five impingement technology options is discussed, providing a description of the proposed engineering design and issues, expected biological performance, necessary studies and estimated costs. For the expected biological performance evaluation, the current impingement level based on the first year of the new study is used (11,059). The second year of the current study is not used for the evaluation, since Unit 1 that had 82% of the annual impingement was out of service from the end of August through the end of January 2014.

As for Harbor, two classes of technologies are available to reduce impingement mortality at Haynes, exclusion devices/velocity reduction, and collect and transfer and technologies that were described in Sections 1.2.2 and 1.2.3 respectively. The statements focusing EPA's determinations for these technologies discussed in Section 3.2 also apply.

4.2.1 Modified Traveling Water Screens with a Fish Return

4.2.1.1 Description of Engineering Design

The fixed-panel and TWS in the Haynes screen houses can be replaced with coarse-mesh, fish-friendly modified TWS with a fish return. The replacement screens are expected to be 10 ft wide for Units 1 & 2 and 10.9 ft wide for Unit 8. The new screens would include a 0.25 by 0.5 inch smooth-top mesh and each screen basket would have a fish bucket to hold collected organisms in about 2 inches of water while they are lifted to the fish recovery system. A low-pressure spray would gently remove the fish from the fish holding buckets and into a fish return trough. A high-pressure wash would then flush the remaining debris off the screens and into a debris trough. The fish and debris troughs for each CWIS would combine into a single fish and debris trough that would return fish to Alamitos Bay (Figure 4.1). The location for the fish return troughs in Alamitos Bay was selected to prevent organisms from being exposed to the high water temperatures associated with thermal effluent discharge into the San Gabriel River. This conceptual design calls for closing off three of the existing intake bays to increase the distance from the fish return discharge to the intake bays, reducing the potential for re-impingement. Closing off three bays increases the velocity at the intake bays from 0.3 fps to 0.6 fps at the mean lower low water level (El. -2.7 ft).

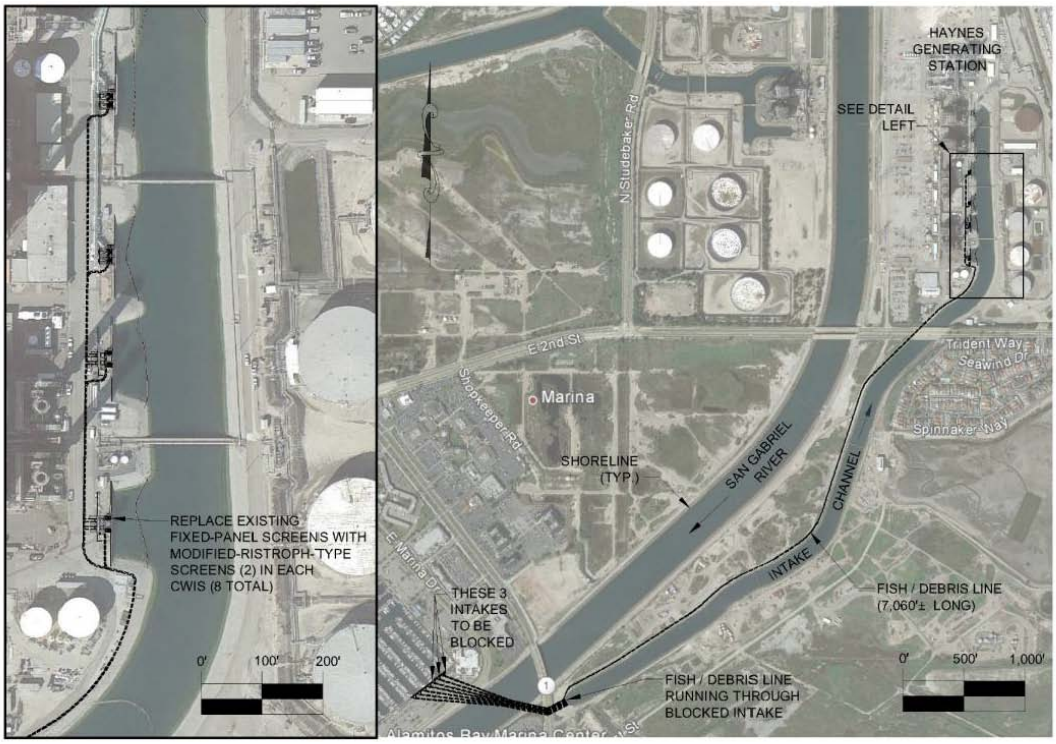

Figure 4.1 – Fish-friendly modified traveling water screens at Haynes

Necessary design features of a fish return system include the following:

- a smooth return trough with no sudden changes in flow direction;
- a cover to prevent predation by birds and mammals;
- sufficient velocity to prevent habitation by predatory species; and
- sufficient water depth to cover the fish.

These features were included to reduce the stresses on and predation of impinged organisms as they are transported back to the Alamitos Bay. The fish return was designed to operate under all potential water levels. In addition, the discharge location was selected to return impinged organisms where they are not likely to re-impinge and will not be exposed to the warm water plume. Macro-fouling of the fish return can be an issue. Therefore the design calls for installation of a redundant return line allowing one line to be taken out of service for cleaning (see Section 4.2.1.3.2). The cost estimate for this alternative assumes that a redundant return line would be used.

The existing fixed-panel and TWS would be removed in order to install the new modified-TWS. The Unit 1 & 2 screen houses are not designed for TWS and would require structural changes to accept the new screens. New screen wash pumps would be installed in each screen house. High- and low-pressure screen wash pumps would be needed for Units 1 & 2. Only new low-pressure spray wash pumps are expected to be needed for Unit 8, because the existing high-pressure spray wash pumps should be compatible with the new screens. No changes would be needed to the circulating water pumps. Replacement of the existing screens is expected to take approximately two weeks per screen and can be conducted during scheduled maintenance outages eliminating the need for additional shutdowns. The new fish return lines would be constructed prior to the installation of the new screens. The capital cost of installing the new screens and fish return for all three units is expected to be $18,767,000, including modifications to the entrance to the intake tunnels. Adding modified TWS to the Units 1 & 2 intakes would cost $9,739,000. Retrofitting the Unit 8 intakes would cost $8,813,000. Modifications to the entrance of the intake tunnels would cost an estimated $ 215,000.

Maintenance of the new modified-TWS would be similar to the existing Unit 8 screens. The screens would be rotated and cleaned continuously to reduce impingement duration and improve organism survival. Continuous operation of the screens, auxiliary pumps, and screen wash pumps would require approximately 6,990 MWh, per year. Continuous screen rotation increases the stress and wear on screen components, requiring increased man-hours to inspect, maintain, and repair the screens. For this evaluation, it was assumed that screens would be inspected daily with a thorough inspection and lubrication conducted at least annually. These maintenance tasks are expected to require 2,254 man-hours per year. It was also assumed that the screens would require a complete overhaul or replacement every three years. The actual maintenance schedule should be based on operating experience with the existing screens and adjusted with increased experience with the new screens.

The fish and debris return lines should be regularly inspected. Obstructions or macrofouling and any damaged sections that could interfere with the safe return of organisms should be removed or repaired. O&M on the fish and debris return systems is expected to require regular switching between return lines to prevent biofouling and pigging or plunging to remove any attached debris. These efforts are expected to require 1,306 man-hours or more per year depending on the number of times the return pipes need to be cleaned.

4.2.1.2 Expected Biological Performance

As noted, the biological performance of modified TWS with a fish return is highly variable and is very much affected by the species being protected. The same two sources of information discussed for Harbor in Section 3.2.1.2 were considered in making BPJ estimates of performance for Haynes. These estimates are provided in Table 4.1. For the species of Concern, which make up 91% of the annual impingement, it is estimated that potential reduction of 12% in impingement mortality can be achieved. For the purpose of this analysis, for Haynes, only the first year of the study were used since Unit 1 that accounts for the majority of the impingement was out of service for a four month period of historically higher impingement. The six months of data for the second year of sampling in the current study suggests that results of the second year are comparable to the first year. Based on the current level of impingement, use of modified-traveling water screens with a fish return would result in an estimated 1,232 species of Concern saved annually. For the remaining 845 non-species of Concern it is assumed that 50% or 423 fish will survive for the purpose of the cost versus performance comparison. If a three years average that included the 2006 data, the estimated survival might be 37.8% higher. For Haynes the estimates are considered conservative given the relatively long transport distance to Alamitos Bay and the risk that some fish are likely to be re-impinged either at Haynes or the Alamitos Generating Station, since the cooling water flows of these two facilities dominate the current in Alamitos Bay. A pilot study to reduce the uncertainty of these estimates is discussed in Section 4.2.1.3.1.

Table 4.1 – Estimated impingement survival if modified traveling water screens with a fish return was installed at the Haynes Generating Station. Estimates are based on year 1 of the current study due to Unit 1 being out of service for four months during a period of higher potential impingement.

Species	Current Avg. Annual Impingement	Estimated % Survival	Estimated # of Fish Surviving
Queenfish	9,629	10%	963
Northern Anchovy	221	15%	33
Bay Pipefish	268	70%	188
Topsmelt	96	50%	48
Total Species of Concern	10,214		1,232
Other Species	845	50%	423
Total Impingement	11,059		
Total Estimated Survival			1,655

4.2.1.3 Uncertainties and Pilot Studies

This section discusses several pilot studies that could be conducted to reduce uncertainties associated with use of modified TWS. These include a pilot study to better estimate survival rates for species of Concern and a study to optimize the fish return system.

4.2.1.3.1 Biological Performance Study

As was the case for Harbor there is uncertainty around the estimated survival rates and the best means to reduce that uncertainty would be to conduct an impingement survival study using a test screen. A description of the methods and cost for such a study are provided in Appendix B. The study would require the following three components to evaluate survival at each stage of the system:

1. Impingement sampling to collect fish for testing off the TWS and to evaluate impingement survival;
2. Impingement sampling at the point of return of fish to the source waterbody to allow quantification of fish survival following transport; and
3. A study of latent mortality study to evaluate survival after 96 hours.

The cost to install a test screen is estimated to be $734,000, while the cost to perform the biological evaluation of screen performance is estimated to be approximately $291,500. (Appendix B). The combined cost of the test screen and the biological testing is $1,025,500. The test screen can be used as a permanent replacement for one of the Unit 1 fixed-panel screens.

4.2.1.3.2 Fish Return Optimization

Fish survival can be adversely affected if the fish return trough is not properly designed or the discharge is not properly located. BPJ was used in selecting the discharge point. However, because the discharge point is located within Alamitos Bay, re-impingement could be an issue due to Haynes and Alamitos Generating Station cooling water flows dominating the current in Alamitos Bay. Studies may be required to better locate the fish return discharge. One approach would be to release dead, dyed fish at the point of fish return discharge and monitor to the movement of the fish return to determine the likelihood of re-impinged. Costs for this type of study could be up to $130,000. Alternatively, a numeric [computational fluid dynamics (CFD)] model could be developed to estimate the probability of re-impingement (see below).

A hydraulic analysis of the fish return would be needed prior to construction to ensure the water depths and velocities are sufficient to safely transport fish and debris back to Alamitos Bay. A one-dimensional hydraulic model should be sufficient to accurately model the fish return. This type of study is expected to cost between $5,000 and $15,000 depending on the complexity of the model and number of iterations needed to achieve the desired flow conditions.

4.2.1.3.3 Hydraulic/Physical Modeling

As referenced above, a CFD model could be developed to optimize the fish return location. In addition, any screen replacement can have a direct effect on intake hydraulics (e.g., head loss, vortices) and circulating water pump performance (i.e., pump submergence). This is not expected to be an issue if the screens are replaced in-kind (i.e., through-flow to through-flow) but may be needed if the existing screens are replaced with a different type of screen (i.e., through-flow to dual-flow, center-flow, WIP, MultiDisc). An assessment of effects using a CFD or physical model may be required if any potential hydraulic issues are identified. Costs for these types of studies are very site-specific and are expected to range from $70,000 to $130,000 for a CFD model and $50,000 to $250,000 for a detailed physical model of the intake.

4.2.2 Modular Inclined Screens

Modular inclined screens (MIS) is a fish diversion system that was developed to guide fish into a bypass at high velocities. The idea came from the Eicher Screen used to bypass fish at hydroelectric facilities. To date it has never been deployed at a power plant. However, EPRI sponsored a laboratory and pilot-scale studies in the 1990s, which demonstrated high bypass efficiency and survival of various species of fish. No testing with complete with the species of Concern at Haynes.

4.2.2.1 Description of Engineering Design

A MIS module consists of a square entrance, upstream and downstream de-watering gates, an inclined screen set at a shallow angle (10 to 20 degrees) to the flow, and a bypass for directing diverted fish to a transport pipe. The module is completely enclosed and is designed to operate at relatively high water velocities ranging from 2 to 10 fps, depending on species and life stages to be protected.

Three MIS units could be installed in the intake channel, about 100 ft downstream from the end of the intake pipes. Each module would have an 8 ft square opening, perpendicular to the intake flow, as shown on Figure 4.2. The average approach velocity to the screen would be 4.1 fps, at the current design flow rate. This flow is based on the combined circulating water (784 cfs) and bypass flow (47 cfs). At this velocity the head loss through the screen would be less than 1 ft with a clean screen. The fish bypass would be located at the downstream end of the screen.

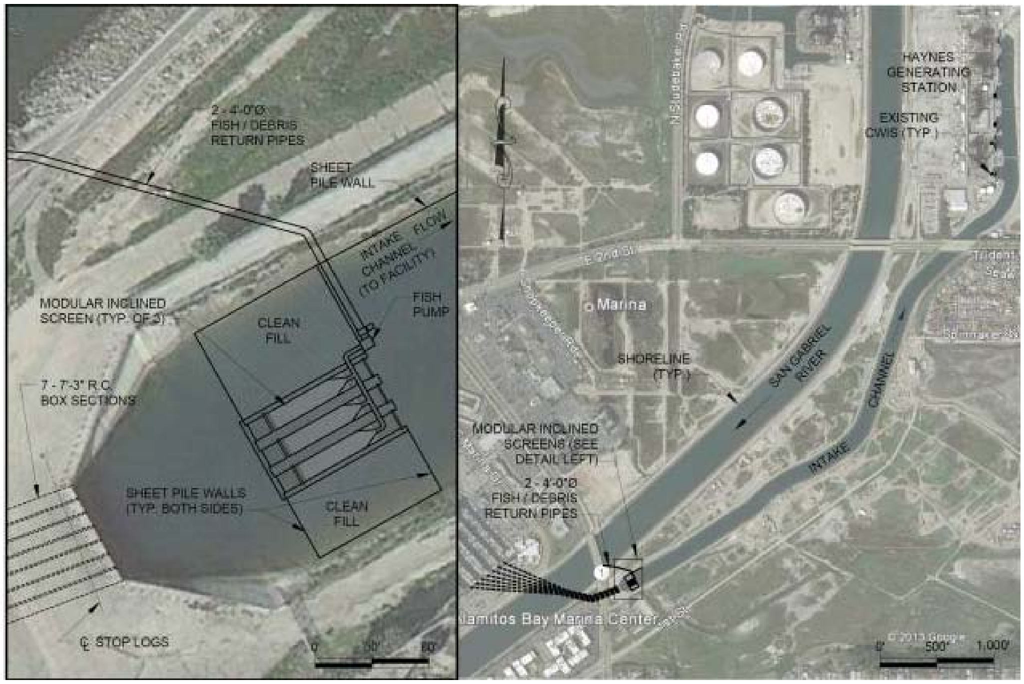

Figure 4.2 – Modular inclined screens at Haynes

The modules would include an 8 ft wide by 36 ft long rectangular screen. The screen would be inclined in the downstream direction at an angle of 15 degrees from horizontal. The screen material would be wedgewire, with the screen bars arranged parallel to the flow direction. The screen panel would have a uniform porosity of 50%, with a 2 mm clear bar spacing along its entire length. The screen would be made out of a copper nickel ally to prevent biofouling of the screen. A steel frame designed for a 5 ft differential pressure would support the panel. The screen would be rotated to backwash debris from the screen face.

The fish bypass entrance at the downstream end of the screens would transition into a 3 ft diameter pipe connected to a large “fish-friendly” pump. The pump would regulate bypass flow to 47 cfs (15.7 cfs per module). The velocity in the bypass pipe would be about 6.7 fps, preventing fish from swimming against the flow. The fish pump would also provide the head needed to return the bypass flow to Alamitos Bay. Alamitos Bay was selected to avoid exposing impinged fish the thermal discharges of Haynes and Alamitos Generating Stations and low salinity and poor water quality conditions associated with storm events during some portions of the year.

Cleaning of the screens would be necessary to reduce adverse impacts on facility operations resulting from debris accumulation (additional head losses) and to maintain the fish diversion efficiency of the screens. The screen section would be rotated allowing the plant flow to backwash the screens. Backwashing of the screens would be conducted daily or when the head loss across the screens reaches a prescribed level. The existing screens would remain in place to prevent the backwashed debris from entering the Units 1, 2 and 8 circulating water systems. Monitoring and cleaning of the screens and bypass pipe would require about 2 hours per day. Additional operation and maintenance efforts associated with operating the fish bypass pump would require 1,117 MWh per year. A manual inspection and cleaning of the screen may be required every year. The screens would be dewatered and cleaned one at time eliminating the need to shutdown the station. When one MIS is out of service for cleaning the velocity approaching the remaining two screens would be 6.1 fps.

Installation of the MIS units could be sequenced to reduce impacts to station operations. First, the MIS units would be fabricated onshore. Modification of the intake channel, installation of the sheet pile walls and the fish bypass system would be constructed concurrent to the screens. Once the MIS are built, they would be floated into place and connected to the fish bypass system. Haynes may need to be shutdown while the screens are installed. Installation of the three MIS is expected to cost approximately $7,570,000.

4.2.2.2 Expected Biological Performance

Current biological performance information on the MIS is limited to laboratory and field testing conducted during the development of the technology. MIS performance is considered better than that achieved by modified TWS, since no impingement on screens is involved and fish remain submerged under water at all times in the process of transfer from the MIS back to the source waterbody. Based on these factors and the information discussed in Section 3.2.1.2, Table 4.2 indicates the BPJ estimate of performance for the species of Concern. These estimates are believed to be very conservative since the returned fish transported to Alamitos Bay are potentially subject to re-impingement at either the Haynes or Alamitos Generating Station intakes. For the species of Concern that make up 91% of the annual impingement, it is estimated that a 32% reduction in impingement mortality can potentially be achieved or a total of 2,126 fishes from the species of Concern saved annually. For the remaining 640 other fishes, it is assumed that 50% or 320 fish will survive for the purpose of the cost versus performance comparison. A pilot study to reduce the uncertainty of these estimates is discussed in Section 4.2.2.3.

Table 4.2 – Estimated impingement survival if modular inclined screens with a fish friendly pump were installed at the Haynes Generating Station

Species	Current Avg. Annual Impingement	Estimated % Survival	Estimated # of Fish Surviving
Queenfish	9,629	30%	2,889
Northern Anchovy	221	30%	66
Bay Pipefish	268	85%	228
Topsmelt	96	75%	72
Total Species of Concern	10,214		3,255
Non Species of Concern	845	75%	634
	11,059		
Total Estimated Survival			3,889

4.2.2.3 Uncertainties and Pilot Studies

There is no operating experience with a full-scale operational MIS system at a power plant intake. The only field data available is from the Green Island Hydroelectric Project on the Hudson River near Albany, New York. This technology has also not been deployed in the marine environment and therefore there are additional uncertainties regarding its potential performance at Haynes. Prior to moving forward with this technology a prototype evaluation of the MIS is needed to determine both its engineering and biological effectiveness. Thus both biological performance and debris and biofouling issues would be address simultaneously. The cost of the equipment to conduct this type of study is estimated at $2,000,000 which includes a full-size screen along with all the necessary pumps. The cost for the biological assessment could be as high as $320,000 depending on the magnitude and duration of the study.

4.2.3 Not Exceeding 0.5 fps Intake Velocity Using Cylindrical Wedgewire Screens

4.2.3.1 Description of Engineering Design

Cylindrical wedgewire screens are designed to provide a through-slot velocity of less than 0.5 fps. The wedgewire screens proposed for Haynes would be divided between the four screen houses. Units 1 & 2 would each use three 84-inch (7-ft) diameter tee-shaped screens and the two Unit 8 screen houses would each be equipped with three 78-inch (6.5-ft) diameter tee-shaped screens. One additional screen per new intake was included in the design to allow one screen to be lifted to the work deck and cleaned without having the remaining screens exceed a through-slot velocity of 0.5 fps. The cylindrical wedgewire screens would use copper-nickel alloy V-shaped wires with 0.375 inch slot openings which will exclude impingeable-sized organisms from the circulating water flow. Copper-nickel alloy was selected to inhibit biofouling growth.

For wedgewire screens to function efficiently a sweeping current is needed to transport fish and debris past the screens. A bypass flow of approximately 700 cfs would be needed to create a 1.0

fps velocity at the last screen. This flow can be created at Haynes by installing “fish-friendly” bypass pumps in the Units 5 & 6 screen houses. The TWS in the Units 5 & 6 screen houses would be removed allowing larger organisms to be transported out of the intake channel. The bypass flow would be pumped into the San Gabriel River. This may result is some thermal stress to bypassed organisms because the river serves as the discharge canal for both Haynes and Alamitos.

The wedgewire screens would be mounted to a bulkhead wall constructed in front of their respective screen houses. A bulkhead-mounted layout was selected over pipe-mounted screens to allow the screens to be removed for cleaning. The new bulkhead wall for each screen house would span the mouth of the small embayments in front of the existing screen houses. The bulkhead structures would be 25 ft wide providing adequate space for screen lifting and cleaning. The proposed layout of the system is provided in Figure 4.3.

Figure 4.3 – Wide-slot wedgewire Screens at Haynes

The primary method to clean the screens would be an air-backwash. Debris removed from the screens during the air-backwash would flow to the bypass system where it will be transported to the San Gabriel River. Supplemental manual cleaning of the screens on the bulkhead deck is also recommended to remove any biofouling and to inspect the screens. The air-backwash system, including air compressors, air receivers, and control system, would be housed on the work decks. A high-pressure spray wash system including a high-pressure pump would also be integrated into the work decks. Mechanical winches, one per screen, would be required to lift the screens to the work decks for cleaning.

Emergency bypass gates are included as part of the proposed wedgewire design to ensure adequate circulating water should the cylindrical wedgewire screens plug. The existing TWS would be retained and maintained in an operating condition to prevent debris from entering the circulating water system if the bypass gates are opened.

Head loss through the screens should not exceed 1 ft (assuming clean screens). Except for the slightly lower water level at the circulating water pumps, flow patterns approaching the circulating water pumps would not change.

Installation of the new wedgewire screen arrays and modifications to the retired Units 5 & 6 intakes would be completed over several years. Prior to installing the wedgewire screens the bypass structures in the Units 5 & 6 intakes and bypass piping should be installed. LADWP should investigate using the existing Units 5 & 6 circulating water piping to reduce the costs of the bypasses. The Units 5 & 6 condensers would need to be bypassed or removed if the existing piping is used. The bulkhead walls can be constructed concurrent to the bypass structures. Once each bulkhead wall is complete, the air-backwash and spray wash and screen lifting systems would be installed. The final step would be to install the wedgewire screens. No modifications would be needed to the existing fixed-panel, TWS, and circulating water pumps. The total capital cost to add wide-slot wedgewire screens to Haynes is expected to be $31,651,000, including $10,000,000 for the bypass system. Each unit would be shut down for 4 to 6 months during the construction of the bulkhead walls and the final tie-in and inspection.

The design incorporates both automatic and manual cleaning systems for the screens. The primary cleaning method would be an automatic air-backwash system. The air-backwash frequency cannot be determined without a better understanding of the debris loading rate. Each screen could also be raised and manually cleaned with the high-pressure spray wash system to remove attached biofouling and to inspect the screen. It was assumed that the air-backwash system would be operated once daily requiring approximately 110 MWh and 2,920 man-hours per year to monitor, operate, and maintain the air supply equipment. Manual cleaning would be conducted once per month and is expected to take approximately 2,880 man hours and require 2.2 MWh annually to operate the high-pressure spray wash system. Operation and maintenance on the bypass structures would require 5,256 MWh and 850 man-hours. In addition, an annual diver inspection was included to identify any damage that could affect plant operations and to remove any debris that has accumulated around the screens. Each inspection is expected to take a three man dive crew approximately 4 days.

4.2.3.2 Expected Biological Performance

The high level of performance estimated for Harbor for this technology would not be achieved at Haynes. There are two issues that prevent higher performance. First, fish pulled through the Unit 5 and 6 bypass pumps will be exposed to the thermal effluents of Haynes and Alamitos Generating Stations in the San Gabriel River resulting in some additional mortality, especially during the hot summer months, as well as poor water quality conditions and low salinity that occur during storm events. Additionally, use of the Unit 5 and 6 pumps will result in entrainment of additional fish eggs and larvae into the intake channel and exposure to thermal discharges and poor water quality conditions. For the purpose of this evaluation it is therefore assumed that impingement mortality would be reduced by 80% rather than the 100% assumed for Harbor. No estimate is made of the additional entrainment mortality for entrainable life stages.

4.2.3.3 Uncertainties and Pilot Studies

Several pilot studies are discussed to address uncertainties associated with operating the screens and ensuring good performance. These include a fouling and debris study to verify that the air burst system can control fouling and debris; modeling to ensure flow through the screens is balanced and a study to evaluate survival of fish that by-pass the screens and are transported to the San Gabriel River.

4.2.3.3.1 Debris and Biofouling Evaluation

Prior to installing cylindrical wedgewire screens, a pilot study is recommended to ensure that the screens can be maintained in a clean condition under normal operating conditions. The pilot study could be conducted using small tests screens in a location with similar hydraulic, sediment, bio-fouling and debris conditions to the proposed deployment location. The duration of the study would be dictated by seasonal changes to the water level and the quantity and type of debris experienced at Haynes. Head loss across the test screens would be the primary indicator of screen cleanliness. The head loss should be measured for the screens under clean condition (baseline condition) and then monitored during the study. Photographs of the screens could be taken to determine the debris and bio-fouling type and the effectiveness of the screen cleaning system. Other parameters including water temperature, air temperature, turbidity, wind direction/magnitude, and current direction/magnitude could be included as part of the pilot study to gather data that could be used to evaluate their possible use for predicting periods of heavy debris loading. The costs to conduct this study could range from $80,000 to $612,000 depending on the design of the test rig(s), testing duration, and parameters measured.

The assumption at the low end of the range (i.e., $80,000) is that a single small cylindrical screen unit would be deployed with a pump of sufficient size to generate flow through the screen that would simulate flow with a full-sized screen. The data provided from such a study would reduce the uncertainty as to the time interval between cleanings. However, for that cost, the screen would be cleaned manually and provide no data on the frequency or effectiveness of an air burst or other system (mechanical) to remove debris and biofouling. At the high end cost (i.e., $612,000), a larger screen and pump would be deployed along with a debris and biofouling control system. Sampling would take place over the course of a year and would require divers or the ability to remove screens from the water for observation. Such a study would provide the information necessary to reduce the risk that wedgewire screens could not be operated and maintained, as well as the need for and cost of manually cleaning.

4.2.3.3.2 Hydraulic/Physical Modeling

Hydraulic model studies (numeric and/or physical) are recommended to balance the flow through the screens and determine if there is any impact to circulating water pump operations. Cost for these studies could range from about $20,000 for a simple two-dimensional numeric study to about $200,000 for both three-dimensional numeric and physical models.

4.2.3.3.3 Bypass Study

Fish survival can be adversely affected if the fish return trough is not properly designed or the discharge is not properly located. Exposing fish to the thermal discharges should fish be returned to the San Gabriel River or the potential for re-impingement if fish are returned to the Long Beach Marina are the primary issues of focus. BPJ was used in selecting a discharge point. However, the location(s) have not been optimized and studies may be required to do so. LADWP should conduct a study to evaluate the feasibility of using the existing Units 5 & 6 circulating water piping for fish bypasses. Additionally, thermal modeling of the San Gabriel River near the station could be conducted to determine the travel time and thermal mixing that would occur under different ambient and operating conditions. The estimated cost for a San Gabriel River survival study is approximately $84,000 (see Appendix B).

4.2.4 Not Exceeding 0.5 fps Intake Velocity Using a Fixed-panel Screen

4.2.4.1 Description of Engineering Design

It may be possible to install fixed-panel screens with 3/8 inch openings at the face of the seven intake openings along the bulkhead wall adjacent to the Long Beach Marina. This option would allow LADWP to meet the 0.5 fps velocity criterion, and eliminate the need to transport impingeable-sized organisms from the intake channel back to Alamitos Bay.

Flat-panel wedgewire screens were assumed for this design. The screens would be made out of a copper-nickel alloy to inhibit biofouling growth, similar to the cylindrical wedgewire option. Flat-panel wedgewire was selected over woven mesh screens because it provides a flat surface that is easier to clean. These screens would replace the existing trash racks. A total of 36, 10 ft by 7.5 ft panels with 4 inch wide framing were assumed for this design. The location of the intake bays is shown on (Figure 4.4). One extra panel is included in the design to allow the panels to be swapped out during cleanings while preventing fish and debris from entering the intake channel.

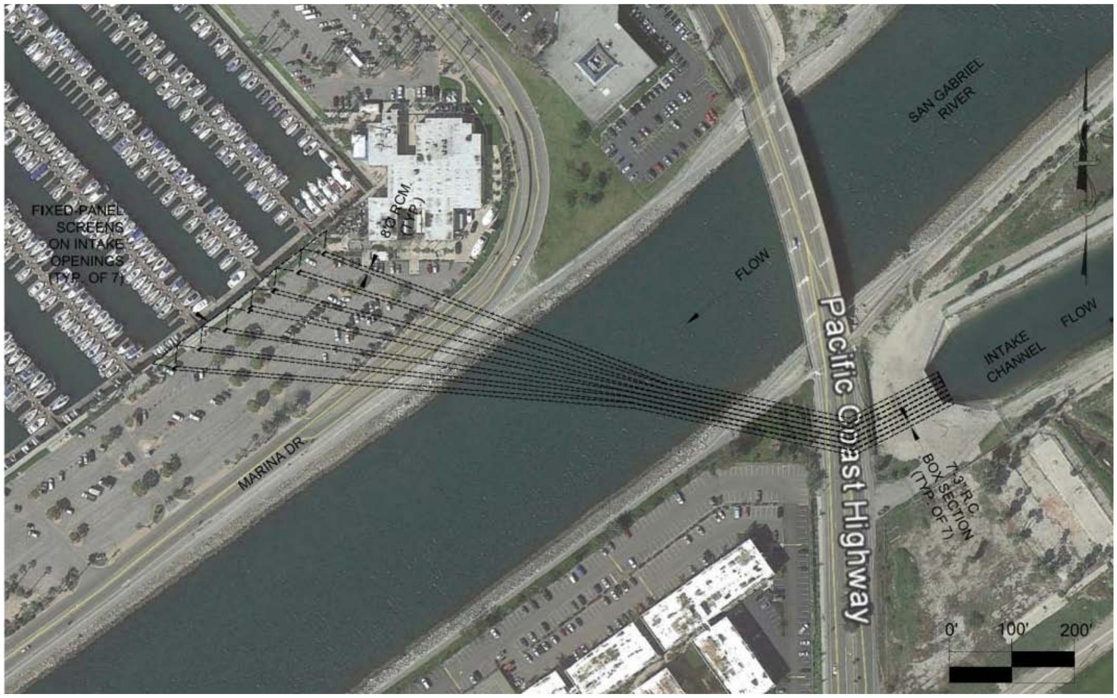

Figure 4.4 – Fixed-panel screens at Haynes

The velocity at the face of the intake bays is estimated to be 0.3 fps at the lower low water levels (El. -2.7 ft) and full plant flow (784.3 cfs). The 0.375 inch wedgewire mesh is estimated to have an 81% open area and the screen frames a 92% open area. These assumptions result in a 75% net open area for the new screens. Based on this open area the fixed-panel screens would have a through-mesh velocity of approximately 0.4 fps.

Retrofitting the intake bays with fixed-panel screens can be completed without impacting station operations. Cooling water pump flow through the intake tunnel would be turned off during construction as a safety measure for the divers removing the trash rack and installing the new screens. Construction efforts would have to be coordinated with the owners of the Long Beach Marina. Assuming that that the face of the intake openings can be accessed from shore, the installation of fixed-panel screens would cost approximately $4,311,000.

A manual cleaning of the screens would be conducted by lifting the screen panels and removing the debris with brushes or high-pressure spray washes. A movable hoist on the sea wall would be used to lift the screens. Several screens panels would be designed to break away at a predetermined head loss across the screens. This safety feature would reduce potential operating issues during heavy debris loading periods. The frequency of screen cleanings would depend on debris loading at Haynes, however for this evaluation it was assumed that the screens would be inspected daily and cleaned every four days, requiring 6,370 man hours and 4.1 MWh.

4.2.4.2 Expected Biological Performance

Reducing the velocity at the face of the intake to not exceed 0.5 fps through the fixed panel screen would prevent impingeable-sized organisms from entering the intake channel. However, there would continue to be some level of impingement because entrainable sized fish could pass through the screens and grow to a size where they could become impinged (see Section 3.2.4.2). For the purpose of the evaluation a 90% reduction in impingement mortality is assumed. Due to the amount of fish habitat in the intake channel this is believed to be a very conservative estimate.

4.2.4.3 Uncertainties and Pilot Studies

4.2.4.3.1 Debris and Biofouling Study

Prior to moving forward with a fixed-panel screens option, a pilot study would be necessary to verify that the screens can be maintained in a clean condition under normal operating conditions. Some of the uncertainties associated with installing these screens at Haynes include, but are not limited to, debris accumulation biofouling and cleaning. A pilot study could be conducted by replacing one of the existing trash racks with a fixed-panel screen to determine the rate and size of debris collected on the screen face and to determine an effective cleaning method and schedule. The duration of the study would be dictated by seasonal changes in the quantity and type of debris experienced at Haynes. Underwater videography or photographs of the screen face could be used to determine the debris and biofouling type, the effect on head loss, and the effectiveness of the screen cleaning system. Other parameters including water temperature, air temperature, turbidity, wind direction/ magnitude, and current direction/magnitude could be included as part of the pilot study and may be of value for predicting periods of heavy debris loading. The costs to install a fixed-panel screen in a single bay would be $186,000. The cost for conducting the test is expected to be approximately $80,000 to $170,000 depending on the testing duration, and number of cleanings and inspections.

4.2.4.3.2 Access to Alamitos Marina Property for Fixed Panel Screen Maintenance

A major focus for this option is that LADWP does not own the property in the Long Beach Marina above the intake or the marina itself. Use of this property or the area above the seawall must be made available to remove debris and control biofouling. Cleaning also requires use of high pressure hoses and will create debris in the cleaning area. The location of the wall section in the marina where the Haynes intake is located is shown in Figure 4.5. The intake below the wall extends from approximately the top side of the first boat dock pier in the bottom left hand corner of the photograph to the bottom of the fourth pier in the upper right hand corner of the photograph. Deployment of a screen lifting hoist at the top of the seawall above the intake opening will interfere with the roadway for boat access. Use of the marina dock for cleaning may interfere with access to the marina piers. Therefore, the Marina and boat owners are likely to strongly oppose this option due to reduced space for boat dockage, safety issues, interference with the existing road and walkways for boat access along the marina wall and cleaning debris that would be generated.

A potentially additional significant cost associated with this alternative is permitting and negotiating with the Long Beach Marina. Should the Marina agree to allow this option there would likely be a cost to compensate the Marina for the lost revenue for use of slip space and to reconfigure access to the piers. Those costs are not included in the cost estimates discussed in Section 4.3.

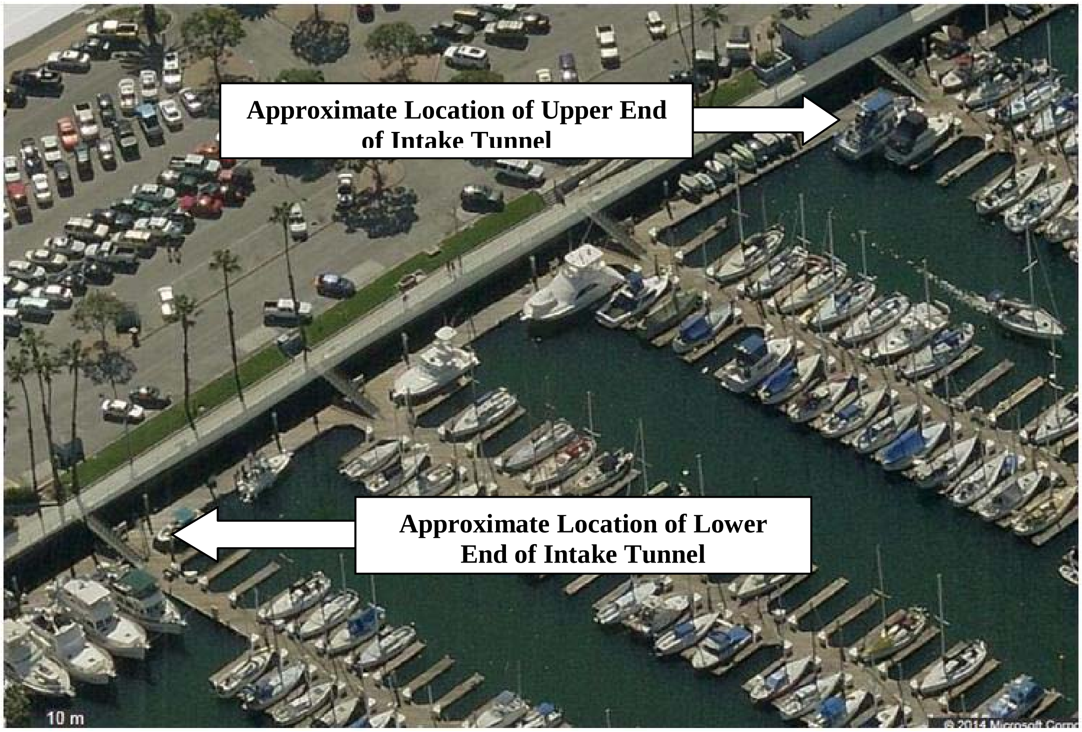

Figure 4.5 – Alamitos Bay Marina showing wall section below which is the Haynes cooling water intake.

4.2.5 Not Exceeding 0.5 fps Intake Velocity Using Modified Traveling Water Screens in Expanded Intakes

4.2.5.1 Description of Engineering Design

At Haynes the actual benefit of reducing the screen approach velocity is not clear. While the velocity would be reduced near the screens, fish may not be able to escape from the intake due to the velocities in the intake tunnels between the intake opening in the Alamitos Marina and head of the intake channel on the other side of the San Gabriel River. Two methods to expand the screening area were considered, expanding the existing screen houses or constructing new screen houses in front of the existing ones. Expanding the screen houses involves replacing the circulating water pumps with new smaller pumps and modifications to the circulating and service water piping. The costs associated with these changes, including forced outages during construction, are expected to be higher than those associated with new screen houses in front of the existing ones; therefore, a layout using new screen houses was considered a less expensive alternative. The new screen houses were designed for dual-flow TWS to reduce the number of screens required as well as the size of the new intake and to eliminate debris carryover.

Each of the four active screen houses at Haynes would be replaced with a new screen house. The new screen houses for Units 1 & 2 would require four (4) screens with a bottom invert at El. -17.0 ft. The two Unit 8 screen houses would each have four (4) screens with a bottom invert of

El. -15.0 ft. The inverts of the Units 1 & 2 and Unit 8 screen houses differ to minimize the size of the screens while still achieving a through-screen velocity of less than 0.5 ft/sec. All of the screens in the new screen houses would be 10 ft wide dual-flow screens equipped with fish protection features. These features include a smooth woven mesh, fish buckets, a low-pressure fish spray wash and a high-pressure debris sprays wash. A 0.25 inch by 0.5 inch smooth woven mesh was selected for the new screens because this mesh is used on state-of-the-art modified-TWS.

The four new screen houses would each be 53 ft long and located 35 ft in front of their respective screen house. The locations of the new screen houses are shown on Figure 4.6. Trash racks are not included in the new screen houses because the trash racks located at the intake openings prevent large debris from entering the intake channel. The new screen houses would include a fish return system to return fish back to Alamitos Bay, near the existing intake bays. This discharge location was selected over discharging the fish return to the San Gabriel River to reduce the potential for thermal stress on impinged organisms. For this design, three of the existing intake bays were sealed off to reduce potential re-impingement. Sealing off three bays would increase the velocity at the face of the operating bays to 0.6 ft/sec. A work deck over the plenums between the new and old screen houses would prevent debris from entering the plenums allowing the existing screens to be removed. Construction for this option can be sequenced to limit construction-related outages; however, each unit may need to be shut down for several weeks during the final tie-in. The capital cost of increasing the screening area and adding a fish return for all three units is expected to be $31,651,000, including modifications to the entrance to the intake tunnels. The cost to expand the screen houses and add modified TWS for Units 1 & 2 is estimated to be $15,948,000. Retrofitting the Unit 8 intakes would cost $15,491,000.

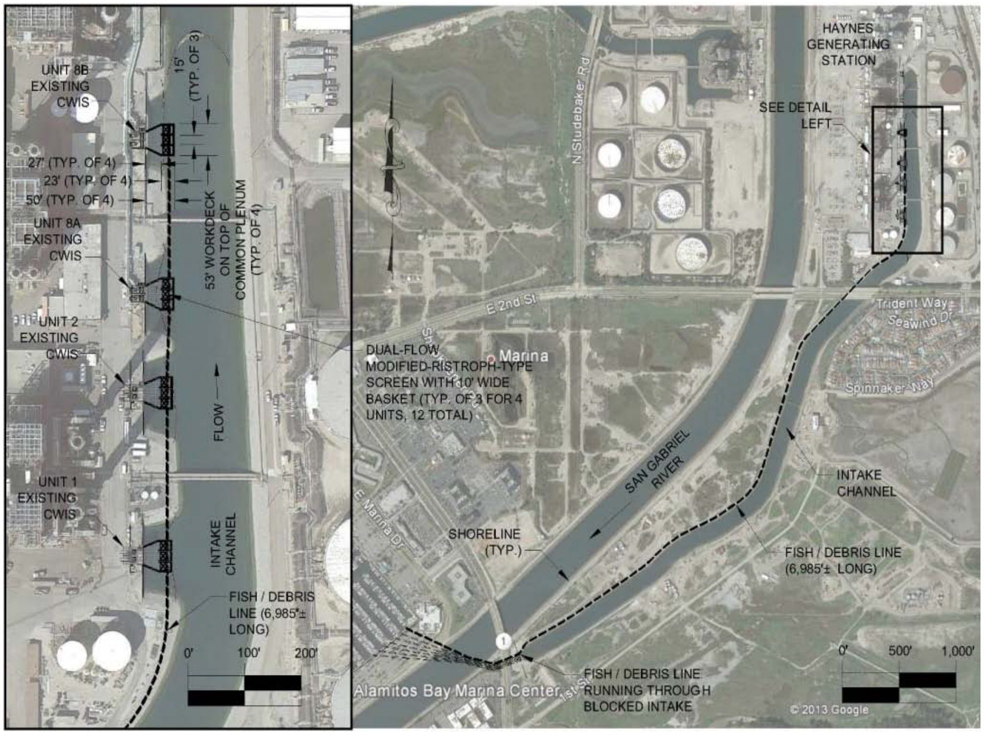

Figure 4.6 – Fish-friendly modified traveling water screens in expanded intakes at Haynes

The new screens would be rotated and cleaned continuously, minimizing debris loading and reducing impingement duration. The power requirements for continuous operation of the screens, auxiliary pumps, and screen wash pumps is estimated to be approximately 10,486 MWh, per year. Fish and debris removed from the screens would be transported back to the bay outside of the intake channel where the potential for re-impingement is low. Fish-friendly pumps are included in the fish return design because of the fish return length (~7,000 ft). The new fish return would incorporate all the features detailed in Section 4.2.1.1. For this evaluation, it was assumed that the screens would be inspected daily and be thoroughly inspected and lubricated annually. These maintenance tasks are expected to require 3,382 man-hours per year. It was also assumed that the screens would require a complete overhaul or replacement every three years. The actual maintenance schedule should be based on operating experience with the existing screens and adjusted with increased experience with the new screens. Inspection and cleaning of the fish return line is expected to require 1,960 man-hours or more per year depending on the number of times the return pipes need to be cleaned.

4.2.5.2 Expected Biological Performance

As discussed in Section 1.2.2 and shown in Figure 1.1, not exceeding a velocity of 0.5 fps is highly protective of fish and would virtually eliminate impingement of fish at the TWS. However, as discussed in Section 3.2.4.2 for Harbor, if there are higher velocities upstream in the intake, entrapment can be an issue. The velocities in the Haynes intake tunnel leading from Alamitos Bay to the head of the beginning of the intake channel would exceed this velocity (intake tunnel velocities calculated to be 2.2 fps) and could result in fish entrapment for the small juvenile fish that dominate the impingement samples. Entrapped fish would likely be lost to the fishery and ultimately end up being impinged on the screens, regardless of the low through screen velocity. For the cost-biological performance comparison the assumed level of biological performance is 90%. This is considered highly conservative since it is unlikely based on the current intake tunnel velocities that would prevent escape from the intake channel and return to the source waterbody.

4.2.5.3 Uncertainties and Pilot Studies

There is uncertainty associated with biological performance due to fish entrapment in the intake channel. The 2.2 fps intake tunnel velocities are likely to exceed the swimming ability of small juvenile fish that dominant the impingement to return to the source waterbody. At this point it is unclear whether fish such as queenfish can live in the canal and grow to a size where they can exit the tunnel. No pilot studies are suggested.

4.3 Evaluation of Cost and Performance

This section provides the capital, O&M, component replacement cost as well as the annualized cost for comparison to the expected performance. Costs are discussed in Section 4.3.1, while the comparison of cost to performance is discussed in Section 4.3.2.

4.3.1 Cost of Impingement Mortality Reduction Technologies

The capital and O&M costs for Haynes are based on the same assumptions as Harbor and have a confidence interval of +/- 30%. The amortization period for Haynes is 10 years (2020-2029) because the current Policy schedule calls for Haynes to be in compliance by no later than December 31, 2029 and LADWP plans to have converted to dry cooling by that date.

The basis of the cost estimates is the same as those used for Harbor but are restated here. O&M cost estimates were based on preliminary estimates of the labor and power requirement of each technology. O&M estimates were monetized using a labor cost of $46.20 per hour, that reflects the cost for a skilled worker, and a replacement power cost of $35.00 per MWh. Component replacement costs were estimated by dividing the direct technology cost by the estimated service life. As with the capital costs, the O&M and replacement costs are preliminary in nature and would have to be refined based on detailed assessment of each technology and the results of any engineering pilot studies.

Costs for each technology were annualized to allow them to be compared to their annual benefits. The total annual costs include the capital costs annualized over the life of the project, annual O&M, and annual component replacement costs. The capital costs were annualized over a 10 year period (2020 to 2029) using a 7% discount rate. A 20 year amortization period was used because in 2029 Haynes will have been retrofitted to dry cooling and the screens would no longer be needed. All costs for the technologies evaluated, including the annualized costs associated with each technology evaluated for Haynes are presented in Table 3.3

For Haynes the costs for modified TWS with a fish return were estimated for all the Units/Intakes as well as just for Units 1 and 2. This was done since just less than 99% of the impingement takes place at Units 1 and 2. However, since there is a risk that after modifying the

Unit 1 and 2 screens impingement at Unit 8 would significantly increase, those costs need to also be considered.

Table 4.3 – Haynes cost summary

Technology	Capital Cost	O&M Cost	Component Replacement	Annualized Cost
Coarse Mesh Modified Traveling Water Screens	$18,767,000	$410,000	$4,497,000	$7,579,000
Coarse-mesh Modified Traveling Water Screens (Units 1 & 2 with Intake Modifications)	$9,954,000	$205,000	$2,361,000	$3,983,000
Wide-slot Cylindrical Wedgewire Screens	$31,245,000	$507,000	$1,846,000	$6,802,000
Fixed-panel Screens	$4,311,000	$295,000	$314,000	$1,223,000
Coarse-mesh Modified Traveling Water Screens in Expanded Intakes(All Units with Intake Modifications)	$31,651,000	$614,000	$2,022,000	$7,142,000
Coarse-mesh Modified Traveling Water Screens in Expanded Intakes(Units 1 & 2 with Intake Modifications)	$16,160,000	$307,000	$1,050,000	$3,658,000
Modular Inclined Screens	$7,570,000	$93,000	$551,000	$1,722,000

In addition to the technology costs in Table 4.3 there are also pilot study costs to determine if the technology would be practical and/or to verify its performance. These studies were discussed in the uncertainties section for each of the technologies evaluated and the costs for these studies are summarized in Table 4.4.

Table 4.4 – Estimated costs of Haynes pilot studies necessary to evaluate the feasibility, cost or biological performance of the technologies evaluated.

Pilot Studies	Modified Screens	Modular Inclined Screens	Cylindrical Wedgewire Screens	Fixed Panel Screen (3)	Velocity Reduction
Biological Performance Study	$1,110,000	$2,320,000	NA	NA	NA
Fish Return Optimization Study	$130,000	NA	NA	NA	NA
Biofouling/Debris Control	NA	(1)	$80,000 to $612,000	$80,000 to $160,000	NA
Hydraulic/Physical Modeling	Optional	NA		NA	NA
Fish Bypass Study	(2)		$84,000	NA	NA

(1) The biological performance study would also address biofouling and debris handling
(2) Covered by fish optimization study
(3) Due to the existing use of fixed panel screens at Units 1 and 2 no pilot studies are necessary for this option.

4.3.2 Comparison of Cost to Expected Performance

As discussed in Section 4.2, for the expected biological performance evaluation, the current impingement levels based on the new study are used. Current annual impingement is estimated to be 11,059 fish per year. This estimate is based on the first year of the new study when a full year of sampling was completed and all units were in operation. A comparison is provided in Table 4.5 of the estimated annualized cost of each of the impingement mortality reduction technologies to the estimated number of fish that will survive annually as a result of the technology. The per fish cost to increase fish survival at Haynes ranges from a high of $4,580 per fish for installing modified TWS with a fish return on all units to $123 per fish for installation of fixed-panel screens at the entrance to the intake channel to not exceed 0.5 fps. Also if the 2006 impingement levels were average with the current levels of impingement the cost per fish saved would be 37.8% or range from $2,849/fish saved to $77/fish saved. Additionally the $123 per fish estimate does not include all costs, since LADWP does not own that property and the current owner may not allow the screens to be operated on the property or charge additional costs to allow LADWP to use it since significant modifications to the existing piers would be necessary.

Table 4.5 – Comparison of the annualized cost of evaluated impingement mortality reduction technologies to the number of fish projected to be saved based on current impingement levels at the Haynes Generating Station

Technology	Estimated Annualized Cost ($)	Estimated Fish Saved Per Year	Estimated Cost Per Fish Saved ($)
Coarse-mesh Modified Traveling Water Screens (All Units with Intake Modifications)	**$7,579,000**	**1,655**	**$4,580**
Coarse-mesh Modified Traveling Water Screens (Units 1 & 2 with Intake Modifications)	**$3,983,000**	**1,614**	**$2,468**
Modular Inclined Screens	**$1,722,000**	**3,889**	**$443**
Wide-slot Cylindrical Wedgewire Screens	**$6,802,000**	**8,847 (1)**	**$769**
Fixed-panel Screens	**$1,223,000**	**9,953 (2)**	**$123(3)**
Coarse-mesh Modified Traveling Water Screens in Expanded Intakes(All Units with Intake Modifications)	**$7,142,000**	**9,953 (2)**	**$714**
Coarse-mesh Modified Traveling Water Screens in Expanded Intakes (Units 1 & 2 with Intake Modifications)	**$3,658,000**	**9,953 (2)**	**$368**

(1) 80% reduction in IM

(2) 90% reduction in IM

(3) Equates to $12,505/pound of fish saved (current biomass estimate is 44.4 Kg/year = 97.8 lb/year)

5 SUMMARY AND CONCLUSIONS

A summary and the conclusions of the evaluation of potential interim impingement mortality reduction alternatives are provided separately for Harbor and Haynes as follows:

5.1 Harbor

Current Impingement Levels - New impingement studies were initiated at Harbor in April 2012 and consisted of collecting 24-hour impingement samples every other week. The new study was initiated to document current impingement levels. Estimated annual impingement during the one-year impingement study conducted at Harbor in 2006 was 8,851 fish. During the first year of the current study, the estimated annual impingement at Harbor was 2,315 in year one (73.9% fewer fish impinged) and 1,735 in year two (80.4% fewer fish impinged). The most abundant fishes from the impingement sampling (i.e., fish that made up more than 1% of the annual impingement) include Northern Anchovy (53.3%), Round Stingray (23.2%), Shiner Perch (6.7%) and Spotted Kelpfish (3.3%) and together these species made up 86.5% of the total estimated annual impingement. LADWP is planning to continue impingement sampling at Harbor for an additional year.

Technologies Evaluated – One collect and transfer technology (TWS) and three technologies that would reduce the maximum through-screen intake velocity to not exceed 0.5 feet per second (fps) (cylindrical wedgewire screens, barrier nets and restoring currently retired screens back into operation) were evaluated to reduce impingement mortality with results as follows:

- Modified TWS with a Fish Return System – This screen system could be placed in the existing screen wells for Unit 5 for an estimated annualized capital and O&M cost of approximately $2.9 million. The technology is expected to perform poorly for fragile Northern Anchovy that dominate impingement. Installing modified TWS on Unit 5 is estimated to save 865 fish per year with an estimated cost per fish of $3,338.

- Barrier Nets – Barrier nets could potentially be installed in front of the entrance to the Harbor intake tunnels in Slip 5 for an estimated annualized cost of $899,000. However, this cost does not include lost revenue from having to take the unit off line to turn off the cooling water pumps in order to change the nets to control biofouling and debris loading. Also not included is the cost to conduct pilot studies or to obtain necessary approvals and permits necessary to deploy the technology in the Pier 5 harbor. The technology would be expected to have a relatively high level of biological performance (estimated to be 90% effective), saving an estimated 1,825 fish per year with an estimated cost per fish of $493, primarily Northern Anchovy that have no commercial or recreational value.

- Cylindrical Wedgewire Screens – Cylindrical wedgewire screens could potentially be installed in front of the Harbor intake tunnel in Slip 5 for an estimated annualized cost of

$932,000. This does not include the cost of lost revenue for an estimated 3 to 4 month outage needed to install the screens. Also not included is the cost of pilot studies or obtaining necessary permits and approvals for this option. These screens would likely eliminate impingement, saving an estimated 2,028 fish annually for an estimated cost per fish of $460 (primarily Northern Anchovy).

- Reducing the Through-Screen Velocity to Not Exceed 0.5 fps by Restoring Now Retired Screens to Operation –The four currently retired screen bays at Harbor could be brought back into service by installing new screens for an estimated annualized cost of $803,000. This action would save an estimated 1,521 fish annually for a cost of $528 per fish.

Key Uncertainties Associated with Harbor Cost and Performance Estimates

- Inter-annual variability – If 2006 impingement levels were averaged with the two years of current data the annual impinged estimates would be approximately double and the cost per fish saved would be 52.2% lower.
- Cost estimates for technologies are + or – 30%.
- The technology cost estimates do not include the cost of pilot studies that are recommended to better estimate biological performance, design considerations or operation and maintenance costs.
- There is uncertainty regarding permitting approval for the barrier net and cylindrical wedgewire screen options that extend out from the intake into the slip, due to potential interference with ship docking. Additionally, if approvals are obtained, the time period to obtain the approvals may extend beyond the December 31, 2020 compliance date for installation.
- Biological performance of for Modified TWS with a fish return and potential entrapment for barrier nets and restoring retired screens to operation are based on BPJ and would require pilot studies to reduce biological performance uncertainty.

Conclusions

- Impingement levels have declined significantly since 2006 (estimated to be 77.1%). The decline appears to be associated with inter-annual variability of west coast species.
- Currently estimated annualized costs of fish protection technologies are relatively high (i.e., range from an annualized cost of $803K to $2.9 million) compared to the cost per fish saved (i.e., ranges from $460 to $3,345) due to the current relatively low level of impingement. An additional planned one year of sampling will verify whether the current low level of impingement continues.
- It is uncertain whether or not the lowest cost option (a barrier net) can be permitted in Slip 5. Further, the need to cease cooling water pump operation and take the unit offline two or more times per week to perform net changes is highly problematic for LADWP due to the low power generation reserve margin as it transitions for OTC to dry cooling. While this option would eliminate impingement the estimated cost is $460 per fish saved or for biomass would equate to $5,839.60 per pound of fish. The fish saved would be primarily northern anchovy, a common forage species with no recreational or commercial value.

The overall result of the evaluation is that none of technologies evaluated, could be deployed for a cost that is not significantly disproportionate to the benefit and the two highest performing options (a barrier net and cylindrical wedgewire screens) many not be allowed due to potential interference with ship navigation in Pier 5). LADWP is committed to eliminating impingement and entrainment mortality through conversion to dry cooling no later than December 31, 2029.

LADWP is committed to eliminating impingement and entrainment mortality through conversion to dry cooling no later than December 31, 2029. LADWP will also be paying $3 per MGD to compensate for impingement and entrainment losses through fish habitat restoration mitigation. By converting from OTC to dry cooling Harbor will over comply with the OTC Policy. Use of wet closed-cycle cooling is estimated to reduce use of cooling water flow and entrainment by approximately 93%, while dry cooling is 100% effective. Thus after conversion, there will be 7%/year reduction in entrainment compared to use of wet closed-cycle cooling and the benefit is expected to be for a period longer than the interim impingement and entrainment mortality reductions apply.

Haynes

Current Impingement Levels - New impingement studies were initiated at Haynes in April 2012 and consisted of collecting 24 hour impingement samples every other week. The new study was initiated to document current impingement levels. The annual impingement estimates based on actual cooling water flow declined from 31,226 in 2006, to 11,059 in year one (65% fewer fish impinged). A direct comparison cannot be made to year two since Unit 1 that impinges 82% of the fish was offline from late August of year two through January 2014. The substantial decline in impingement after August, 2013 was likely due primarily to Unit 1 being taken out of service. However, there was also a 45% reduction of cooling water flow into the intake channel when Units 5 and 6 were retired in late August that may also have contributed to the reduction. For the expected biological performance evaluation, the current impingement levels are based on the first year of the new study (i.e., annual impingement is estimated to be 11,059 fish per year).

LADWP plans to continue impingement sampling for an additional year. Dominant impinged species included Queenfish (86.3%), Northern Anchovy (2.5%), Bay Pipefish (2.3%), Giant Kelpfish (1.2%) and Topsmelt (1.1%) and together these species made up 93.3% of the estimated annual impingement. Impingement at Unit 1 accounted for 82% of the total abundance in the new study (both years combined) followed by Unit 2 (16%), Unit 8b (1%), and Unit 8a (<1%).

Technologies Evaluated – Two collect and transfer technologies (modified TWS with a fish return and modular inclined screens [MIS]) and three technologies that would reduce the maximum through screen intake velocity to not exceed 0.5 fps (cylindrical wedgewire screens, fixed-panel screens at the intake and new expanded intakes) were evaluated to reduce impingement mortality with results as follows:

- Modified TWS with a Fish Return System – Such screens could be placed in the existing screen wells for Unit 8 but the fixed screens for Units 1 and 2 would require modifications to accommodate such screens. The estimated annualized capital and O&M costs to install these screens on Units 1, 2 and 8 are approximately $7.6 million and $4.0 million for only Units 1 and 2 that currently account for approximately 99% of the annual impingement. The cost does not include the cost of pilot studies to better determine actual biological performance. The technology is expected to perform poorly for fragile juvenile queenfish that dominant impingement. Installing modified TWS on all units is estimated to save 1,655 fish per year and 1,614 fish per year if installed at Units 1 and 2 only with an estimated cost per fish of $4,580 and $2,468 respectively.

- MIS – An MIS system could be installed in the Haynes intake channel with a fish friendly pump to return fish back to Alamitos Bay. The estimated annualized capital and O&M cost is estimated to be approximately $1.7 million. The cost estimate does not include the cost of pilot studies. This technology is expected to perform better than modified TWS saving an estimated 3,889 fish per year with an estimated cost per fish of $443.

- Cylindrical Wedgewire Screens – Cylindrical wedgewire screens could be installed in the Haynes intake channel using fish friendly pumps installed in the now retired Units 5 and 6 intakes to create a sweeping flow that would transport fish to the San Gabriel River. The estimated annualized cost is $6.8 million. This cost does not include the additional cost of lost revenue for each of the four units to be shut down for 4 to 6 months to complete construction. Such screens are estimated to save 8,847 impingeable sized fish per year for an estimated cost of $769 per fish. However, this option would double the flow into the intake channel, thereby doubling the number of entrainable sized fish and expose the entrained fish to the thermal discharges of both Haynes and the Alamitos Generating Station.

- Fixed-Panel Screens at the Entrance to the Intake Channel – It may be possible to install fixed-panel screens at the entrance to the intake channel in the Long Beach Marina. The estimated annualized cost for such screens is $1.2 million and an estimated 9,953 fish would be saved per year for an estimated cost of $123 per fish. LADWP does not own the property that would have to be used to operate and maintain such screens and this option would require modifications to three piers and reduce the number of boats that could be docked in the marina. Thus permitting for this option may be difficult and additional costs associated with such permitting (i.e., cost of lost slip space and pier relocation) have not been included in the estimates.

- Install New Intakes of a Size Adequate to Not Exceed 0.5 fps Through-Screen Velocity – The existing intakes for Units 1, 2 and 8 could be replaced with new larger intakes with sufficient screening area to not exceed a 0.5 fps through-screen velocity. The estimated annualized cost for this alternative is approximately $7.1 million for all units and $3.7 million for Units 1 and 2 only. The cost estimate does not include the cost of pilot studies. An estimated 9,953 fish per year would be saved (regardless of whether Units 1 and 2 or all three units are upgraded) for an estimated cost of $718 per fish if new intakes were installed at all units and $368 per fish if new intakes were only installed at Units 1 and 2. However, installing such intakes at Units 1 and 2 may simply transfer impingement that is occurring at Units 1 and 2 to Unit 8. Additionally, due to the high velocities in the intake tunnels leading to the head of the discharge canal there would be entrapment of fish in the intake. Thus while impingement mortality on the traveling water screens would be low the fish in the canal would be unable to return to the Pacific Ocean.

Key Uncertainties Associated with Haynes Cost and Performance Estimates

There are a number of uncertainties associated with the Haynes technology evaluations that are summarized as follows:

- Inter-annual variability – If 2006 impingement levels were averaged with the current estimate the annual impinged estimates would be 37.8% higher and the cost per fish saved would be 37.8% lower.
- Cost estimates for technologies are + or – 30%.
- Technology cost estimates do not include the cost of pilot studies that would be necessary to better estimate biological performance, design considerations or operation and maintenance costs have not been included.
- The cost estimates also do not include permitting costs or the cost for the major modifications that would be required in the Long Beach Marina for fixed-panel screens. Permitting, legal fees or the cost to the Long Beach Marina to deploy the screens (if allowed) are likely to be significant.
- LADWP may not be able to obtain approval from the Long Beach Marina to install and operate fixed-panel screens in the marina. Also not included are the cost of permitting the fixed-panel screens and compensating the Long Beach Marina for significant modifications to operate the screens and the loss of boat docks. Additionally the permitting time frame for this option could extend longer than the December 31, 2020 date for completing installation of interim technologies.
- The estimated biological performance of for Modified TWS with a fish return and the MIS, entrapment or risk of re-impingement at Haynes or Alamitos for fish returned to Alamitos Bay or potential additional mortality due to the Hayne’s and Alamitos’s thermal discharges if fish are returned to the San Gabriel River are based on BPJ and would require site-specific studies to reduce uncertainty associated with use of wedgewire screens.
- Haynes will also over comply with the OTC Policy by achieving a 100% reduction in cooling water flow as opposed to 93% on which the California Policy is based. Thus after conversion, there will be 7%/year reduction in entrainment this is expected to be for a period longer than the interim impingement and entrainment mortality reductions apply.

Conclusions for Haynes - Conclusions for Haynes are as follows:

- LADWP has already completed a flow reduction of 50% for Haynes, 45% of which took place after the July 2011 interim Policy condition that went into effect; and the current schedule to convert Units 1 and 2 to dry cooling is scheduled to be completed prior to the requirement for interim impingement further reduction flow by 77%.
- Impingement levels have declined significantly since 2006 and the retirement of Units 5 and 6 may contribute to that trend.
- Currently estimated annualized costs of fish protection technologies are relatively high (i.e., range from an annualized cost of $1.2 to $7.6 million) compared to the cost per fish saved (i.e., ranges from $123 to $4,580) due to the current relatively low level of impingement. The cost per fish saved are very conservative since they do not include the cost of pilot

> studies, a 4 to 6 month outage required for cylindrical wedgewire screens or the cost of approvals and permitting. An additional planned one year of sampling will verify whether the current low level of impingement continues. If the lowest cost option (fixed-panel screens) can be permitted in the Long Beach Marina impingement it may achieve a 90% reduction in impingement mortality for a cost of $123 per fish which equates or in terms of biomass equates to $12,505 per pound of fish saved. The cost per pound of fish saved for the other options would all be greater.

As for Harbor, the overall result of the evaluation is that none of four technologies evaluated, could be deployed for a cost that is not significantly disproportionate to the benefit and the highest performing options (fixed panel screens deployed at the intake) many not be allowed due the major modifications that would be required in the Long Beach Marina). LADWP is committed to eliminating impingement and entrainment mortality through conversion to dry cooling no later than December 31, 2029.

LADWP is committed to eliminating Haynes's impingement and entrainment mortality through conversion to dry cooling no later than December 31, 2029. For Haynes, LADWP will also be paying $3 per MGD to compensate for impingement and entrainment losses through fish habitat restoration mitigation. Also, by converting from OTC to dry cooling Haynes will over comply with the OTC Policy. Use of wet closed-cycle cooling is estimated to reduce use of cooling water flow and entrainment by approximately 93%, while dry cooling is 100% effective. Thus after conversion, there will be 7%/year reduction in entrainment compared to use of wet closed-cycle cooling and the benefit is expected to be for a period longer than the interim impingement and entrainment mortality reductions apply.

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Appendix A – Alternative Types of Modified Traveling Water Screens

Appendix A
Overview of Technologies with Potential to Meet Compliance Alternative 1

Modified-Ristroph through-flow traveling screens were used as replacements of existing screens in an existing screen house for Compliance Alternative 1 (Section 2.1). The design components for a state-of-the-art traveling water screens with fish protection features included:

- Continuous rotation;
- A fish bucket with minimal turbulence;
- 0.25 x 0.5 inch smooth top mesh;
- A low-pressure wash to remove fish prior to a high-pressure wash for debris removal;
- Incorporation of a flap seal to enhance fish transfer to a return trough; and,
- A fish-friendly return system.

However, there are several variations in traveling screen designs (all available with fish protection features) that could be used. EPA provided specific guidance on screen features that should be used with modified-Ristroph-type screens. This guidance included specific components of a fish-friendly system but, as discussed in Section 2.1, currently no one screen type incorporates all components as listed. If it can be demonstrated that the numeric impingement mortality performance standards can be met, use of any available technology is allowed. The selected technology must allow the direct measurement of impingement mortality through sampling to demonstrate a monthly average of fish impingement mortality of 31% or less, and an annual average of 12% or less.

There are several alternative screen designs with potential to meet the proposed impingement performance standards. These include:

- Modified-Ristroph-type dual-flow screens;
- Modified-Ristroph-type center-flow screens;
- Bilfinger multi-disc screens;
- Hydrolox screens;
- Beaudrey WIP screens; and,
- Modular inclined screens (MIS).

All of these screens would be used with a fish return system to safely transport impinged fish back to the source waterbody. In addition to meeting the requirements for Compliance Alternative 1, these screens can also be considered as an alternative technology to address Compliance Alternative 2. Contact information for vendors is provided in Table A-1.

A brief description of each screen type and the potential advantages or disadvantages with respect to overall fish protection performance and debris control is provided below, as well as, a discussion engineering and cost considerations is provided at the end of this attachment.

Modified-Ristroph-Type Screens

Modified-Ristroph-type screens are very similar to conventional traveling water screens except they incorporate modifications that improve survival of impinged fish. Such state-of-the-art modifications can significantly reduce fish mortality associated with screen impingement and spray wash removal. Each screen basket is equipped with a water-filled lifting bucket that safely contains collected organisms as they are carried upward with the rotation of the screen. The screens typically operate continuously to minimize impingement duration. As each bucket passes over the top of the screen, fish are rinsed into a collection trough by a low-pressure spray wash system. A high-pressure spray wash system then removes remaining debris. Once collected, the fish are transported back to a safe release location. Such features have been incorporated into through-flow (Figure A-1), dual-flow (Figure A-2), and center-flow (Figure A-3) screens. Either screen type can be modified to allow a front-wash process or a front- and back-wash process. Regardless of the location (front or back), the low-pressure spray wash should be used prior to the high-pressure spray wash to reduce fish mortality.

Improvements that were made to the original Ristroph screen design have resulted in further increases in fish survival. The state-of-the-art modified-Ristroph screen design was developed through extensive laboratory and field experimentation. A series of studies conducted by Fletcher (1990) indicated that substantial injury associated with traveling screens was due to repeated buffeting of fish inside the lifting buckets as a result of undesirable hydraulic conditions. A number of alternative bucket configurations were developed to create a sheltered area in which fish could safely reside during screen rotation to eliminate these conditions. After several attempts, a bucket configuration was developed that achieved the desired conditions (ENVIREX 1996). In 1995, PSE&G performed a biological evaluation of the improved screening system installed at the Salem Generating Station in the Delaware River (PSE&G 1999; Ronafalvy 1999). The reported survival rates for this installation are among the highest for any traveling screen system (PSE&G 1999).

Passavant-Geiger Multi-disc Screen:

Passavant-Geiger Multi-Disc™ screens (multi-disc screens) are a variation on “conventional” traveling water screens. In a traditional modified traveling screen, only the ascending side of the screen removes fish and debris from the raw water. By contrast, the total submerged screening area (the descending and ascending mesh panels as well as mesh panels in the lower guiding section) of multi-disc screens screen raw water. Fish and debris are retained on the mesh panels and carried upwards in a bucket as the screen band travels through the water column to the discharge position above deck. Debris and fish are washed off the screen by spray wash headers into a collecting/transfer trough. A low-pressure wash is used first to clear the ascending panels and a high-pressure spray wash is used as the panels descend. As both the ascending and descending side of the screen are on the same plane (the upstream side) of the system, carryover is eliminated.

The main components of the multi-disc screen are the sickle-shaped mesh panels, one central chain guide-way integrated in the supporting structure, one revolving chain, one lower guide, low-pressure and high-pressure spray washes, debris/fish buckets, a debris/fish collection/return trough, a drive unit, and a splash guard. Each panel is equipped with debris/fish buckets, which retain water for fish removal during upward travel after the screen panels exit the water. Alden worked with Passavant-Geiger to develop their fish bucket to assure that turbulence is reduced to a level comparable to that found with the Fletcher (i.e. modified-Ristroph) design. A low-pressure spray header washes impinged organisms from the screen surface into the bucket. Fish impinged on the mesh below this bucket are sluiced via an opening in the lower panel frame into the bucket of the adjacent mesh panel below. As each screen panel rotates to descend for another cleaning cycle, the retained water and fish are conveyed into a return trough located at the upstream side of the head section and then routed to a common fish return trough (Figure A-4).

A multi-disc screen with fish protection features was tested at the Potomac River Generation Station in 2005-06 (EPRI 2007). Injury and survival of fish exposed to the impingement and collection process were evaluated. During the evaluation, the screen was rotated continuously, and wash water was diverted to a fish collection system. Fish were transferred to on-site holding facilities for latent impingement mortality (LIM) assessment. Overall, mortality was comparable to results for other modified-Ristroph-type screen studies.

Hydrolox Screens:

Hydrolox Inc. has developed a polymer-based traveling screen (Hydrolox screen), with fish handling features. This screen's operation is similar to conventional traveling screens with a few significant differences. The screen material and the sprockets are made of a polymer, which results in a lighter weight screen compared to standard traveling water screens (similar to the logic used by Fletcher in developing the lighter weight "composite" screen baskets). In addition, the top sprocket of the screen is offset from the bottom sprocket, allowing gravity to assist in debris/fish removal reducing the potential for debris carryover (Figure A-5). In fact, during a biological evaluation of the Hydrolox screen at Barrett Station, none of the fish collected were found in the debris trough; all were collected from the fish trough, supporting the concept that the gravity-assisted removal from the Hydrolox screen could greatly reduce carryover (ASA 2008).

These screens have been evaluated in both laboratory and field settings. Alden worked with Hydrolox to develop their fish bucket to assure that turbulence is reduced to a level comparable to that found with the Fletcher design. In the laboratory, the mortality, injury, and scale loss rates of five species of freshwater fish impinged and recovered with a Hydrolox screen were evaluated and found to be generally low (Alden 2006). One Hydrolox screen with fish protection features was installed and tested National Grid's Barrett Station on Long Island, New York (ASA 2008). The results demonstrated that survival of fish impinged on the Hydrolox screen at Barrett was near the upper bound of estimates for most species reported in other studies and consistently equal to or greater than that found on the other modified traveling screen at the station (ASA 2008).

Beaudrey WIP Screen:

The Beaudrey Water Intake Protection screen (WIP screen) is the most recent variation of a modified traveling water screen. These screens incorporate large, filter disks that are divided into several pie-shaped wedges that rotate on a center axle (Figure A-6). Each disk rotates perpendicular to the net intake flow, eliminating any potential for debris carryover. As the disk rotates, each "wedge" passes under a stationary suction scoop mounted over one section of the filter disk. Fish and debris impinged on the screen are "vacuumed" off as the screen rotates under this section. A fish-friendly pump, one which is designed to handle fragile materials, is used to transport impinged organisms and debris to a return trough. Organisms removed from the screen are continuously submerged, which may reduce or eliminate some of the stresses (e.g., air exposure) associated with handling and return to the waterbody.

A Beaudrey WIP screen was tested at Omaha Public Power's North Omaha Station (Bigbee et al. 2010; EPRI 2009). Fish collected off the screen were held for 48 hours to assess post-impingement survival. Results showed that fish impinged and recovered from the Beaudrey WIP screen exhibited high survival. In fact, survival rates of impinged fish showed no significant differences ($P<0.05$) from control fish, indicating that screen contact and collection added no additional mortality.

Modular Inclined Screens

The Modular Inclined Screen (MIS) was developed and tested by the Electric Power Research Institute (EPRI 1994; EPRI 1996; Taft et al. 1997). MIS is fundamentally different, in that fish are never impinged on a screen or otherwise collected in a bucket. The MIS is intended to protect juvenile and adult life stages of fish at all types of water intakes. An MIS module consists of an entrance with trash racks, de-watering stop logs in slots, an inclined screen set at a shallow angle (10 to 20 degrees) to the flow, and a bypass for directing diverted fish to a transport pipe (Figure A-7). The module is completely enclosed and is designed to operate at relatively high water velocities ranging from 2 to 10 ft/sec, depending on the species and life stages to be protected. This design of this technology would require major intake modifications which would be comparable to a new intake structure considered under Compliance Alternative 2.

The MIS was evaluated in laboratory studies to determine the design configuration which yielded the best hydraulic conditions for safe fish passage, and the biological effectiveness of the optimal design in diverting selected fish species to a bypass (EPRI 1994a). Screen effectiveness (diversion efficiency and latent mortality) was evaluated at water velocities ranging from 2 ft/sec to 10 ft/sec. Diversion rates approached 100% for almost all species at water velocities up to at least 6 ft/sec. Generally, latent mortality of test fish that was adjusted for control mortality was low (0 to 5%).

Based on the laboratory results, a pilot-scale evaluation of the MIS was conducted at Niagara Mohawk Power Corporation's Green Island Hydroelectric Project on the Hudson River near Albany, NY (EPRI 1996). The results obtained in this field evaluation were similar to those obtained in laboratory studies (Taft et al. 1997).

Studies to date have only evaluated possible application at hydroelectric projects. Further, no full-scale MIS facility has been constructed and evaluated. As a result, the potential for effective use at cooling water intakes is unknown. Any consideration of the MIS for CWIS application should be based on pilot studies with large-scale, prototype evaluations.

Engineering and Cost Considerations

All modified traveling screen types are designed to be installed in existing traveling screen bays. The multi-disc screens have a 10 ft wide limitation. Also, a dual-flow screen retrofit would be limited to a screen width roughly half that of an existing "conventional" traveling screen. That is, an existing 10 ft wide conventional screen could be replaced with a 4-5 ft wide dual-flow screen.

The multi-disc, WIP, and dual-flow screens eliminate and the Hydrolox screen virtually eliminates debris carry-over.

The open area will vary among screens due to presence/absence of boot seals, mesh type, and framing; all of which affect through-screen velocity. The WIP screen would have the least open area followed by multi-disc, Hydrolox, and dual-flow screens compared to the modified-Ristroph design.

Finally, a comparison of actual quotes for a modified traveling screen for a pilot study results in an average cost of $335,000 and a range from $225,000 to $375,000. Although actual costs will vary among stations due to height, width, and shipping costs, the relative screen costs are valid.

Table A-1: Vendor Contact Summary

Company	Contact	E-mail
Passavant-Geiger Multi-disc Screen	Dave Anderson	dlanderson@passavant-geiger.us (631) 239-4121
Beaudrey Water Intake Protection Screen	Brian Hittle	brian.hittle@beaudreyusa.com (913) 390-5227
Hydrolox Screen	Brett DeRousse	Brett.Derousse@Intralox.com (504) 570-7419
Atlas Screens	Ford Wall	ford@atlasscreens.net (601) 587-4511
OVIVO Screens	Paul Shields	paul.shields@ovivowater.com (215) 260-0786
Siemens Screens	Steve Thomas Thomas Kofeldt Henry Petrovs	stephen.b.thomas@siemens.com thomas.kofeldt@siemens.com (215) 712-7064 henry.petrovs@siemens.com (630) 841-7944
Screen Systems International, Inc. (SSI)	Rodney Brown	rbrown@screeningsystems.com (225) 654-3900 ext 145

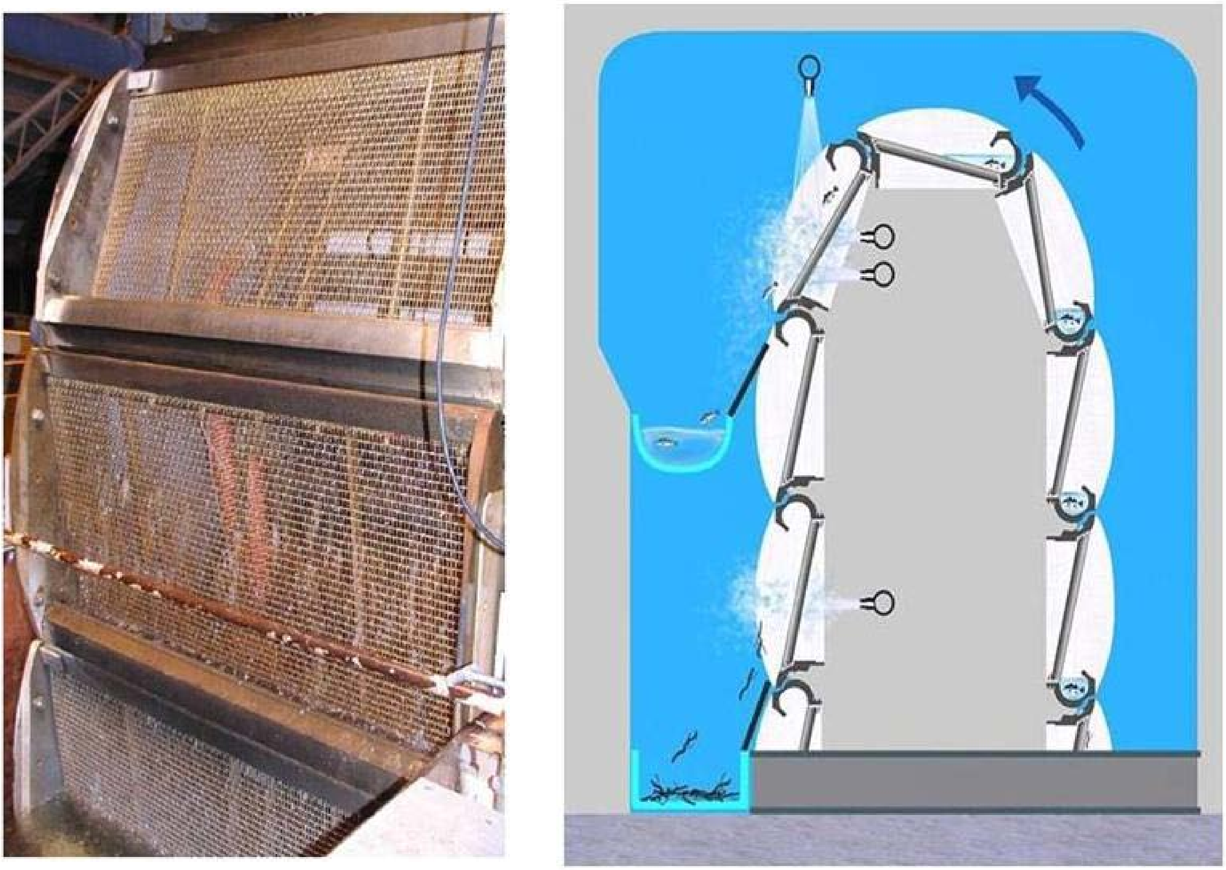

Figure A-1 Typical Modified-Ristroph Through-flow Screen

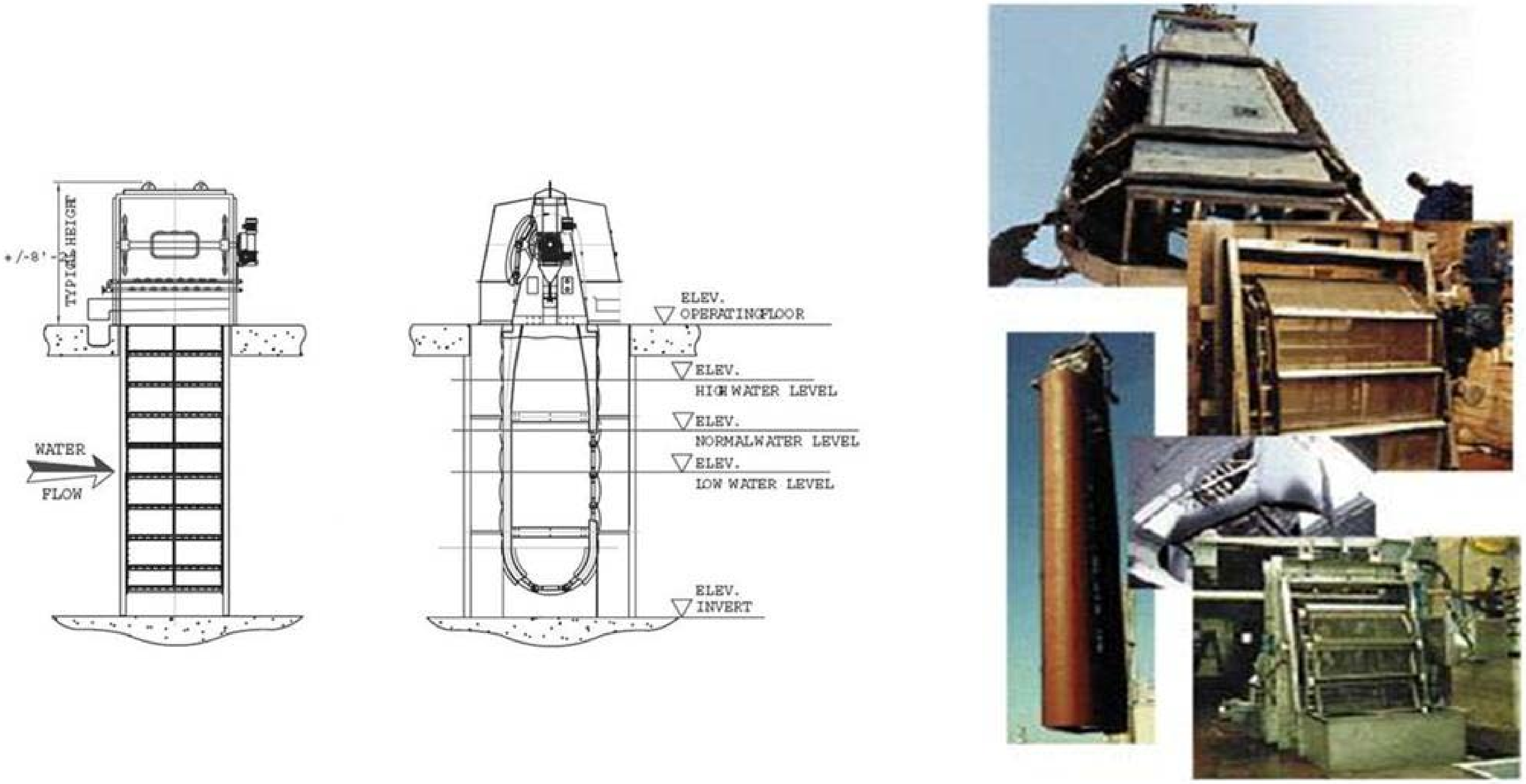

Figure A-2 Typical Modified-Ristroph-Type Dual-flow Screen (Courtesy of Bracket Green)

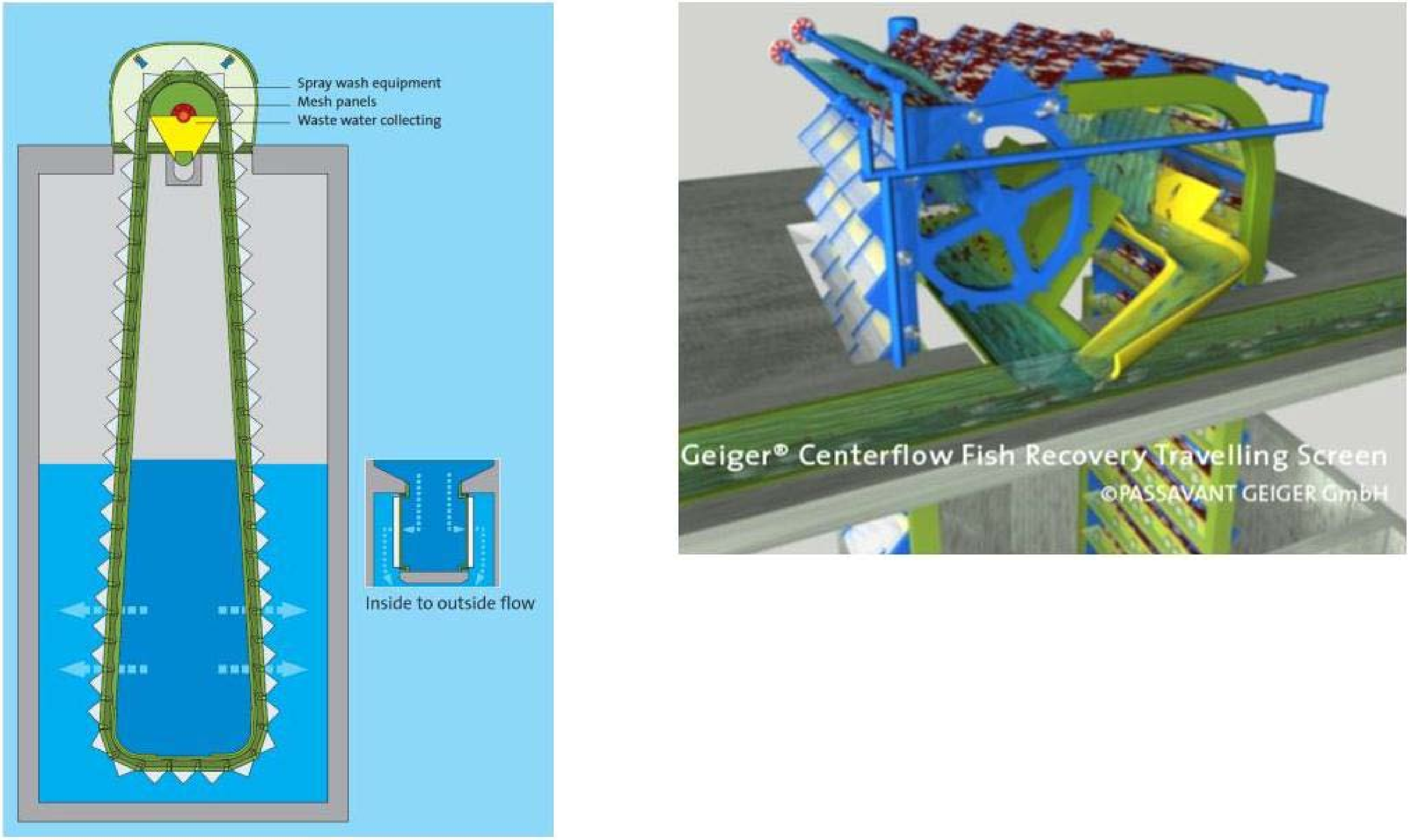

Figure A-3 Typical Modified-Ristroph-Type Center-flow Screen (Courtesy of Passavant-Geiger)

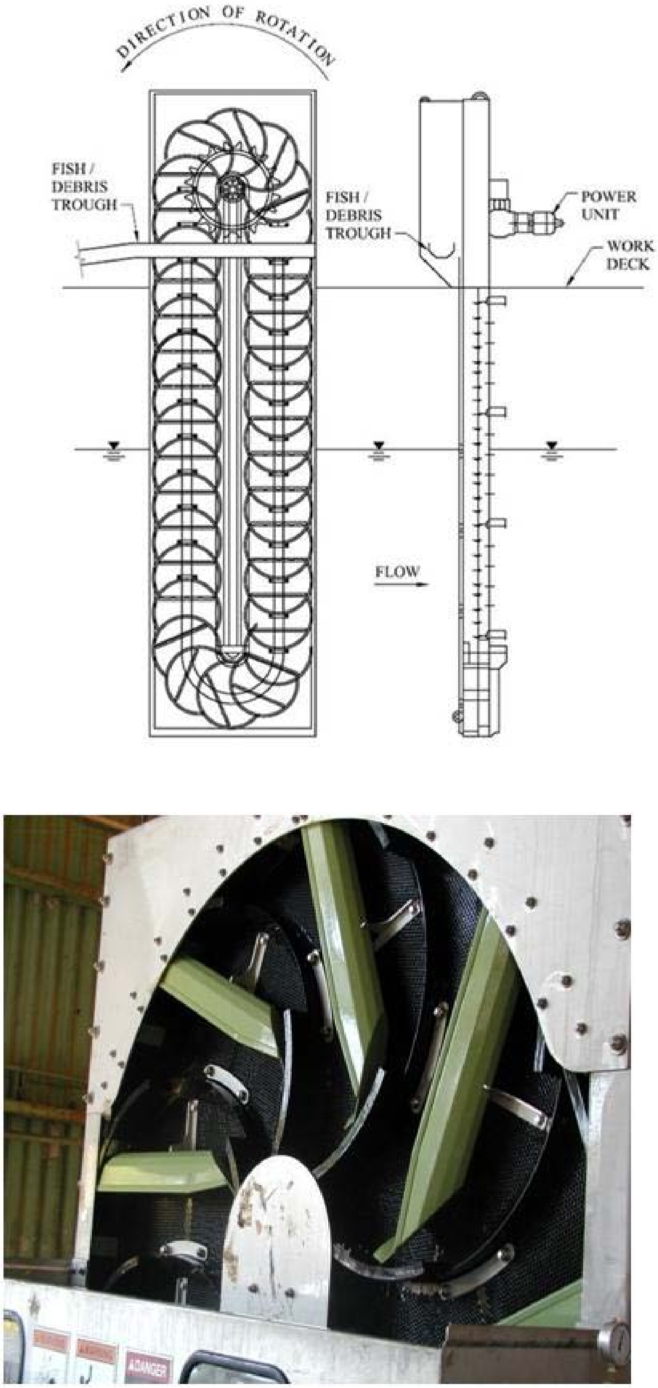

Figure A-4 Passavant-Geiger Multi-Disc Screen (Courtesy of Passavant-Geiger).

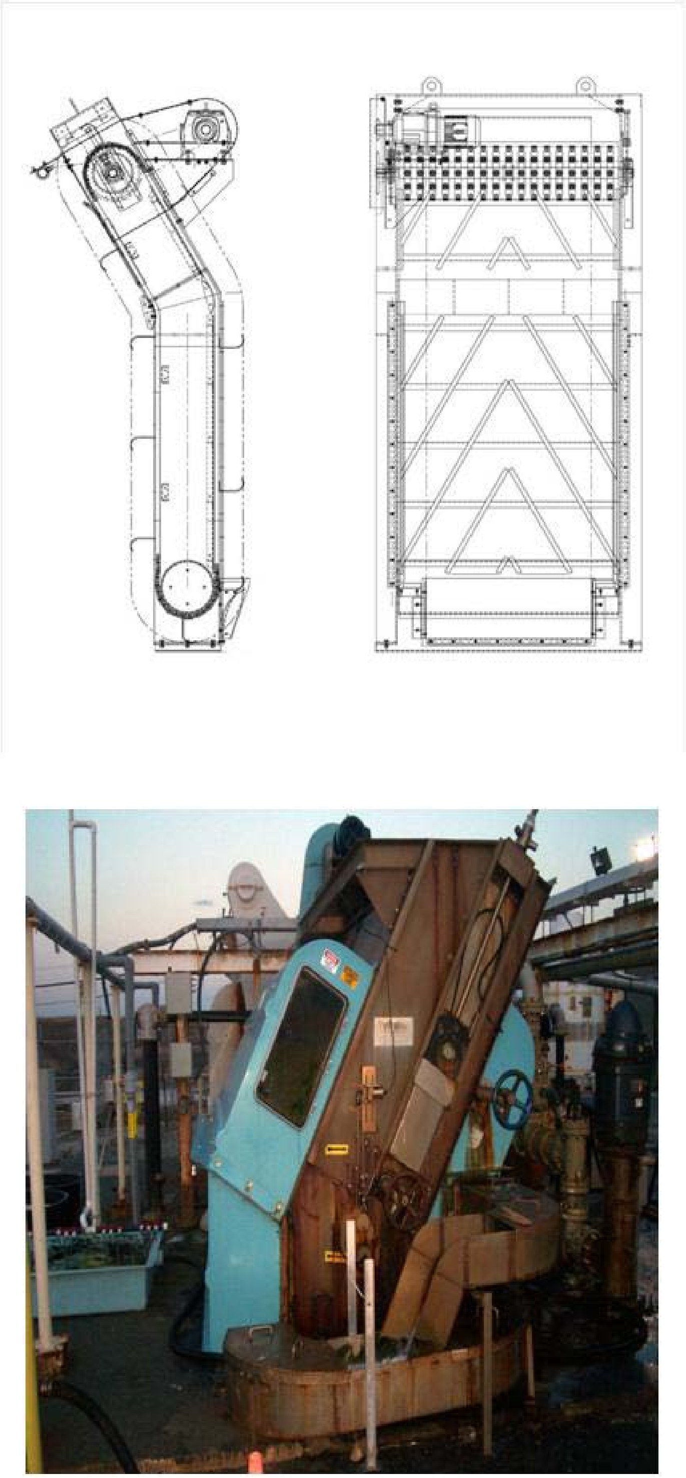

Figure A-5 Hydrolox Screen (Courtesy of Hydrolox Inc.).

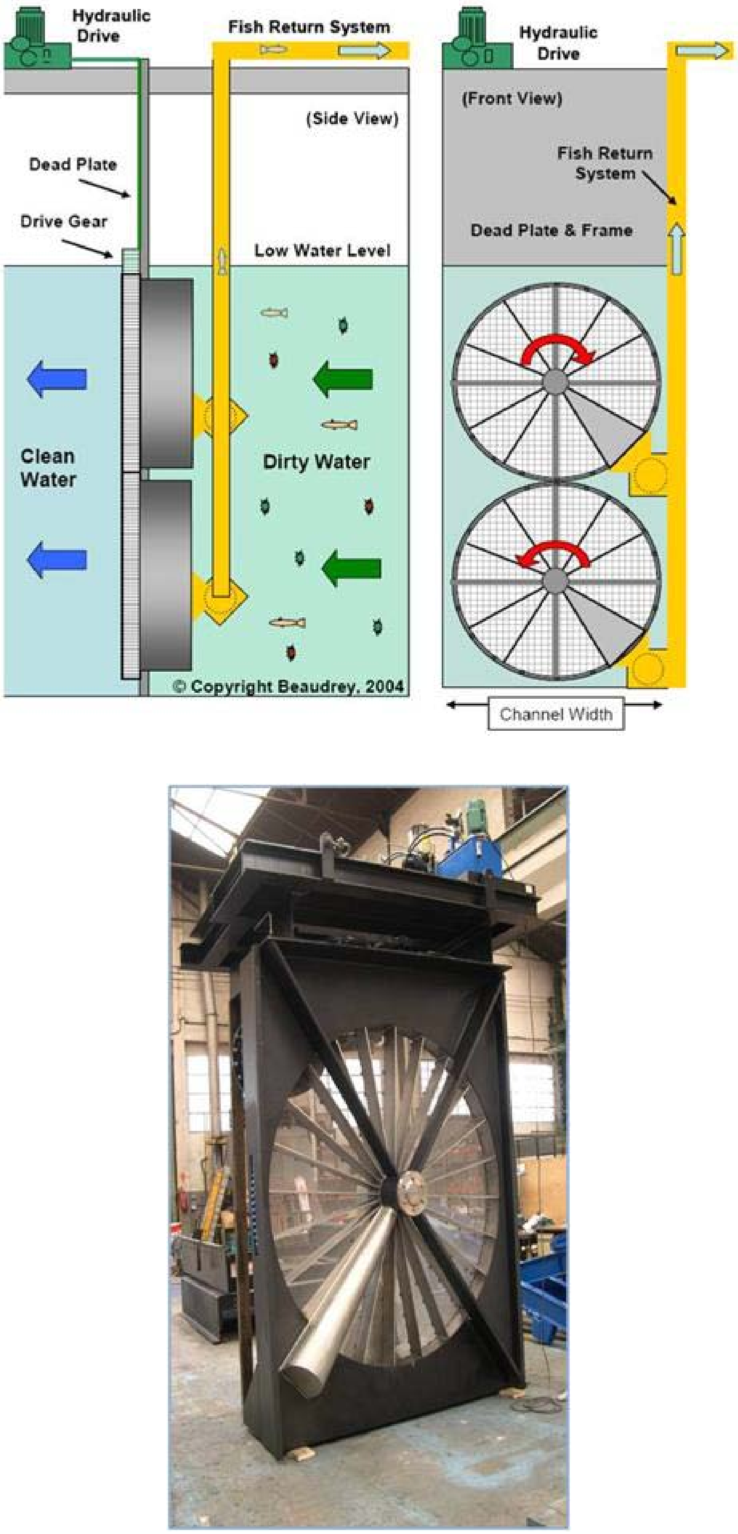

Figure A-6 Beaudrey WIP Screen (Courtesy of Beaudrey).

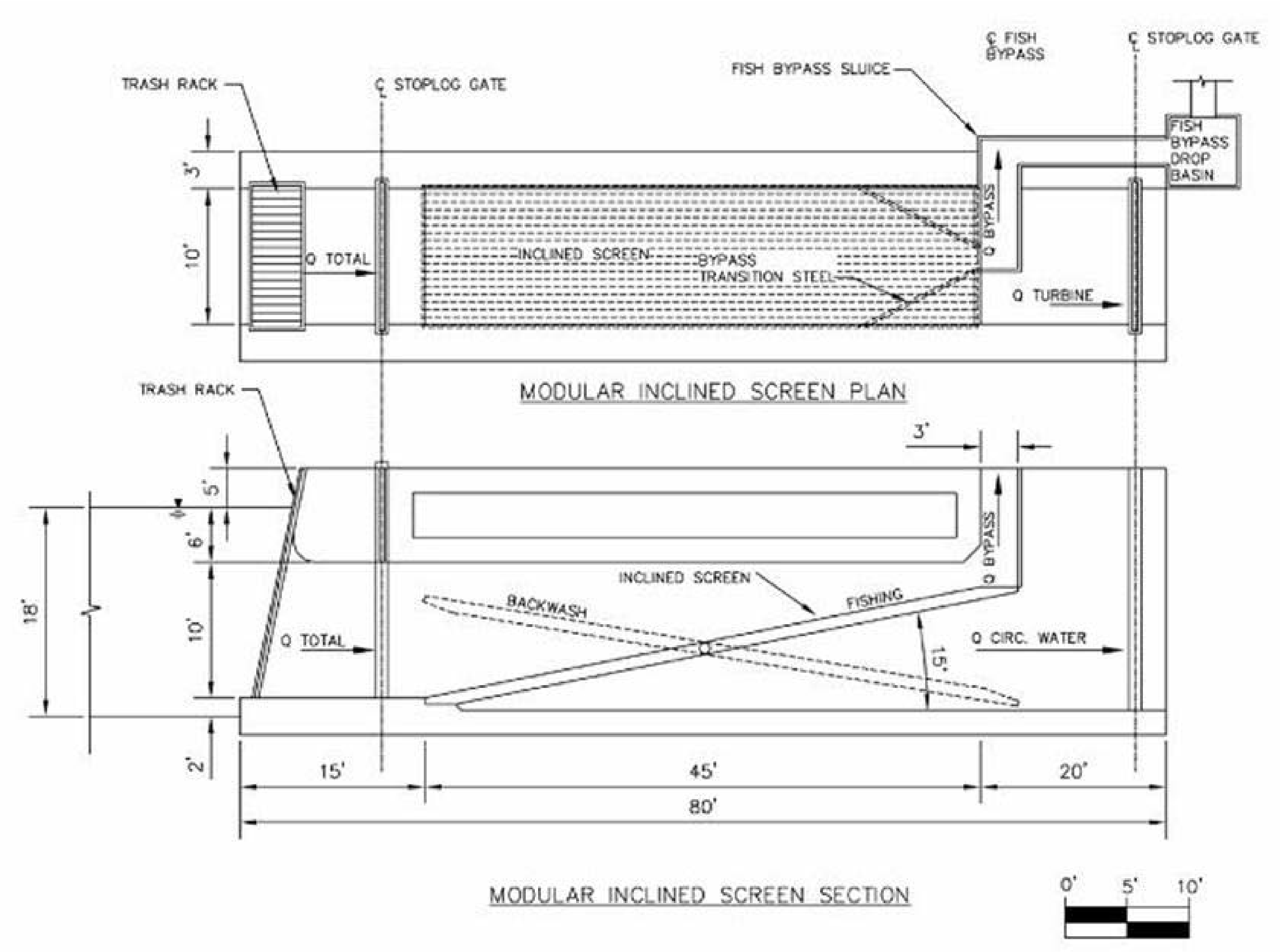

Figure A-7 Modular Inclined Screen.

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Smith, H. 1997. Operating History of the Puntledge River Eicher Screen Facility. Proceedings of Fish Passage Workshop, Milwaukee, Wisconsin, May 6-8, 1997. Sponsored by Alden Research Laboratory, Conte Anadromous Fish Research Laboratory, Electric Power Research Institute, and Wisconsin Electric Power Company.

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Appendix B – Impingement Survival Performance Studies for Harbor and Haynes

March 13, 2014

Mr. David Bailey
Electric Power Research Institute
8819 Trafalgar Ct.
Springfield, VA 22151

Technical Memo: Task 5 Impingement Survival Studies

Dear Mr. Bailey:

I have included a detailed description of MBC's proposed impingement survival studies. Included is the study design and associated costs. Estimated costs and assumptions used in generating the cost estimate are listed at the end.

Respectfully,

MBC *Applied Environmental Sciences*

Eric Miller
Senior Scientist

MBC *Applied Environmental Sciences*, 3000 Red Hill Avenue, Costa Mesa, California 92626 (714) 850-4830

Modified Traveling Water Screen with a Fish Return System

The same methodology would be applied to both Haynes and Harbor Generating Stations. MBC will document the effectiveness of a modified traveling water screen and fish return system that will be designed and specified by Alden Research Laboratories and installed at each facility. The program is divided by location of sample collection. Impingement samples will be collected from the traveling screens but before the material enters the fish return system. A second study will collect samples after they have transited the fish return system. Studying each component individually is needed to identify mortality and survival associated with (1) impingement, and (2) impingement, rinsing off the screens, and return to the source water. With this information, modifications can be made as needed, if possible, to improve the performance of the system. Only species of concern (SOC) listed under tasks three and four will be studied in this program.

Unfortunately, developing a control treatment for any of these studies is an insurmountable task. Most of the SOC are not currently cultured, so collection of a group independent of impingement would require field sampling. Net sampling, which would likely be required to provide sufficient numbers of individuals, causes mortality on its own. Therefore, animals would need to be allowed to acclimate in holding tanks while the weak and/or injured individuals die off. This would add additional layers of variability not easily counteracted or accounted for. Therefore, a more straightforward program was developed below with the intention of collecting sufficient samples to result in robust statistical analysis of the simple survivability questions.

Study 1. Impingement - Impingement survival studies will be conducted at two-hour intervals over a 24-hour period each month for one (1) year. This will capture both diel and seasonal patterns while capturing enough data points to support statistical analysis. During each interval, the SOC will be collected as they are washed off the screen by placing a small collection tank at the end of the trough built into the traveling screen housing to convey material away after being washed off the screens. This collection will last 10 minutes regardless of the traveling screen operation (continuous or manual operation). Each collection tank will be on a wheeled cart to allow it to be moved away without the need to transfer the collected SOC, and potentially introducing stress/mortality from handling effects. Non-SOC individuals and debris will be carefully removed with a mesh net. Then all dead SOC individuals will be netted out. The condition of these individuals will be assessed to determine the likelihood the individual died as a result of impingement or if it was dead prior to being impinged. All of these individuals will be photographed for archival records. All SOC will be considered dead from impingement if it was alive when collected but died within the next two hours.

Fish survival will be characterized by loss of righting response. Living fish are able to maintain a normal species-specific swimming orientation. Shellfish will be considered alive if movement is observed. Up to 30 individuals of each dead SOC will be identified, measured to the nearest mm length (species-specific appropriate measure), and weighed individually per interval. Individuals beyond this 30 will be counted by species. At the end of the two-hour period, the collection tank will be emptied into a larger tank to hold the SOC for latent mortality studies as described later. All the live SOC will be composited into one latent mortality holding tank. If needed, species will be separated into different tanks to minimize in-tank predation.

Study 2. Fish Return System - Survival through the complete system will also be conducted using a similar design as detailed for Study 1. However, the samples will be collected after the SOC have transited through the fish return system. These studies would not be conducted concurrently; rather, a week would separate the two to allow for the latent mortality study to be completed without interruption or overtaxing the logistical resources.

Latent Impingement Mortality

As noted for Studies 1 and 2, SOC collected and surviving the initial two-hour period would be composited and held for a minimum of four days or 96 hours from the last 2-hr trial. A maximum of 50 individuals will be held to study latent mortality. Limiting the abundance to 50 will minimize potential density effects in the holding tanks. The total sample size will be reduced based on the size of the animals, e.g. large Round Stingrays (*Urobatis halleri*). These individuals will be selected at random to mirror the species-specific impingement proportions to the extent possible. Flow-through seawater systems would feed the tanks with fresh seawater to maintain as near to ambient conditions as possible. On day three, the surviving SOC will be fed according to their species-specific diets, e.g. anchovies or similar for piscivorous species. Uneaten food and feces will be cleaned from the tank. Supplemental aeration will be provided. Each day, the SOC's condition in the tank will be monitored. Animals appearing distressed will be monitored for 10 minutes. If after 10 minutes no improvement is observed, the animal will be considered mortally injured and removed from the tank. This will maintain a healthy environment in the tank and avoid introducing stress/mortality from poor water quality. Water quality in the tank can rapidly deteriorate should an animal die and be left in the tank for an extended period of time. Up to 30 individuals of each dead SOC will be identified, measured to the nearest mm length (species-specific appropriate measure), and weighed individually per day. Individuals beyond this 30 will be counted by species. On the fourth day, the surviving individuals will be assessed and processed as described for dead individuals. The holding tanks will be cleared, cleaned, and made ready for the next trial.

San Gabriel River Fish Survivability Study

Release into the San Gabriel River is one consideration for a fish return system at Haynes Generating Station. Both Haynes and Alamitos Generating Stations currently discharge heated cooling water into the river. This is in addition to discharges into the river from other large, small, and non-point source discharges farther upstream. The combination of all of these discharges could affect the survival of any returned SOC. Therefore, a study of mortality rates among fishes exposed to the San Gabriel River is proposed.

Field collection of live fish can cause mortality on its own, therefore attempts will be made to obtain cultured fish from a southern California hatchery. A hatchery source may be the only way to obtain live individuals in sizes commensurate to what is most commonly impinged at Haynes Generating Station. Small fish are unlikely to survive most field net sampling techniques. Field collections using a beach seine and otter trawl will be attempted in the absence of hatchery sourced fish. Beach seine collection is more likely to result in live, largely undamaged fish than a trawl net effort, but larger numbers of a more diverse number of species can be collected using an otter trawl. To minimize collection-induced mortality, short-duration trawls (3 minutes) will be completed. If possible, a random subsample of the collected fish will be sacrificed and processed to document the species composition, size, and weight of the fishes used in the survival experiments. Any individuals dying as a result of the collection effort will be used instead of sacrificing live individuals if the dead individual is representative of the living fish.

Net enclosures, or net pens, will be deployed in the San Gabriel River assuming regulatory approval. Each enclosure will be anchored to the bottom and break the surface with a removable top to make delivery of new individuals easier but still limit bird predation. The enclosures will be anchored downriver of all power plant discharges but adjacent to the Haynes Generating Station property. This would facilitate delivery of live animals without the need for a boat. Temperature, dissolved oxygen, and salinity data loggers will be placed near the surface, at mid-depth, and near the bottom of the river. While the river is shallow, distinct changes can occur in water quality parameters between the surface and river bed. Mussels (*Mytilus* sp.) will be deployed at the beginning of each sampled quarter as a means of monitoring the contaminant loads in the water the transplanted animals were exposed to in the enclosures. While not known to bioaccumulate all potential contaminants, mussels will bioaccumulate sufficient contaminants to provide a general insight into the river's water quality.

The enclosed fish survival will be monitored twice weekly for three weeks during each quarter, excluding winter. No trials will occur in winter due to the possibility of high river flows following rain events. The high flow, and associated debris, would likely damage the net enclosures deployed in the river. As a reminder, the enclosures will be used to monitor survival, but a full-scale fish return system installed to return marine life would not use enclosures. Rather, marine life would be discharged directly into the river and allowed to move as they see fit.

Still digital images captured from outside of the enclosure will be viewed and the number of fish counted. A total of 60 images from three pre-designated positions (20/position) along the enclosure will be reviewed. At the end of the three weeks, all fish within the enclosure will be captured. Species-specific abundance, length (up to 30 individuals), and weight (up to 30 individuals) will be recorded. Wild caught individuals will be released. Hatchery sourced individuals will be disposed of per the hatchery staff's instructions.

Budget Estimate

Below is the cost estimate by study. These costs represent estimates to conduct Studies 1-3 at one facility. If any or all of Studies 1-3 were commissioned at Haynes and Harbor Generating Stations at the same time, the cost estimated below would apply to each facility individually. We presented the costs in this manner in hopes that it would provide more flexibility in decision making and planning. Reporting cost would be applicable by facility and represent the total reporting cost if all four studies were conducted at Haynes Generating Station (Studies 1-3 and the San Gabriel River Survival Study) with one report encompassing the results of all four impingement mortality reduction studies documented.

Table 1. Cost estimates to conduct Studies 1-3 and reporting at one facility (Harbor or Haynes Generating Station). Estimates apply to either facility.

PROJECT COST SUMMARY

		TASK I: Study 1	TASK 2: Study 2	TASK 3: Study 3	TASK 4: SGR Survival	TASK 5: Reporting
LABOR COSTS		$78,290.00	$71,618.00	$81,102.00	$44,628.00	$27,292.00
DIRECT COSTS						
Subcontractors		$ -	$ -	$ -	$ -	$ -
Other Directs		$8,119.20	$9,119.20	$ 15,934.00	$ 39,612.50	$ -
	Sum Direct Costs	$8,119.20	$9,119.20	$ 15,934.00	$ 39,612.50	$ -
TOTAL ESTIMATED COST BY TASK		$86,409.20	$80,737.20	$ 97,036.00	$ 84,240.50	$ 27,292.00
TOTAL ESTIMATED COST		$ 375,714.90				

Assumptions Included in Budget Estimate

Study 1. Impingement Mortality

- Prior to Month 1 of the study, funds are budgeted for staff to prepare or procure MBC equipment needed to execute the study. This includes setting up equipment at the facility.
- Each month of the study in the days leading up to the experiments at the facility, MBC staff will ready all needed equipment both at MBC's office and at the facility. This will include making sure all equipment is fully operational and in place.
- During the Month 1 experiment, the MBC project manager will join each of the three shifts at the beginning of each shift to conduct on-site training in the sampling design. Costs in excess of the normal monthly sampling program costs, as detailed below, are included to support this training.
- During all 12 months, funds are included in the budget to support three (3) 10-hour shifts of two (2) MBC technicians to conduct the field experiment. This is inclusive of travel time. A typical shift would include approximately eight (8) hours on-site engaged in the experiment and two (2) hours travel time (round trip) between the MBC office and the facility.

Study 2. Fish Return System Survival occurring at least one week after Study 1

- Same budgetary items as listed under Study 1 with the exception of
    - $1000 in misc materials to cover unforeseen costs that will undoubtedly arise during the preparation for Month 1 given the first-of-its-kind fish return system (in southern California at least) to be tested.

Study 3. Latent Mortality

- Extending from Studies 1 and 2, the SOC that survive initial impingement (up to a total of 50) will be kept in a single holding tank
    - A maximum of 50 will be held to minimize potential effects of density within the tank causing mortality
    - The 50 will be chosen at random after the trials are over. To the extent possible, species will be represented in proportions similar to their impingement numbers.
- Prior to Month 1 funds are budgeted for staff to prepare or procure MBC equipment needed to execute the study. This includes setting up equipment at the facility.
- During the study, funds are budgeted to support one MBC technician maintaining the holding tanks daily for four (4) days or 96 hours post impingement. Time will start at end of last 2-hr trial. Each day, the technician will spend six (6) hours tending the tanks, inclusive of travel time. Additional funds are included to purchase food (anchovies, squid, etc.) to use for feeding the animals in the tank. This will be supplemented to the extent possible using fish collected at heat treatments.

Study 4. San Gabriel River Survival 2 weeks/quarter, three quarters during the year

- Funds are budgeted to support field collection of wild animals using an otter trawl and a beach seine during one day effort for each collection method. All labor and equipment are included.
- Funds to procure hatchery fish each quarter
- Funds to procure equipment to deploy into the river to hold the fish and monitor water quality conditions for temperature, dissolved oxygen, salinity, and contamination (mussels)
- Funds to support monitoring during each trial including labor, dive equipment

Appendix C Barrier Net Pilot Study and Operations Cost Estimate

March 26, 2014

Mr. David Bailey
Electric Power Research Institute
8819 Trafalgar Ct.
Springfield, VA 22151

Technical Memo: Potential Barrier Nets at Harbor

Dear Mr. Bailey:

I have included a detailed description of MBC's proposed barrier net fouling study and preliminary cost estimate to maintain a full-scale installation per the Alden design. All estimates are for information and planning purposes, but do not serve as a formal proposal to perform the services. We reserve the right to revise these estimates as needed based on changes in labor and equipment rates when the project is approved and under final negotiation with LADWP.

Respectfully,

MBC *Applied Environmental Sciences*

Eric Miller
Senior Scientist

Fouling Study

Mobilization: 1 X 1 meter square frames will be made of pressure treated lumber and stainless steel hardware. Samples of the two net materials considered for the barrier net will be mounted on each frame. For each net type, a set of six (6) frames will be made and deployed. Replicate pairs will be set at each of three depths: surface, mid-depth, and near-bottom. Each will be weighted down and loosely attached to an anchored mooring line. The frame will be able to slide up and down the mooring line so they can be retrieved from a surface vessel without the need for divers. A main drag line will be attached to the top of the shallow frame and connected to the mooring line buoy to facilitate easy location of the frames. A total of four mooring lines will be installed to support the study. Assumptions include labor and materials to procure and construct the frames and moorings. The preliminary estimated one-time charge is $9000 based on MBC's 2014 labor and equipment rates.

Table 1. Summary of estimated costs for each task.

Task	Subcontractor	MBC
Mobilization	$0	$9,000
Deployment	$0	$5,100
Monitoring	$0	$103,200
Reporting	$0	$6,600
Total	$0	$123,900

Deployment: All moorings and frames will be initially deployed a week before the first month to season frames and minimize any differences in the frames between the surveys. Assumptions include an MBC vehicle, vessel, mileage, fuel, boat captain, two technicians, and the project manager to ensure placement of all moorings and frame deployment proceeds according to plan. The preliminary estimated one-time charge is $5,100 based on MBC's 2014 labor and equipment rates.

Monitoring: Every Monday and Friday for a month each quarter, the frames will be extracted, weighed, and redeployed. Assumptions include 8 hours per event, inclusive of travel time, MBC vehicle, vessel, mileage, fuel, and staff labor. A total of 32 monitoring events are expected. The preliminary estimate is $103,200 based on MBC's 2014 labor and equipment rates.

Reporting: MBC will prepare a complete report, inclusive of all data, summarizing the results. Assumptions include only labor charges associated with the data analysis and report production. The preliminary estimated one-time charge is $6,600 based on MBC's 2014 labor and equipment rates.

Barrier Net Maintenance

Standard Event: MBC proposes to deploy two boats to extract the in-place net and replace it with an exact replica net. We assume that the Harbor Generating Station staff will take possession of the net and allow it to dry out somewhere on the facility's property. All support pilings will be installed by maritime construction firm unaffiliated with MBC and not under subcontract to MBC. A standard event assumes no complications with the net retrieval, such as snagging a piling or stuck under debris. In these events a diver would be needed as detailed under the following diver contingency. For each maintenance event, MBC staff will pick up the dried net from the facility and prep it for deployment the day before deployment (Monday-Friday excluding holidays). Costs are presented on a per-event basis and an annual total assuming 92 (365 days/4day intervals) events. Assumptions include three MBC vehicles, two vessels, mileage, fuel, boat launch fees, boat captain, and technicians. A standard maintenance event is budgeted for an eight-hour day inclusive of all travel on the day the net is switched out. An additional labor charge is budgeted for prepping the net each time. The preliminary estimated charge is $6,900/event or $634,800/92 events based on MBC's 2014 labor and equipment rates.

Diver Contingency: MBC anticipates that the net will not be retrievable by a surface vessel for some reason (snagged on a piling, large debris, etc.). In these instances, a commercial diving enterprise will be needed to free the net and bring it to the surface. MBC will provide one vessel and crew on these instances to assist, but we expect the diving company will not want MBC vessels maneuvering in the area while their divers are submerged. An exact estimate was not solicited from a diving contractor, but we anticipate $10,000 per event would likely suffice. This would need to be verified in a formal cost proposal should the project be selected for installation. Assumptions include six (6) events per year, one MBC vehicle, one MBC vessel, mileage, fuel, boat captain, and technicians. The preliminary estimated one-time charge is $13,400/event or $80,400/6 events based on MBC's 2014 labor and equipment rates.

Table 2. Summary of estimated costs for 92 standard maintenance events and six diver contingency events when commercial divers are needed to free the barrier net from some submerged hang up.

Task	Subcontractor	MBC
Standard Event	$0	$634,800
Diver Contingency	$60,000	$20,400