POSEIDON WATER

Appendix B
Intake/Discharge Feasibility Report

Renewal of NPDES CA0109223
Carlsbad Desalination Project

Carlsbad Desalination Plant Intake/Discharge Feasibility Assessment

Prepared for

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Executive Summary

Poseidon contracted with Alden Research Laboratory Inc. (Alden) to prepare this feasibility study to determine the best available site, design, technologies, and mitigation feasible to minimize intake and mortality of all forms of marine life while transitioning the Carlsbad Desalination Project (CDP) to long term stand-alone operation and increasing plant production to capture recent improvements in the reverse osmosis technology installed at the CDP.

For purposes of Chapter III.M., "feasible" was defined as capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors. We evaluated each of these feasibility criteria for each of the four combinations of intake/discharge approaches. The intake/discharge approaches included in the this study were: 1) a subsurface seafloor infiltration gallery (SIG) intake with discharge flow augmentation, 2) a subsurface seafloor infiltration gallery (SIG) intake with a discharge diffuser, 3) a surface screened intake with discharge flow augmentation, and 4) a surface screened intake with a discharge diffuser.

Relative to the intake alternatives, a recognized advantage of a SIG is its ability to withdraw seawater without impinging or entraining marine life. However, there are a paucity of data on the effective design and operation of SIG intakes for the flows required for the CDP. Conversely, impingement and entrainment can be a concern at screened intakes, though technologies exist to (e.g., fish-friendly modified traveling water screens) minimize this risk. In addition, screened intakes have a long performance record, ensuring that feedwater can be reliably withdrawn for the seawater reverse osmosis (SWRO) process.

This analysis indicates that the screened intake with discharge flow augmentation is the best alternative for the CDP when it begins long term stand-alone operation (see Figure 11). The Bilfinger Water Technology (BWT) center-flow traveling water screens specified for the new intake/discharge structure are considered state-of-the-art for minimizing impingement mortality. The use of 1.0-mm mesh on the BWT center-flow traveling water screens would reduce the potential for entrainment and complies with the screen mesh size requirement in the Amendment to the Water Quality Control Plan for Ocean Waters of California Addressing Desalination Facility Intakes and Brine Discharges (Desalination Amendment). The use existing infrastructure also has very few impacts relative to the alternatives that include constructing a SIG within the Agua Hedionda Lagoon complex. A SIG would require heavy construction both within Agua Hedionda Lagoon and along its shoreline.

The use of flow augmentation with fish-friendly pumps would limit the number of organisms exposed to injury and mortality when compared to the alternative of a multiport diffuser. It is also important to note that the screened intake with discharge flow augmentation alternative can be constructed fully within the existing industrial footprint, unlike the options that consider multiport diffuser or subsurface intakes which all require substantial disturbance of the benthos in surrounding waterbodies.

A comprehensive comparison of the feasibility criteria for the Expanded CDP is presented in the table below.

Carlsbad Desalination Project Intake and Discharge Alternatives

Comparison of Environmental, Schedule and Cost Impacts

Alternative	1	2	3	4
Intake/Discharge Configuration	**Surface Screened Intake with Flow Augmentation**	**Surface Screened Intake with Multiport Diffuser**	**Subsurface Intake with Flow Augmentation**	**Subsurface Intake with Multiport Diffuser**
Intake Water Potentially Exposed to 100% Mortality	128 MGD	128 MGD	0 MGD	0 MGD
Flow Augmentation Water Potentially Exposed to 100% Mortality	171 MGD	0 MGD	0 MGD	0 MGD
Diffuser Water Potentially Exposed to 23% Mortality	0 MGD	217 MGD	0 MGD	217 MGD
Total Water Potentially Exposed to Mortality	299 MGD	345 MGD	0 MGD	217 MGD
Area of Production Foregone	84 Acres[1]	103 Acres[1]	0 Acres	67 Acres[1]
Brine Mixing Zone @ 35.5 ppt	15.5 Acres[2]	14.4 Acres[2]	15.5 Acres[2]	14.4 Acres[2]
Permanent Construction Impacts to Marine Environment	0 Acres	1 Acre	72 Acres	33 Acres
Total Area Impacted Entrainment, Brine Mixing Zone and Construction	99.5 Acres	118.4 Acres	87.5 Acres	114.4 Acres
Permitting Schedule	1.5 Years	3.0 Years	3.0 Years	3.0 Years
Construction Schedule	2.0 Years	3.0 Years	7.2 Years	3.8 Years
Total Duration	3.5 Years[3]	6.0 Years[3]	10.2 Years[3]	6.8 Years[3]
Total Project Cost	$47,108,597[4]	$425,024,742[4]	$1,308,495,009[4]	$745,549,704[4],

[1] Area of Production Foregone is calculated as described in Appendix E of the Staff Report for Amendment to the Water Quality Control Plan for Ocean Waters of California Addressing Desalination Facility Intakes, Brine Discharges, and the Incorporation of other Non-substantive Changes (hereafter, "Appendix E of the Staff Report"). See Report of Waste Discharge Appendix K, Carlsbad Desalination Facility Entrainment Analysis for Dilution and Discharge Options Entrainment Analysis, MBC, July 27, 2015.

[2] Brine Mixing Zone is calculated as described in Section 3.D.

[3] See Appendix Y for project schedule.

[4] See Appendix N and Appendix X for detailed cost estimates.

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1. Introduction

A. Project Purpose and Background

Poseidon contracted with Alden Research Laboratory Inc. (Alden) to prepare this feasibility study to determine the best available site, design, technologies, and mitigation feasible to minimize intake and mortality of all forms of marine life while transitioning the Carlsbad Desalination Project (CDP) to long term stand-alone operation and increasing plant production to capture recent improvements in the reverse osmosis technology installed at the CDP.

The CDP is currently permitted to produce up to 56,000 acre feet per year (AFY) of desalinated water while operating in conjunction with the Encina Power Station (EPS) by using the power plant's cooling water discharge as its source water. The planned retirement of the EPS at the end of 2017 will result in the need to retrofit the CDP for a transition to long term stand-alone operation. At such time, the CDP will be considered an "*expanded facility*" and will become subject to the provisions of Chapter III.M of the Water Quality Control Plan, Ocean Waters of California (Desalination Amendment).

Poseidon also seeks to increase the rated capacity of the CDP to realize the improvements in reverse osmosis membrane production capabilities since the original CDP approvals. The membrane technology advances enable the CDP to increase potable water output from an annual average of 56,000 AFY (maximum production rate of 54 million gallons per day [MGD]) to an annual average of 62,000 AFY (maximum production rate of 60 MGD) with minimal improvements to the plant. Therefore, relative to comparison purposes, the feasibility analysis assumes the maximum production rate of 60 MGD across all of the long term stand-alone options evaluated.

i. Existing Project Operations

The seawater desalination plant is currently co-located with the EPS. A key feature of the co-location concept is the direct connection of the CDP intake and discharge facilities to the discharge tunnel of the power generation plant. This approach allows use of the power plant cooling water system discharge which serves as both source water for the seawater desalination plant and as a blending water to reduce the salinity of the desalination plant concentrate prior to discharge to the ocean. Figure 1 illustrates the co-location configuration of the CDP and EPS intake and discharge facilities.

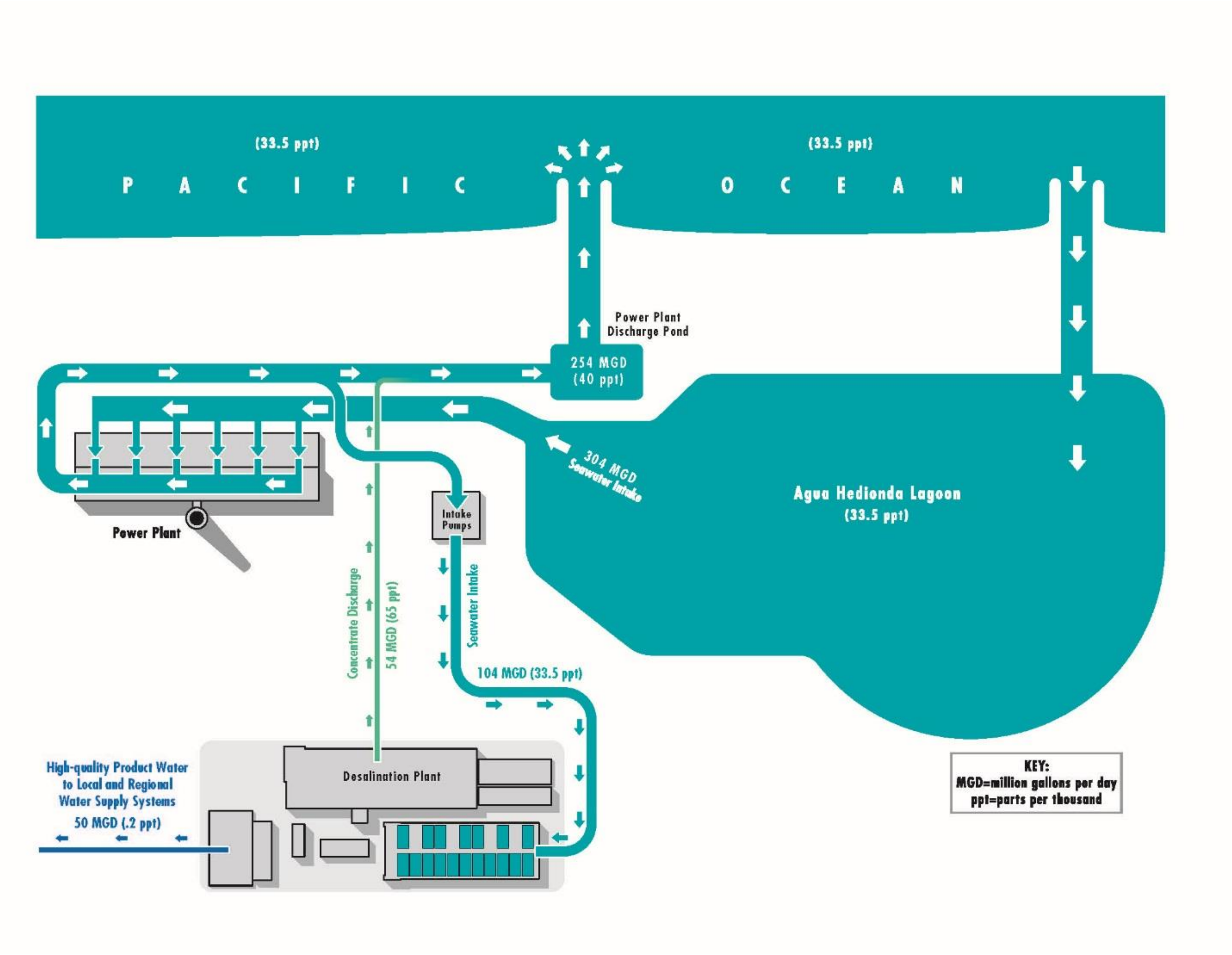


Figure 1. Co-Location of Carlsbad Desalination Plant and Encina Power Station

As shown on Figure 1, under typical operating conditions for the CDP, approximately 304 million gallons per day (MGD) of seawater enter the EPS intake facilities, and after screening are pumped through the EPS's condensers to the discharge tunnel. The CDP intake structure is connected to the discharge tunnel and under normal operating conditions will divert 104 MGD of the 304 MGD of EPS cooling water system discharge for production of fresh drinking water.

Approximately 104 MGD of the diverted seawater is converted to 50 MGD of fresh drinking water which is piped to the San Diego County Water Authority delivery system in the City of San Marcos. The remaining flow (54 MGD) is returned to the EPS discharge tunnel for blending with cooling water prior to discharge to the Pacific Ocean. The discharge consists of brine produced by the reverse osmosis process (50 MGD) and treated backwash water from the pretreatment filters (4 MGD). The salinity of the discharge prior to augmentation is 65 parts per thousand (ppt). The existing NPDES permit requires that the brine is diluted to 40 ppt prior to discharge. This is accomplished by mixing the CDP discharge with approximately 200 MGD of cooling water system discharge from the EPS. The combined CDP discharge and dilution water flow is approximately 254 MGD.

On rare occasions when the EPS' cooling water system discharge is less than 304 MGD, the NPDES permit for the CDP allows EPS to temporarily pump seawater to meet CDP's flow requirements.

a. Objective of Analysis

The Desalination Amendment requires that the Regional Water Board conduct a Water Code section 13142.5(b) analysis of all expanded desalination facilities. The Regional Water Board's analysis for expanded facilities may be limited to expansions or other changes that result in the increased intake or mortality of all forms of marine life. The objective of this feasibility analysis is to determine the best available site, design, technology, and mitigation to minimize the intake and mortality of all forms of marine life while accommodating the transition of the CDP to long term stand-alone operation and increasing plant production to capture recent improvements in the reverse osmosis membrane technology. The analysis will provide general descriptions of the intake/discharge alternatives evaluated and the component pieces that will aid in determining the overall feasibility of each alternative for meeting the project goals. Consistent with the definition of feasibility set forth in the Desalination Amendment, this feasibility analysis evaluates whether the intake and discharge alternatives are capable of being accomplished in a successful manner, within a reasonable period of time, taking into account economic, environmental, social, and technological factors.

2. Description of the Intake/Discharge Alternatives

A. Intake Options – General Description

The Desalination Amendment provides that the Regional Water Board in consultation with the State Water Board shall require subsurface intakes unless it determines that subsurface intakes are not feasible. If subsurface intakes are not feasible, then surface intakes may be used. This feasibility assessment provides an analysis of the subsurface and surface intakes described below.

i. Subsurface Intake

The feasibility of various intake configurations (beach wells, slant wells, horizontal wells, offshore subsurface infiltration galleries, and the existing EPS intake) was extensively studied in the environmental impact report (City of Carlsbad EIR 03-05) and Coastal Development Permit (CDP) (California Coastal Commission CDP E-06-013) review phases of the CDP. A thorough review of the site-specific applicability of subsurface intake technology supported by a comprehensive hydrogeological study of the subsurface conditions in the vicinity of the CDP concluded that the subsurface intakes studied at that time were not feasible due to limited production capacity of the subsurface geological formation, poor water quality of collected source water, excessive cost, and environmental considerations (i.e., construction and operational impacts, aesthetics).

The conditions that led the City of Carlsbad and the Coastal Commission to find that beach wells, slant wells, horizontal wells, and offshore seafloor infiltration galleries were not feasible for the CDP have not changed. However, one new subsurface alterative is evaluated herein as a measure of due diligence. The subsurface intake type considered for the long term stand-alone CDP is a seafloor infiltration gallery (SIG) located in Agua Hedionda Lagoon. A general description of the SIG is provided below. The SIG would essentially eliminate the impingement and entrainment of marine life; however, a number of practical limitations limit the feasibility of the SIG for the long term stand-alone CDP.

a. Seafloor Infiltration Gallery (SIG)

A seafloor infiltration gallery (SIG), also known as a subsurface infiltration gallery or seabed infiltration gallery is a subsurface intake technology. A SIG consists of a submerged collector pipe system installed beneath the seafloor and buried under permeable engineered fill. The collector pipes converge and would be tied into an intermediate pump station for conveyance to the SWRO Pump Station where water is pumped to the treatment system and, under one of the discharge alternatives evaluated herein, it would also be tied into the Flow Augmentation Pump Station. The SIG would be located in the existing source waterbody, Agua Hedionda Lagoon.

ii. Surface Intake

The surface intake considered for the long term stand-alone CDP would be designed to minimize impacts to marine life. Intake water would be withdrawn directly from the EPS intake tunnels on Agua Hedionda Lagoon rather than from the CDP's existing intake connection to the EPS discharge tunnel. Two pump stations would be connected to the intake tunnels: (1) the existing intake pump station which provides feedwater to the CDP's seawater reverse osmosis process (the "SWRO Pump Station"); and (2) a new pump station that would provide seawater for initial dilution of the brine discharge from the CDP (the "Flow Augmentation Pump Station"). The intake screening technologies that have been evaluated for the pump stations are considered state-of-the art for protecting marine life and were selected to fit within the small footprint available at the existing EPS. As provided in the Desalination Amendment, through-screen velocities were designed to meet the 0.5-ft/sec criterion to minimize impingement, the 1.0-mm screen mesh size was selected to minimize impingement and entrainment of marine organisms in the SWRO Pump Station, and a combination of screening technology and fish-friendly pumps were selected to minimize impingement and entrainment mortality in the Flow Augmentation Pump Station.

B. Discharge Options – General Description

The Desalination Amendment provides that the preferred technology for minimizing intake and mortality of marine life resulting from the discharge of brine is to comingle brine with wastewater that would otherwise be discharged to the ocean. Multiport diffusers are the next best method for disposing of brine when the brine cannot be diluted by wastewater. Brine disposal technologies other than wastewater dilution and multiport diffusers, such as flow augmentation, may be used at the CDP if Poseidon can demonstrate that the technology provides a comparable level of intake and mortality of all forms of marine life as wastewater dilution if wastewater is available, or multiport diffusers, if wastewater is unavailable. This feasibility assessment includes an evaluation of each of these discharge options; each is described in further detail below

i. Commingling With Wastewater

To be considered available, wastewater must provide adequate dilution to ensure that the salinity of the comingled discharge meets the receiving water limitation for salinity (approximately 35.5 ppt). To achieve this level of dilution, 60 MGD brine will need to be blended with a sufficient quantity of treated municipal wastewater to reduce the combined discharge to approximately 35.5 ppt.

The closest source of treated wastewater is the Encina Water Pollution Control Facility (EWPCF) owned by the Encina Wastewater Authority. The EWPCF is located approximately two miles south of the CDP. The average daily flow at the EWPCF is 21.6 MGD, which is adequate dilution to reduce the salinity of the CDP discharge to approximately 49 ppt.

The next closest source of treated wastewater is the Oceanside outfall serving San Luis Rey Wastewater Treatment Plant, the Las Salina Wastewater Treatment Plant, the Fallbrook Public Utility District Wastewater Treatment Plant, Camp Pendleton and the Oceanside brackish water reverse osmosis facility. The Oceanside outfall is located approximately ten miles north of the CDP. The current daily flow in the outfall is approximately 20 MGD, which is adequate dilution to reduce the salinity of the CDP discharge to approximately 50 ppt.

As noted above, wastewater within reasonable proximity to the CDP does not provide adequate dilution to ensure that the salinity of the comingled discharge will reliably meet the receiving water limitation for salinity (approximately 35.5 ppt). Additionally, both wastewater treatment facilities have plans for expanded water recycling, which would further reduce the opportunity for commingling with brine. Therefore, wastewater is unavailable, and this alternative will be dropped from further consideration in this feasibility assessment.

ii. Diffuser

An offshore multiport diffuser is a submerged outfall used to discharge undiluted brine through multiple high velocity ports. The brine is quickly mixed with the receiving waterbody to reduce salinity and encourage dispersion of the plume. Multiport diffusers do not require additional intake flow, but the features that maximize mixing (e.g., high velocity) also have potential to entrain and injure marine life. A multiport diffuser at the CDP would be located approximately 4,000 feet offshore and would discharge undiluted brine at a high velocity to the Pacific Ocean.

iii. Flow Augmentation

Flow augmentation is the withdrawal of additional flow through the intake to provide initial dilution of the brine produced by the SWRO process. Flow augmentation at the CDP would be accomplished through the use of low-impact fish-friendly pumps to minimize potential stresses to entrained marine life. Flow augmentation water would be withdrawn through separate intake screens at a new pump station adjacent to the new intake screens to be installed upstream of the existing SWRO Pump Station.

C. Subsurface Intake/Discharge Alternatives – General Description

The Desalination Amendment requires the Regional Water Board conduct a Water Code section 13142.5(b) analysis of all new and expanded desalination facilities. A Water Code section 13142.5(b) analysis may include future expansions at the facility. The regional water board shall first analyze separately, as independent considerations, a range of feasible alternatives for the best available site, the best available design, the best available technology, and the best available mitigation measures to minimize intake and mortality of all forms of marine life. The Regional Water Board shall then consider the best available design, the best available technology, and the best available mitigation measures collectively and determine the best combination of feasible alternatives to minimize intake and mortality of all forms of marine life.

Poseidon has evaluated the various combinations of intake and discharge arrangements to provide a comprehensive review of all potential options. Each of these intake/discharge combinations is presented below in greater detail.

The feasibility of certain subsurface intakes (beach wells, slant wells, horizontal wells, and offshore subsurface infiltration galleries) was extensively studied in the environmental impact report (City of Carlsbad EIR 03-05) and Coastal Development Permit (California Coastal Commission CDP E-06-013) review phases of the CDP. A thorough review of the site-specific applicability of subsurface intake technology, supported by a comprehensive hydrogeological study of the subsurface conditions in the vicinity of the CDP, concluded that the subsurface intakes studied at that time were not feasible due to limited production capacity of the subsurface geological formation, poor water quality of collected source water, excessive cost, and environmental considerations.

The conditions that led the City of Carlsbad and the Coastal Commission to find that beach wells, slant wells, horizontal wells, and offshore seafloor infiltration galleries were not feasible for the CDP have not changed. However, one new subsurface intake alternative is evaluated below as a measure of due diligence. The subsurface intake considered for the long term stand-alone CDP is a seafloor infiltration gallery (SIG) located in Agua Hedionda Lagoon. The following sections describe the SIG in conjunction with flow augmentation and with an offshore diffuser.

i. Subsurface Intake (SIG) with Flow Augmentation

a. Site

The Agua Hedionda Lagoon complex is divided into three bodies of water herein referred to as the "west lagoon", "middle lagoon", and "east lagoon". A depiction of the lagoon complex is shown below in Figure 2. A narrow passageway of approximately eighty (80) linear feet exists between the west lagoon and the middle lagoon, and a narrow passageway of approximately one hundred twenty (120) linear feet exists between the middle lagoon and the east lagoon. Overhead crossings exist at these two passageways for the rail road and the I-5 freeway, respectively.

Seawater tidally migrates into the lagoon via connection with the Pacific Ocean south of Tamarack Avenue. Tidal migration of seawater into the lagoon has also been associated with migration of fine grained sediments into the west lagoon. Therefore, regular maintenance dredging has been required to maintain the flow of seawater into and out of the lagoon complex.

Implementation of a SIG intake with discharge flow augmentation requires the placement of infiltration galleries in the west, middle, and east lagoon sections. Feedwater would be withdrawn from the lagoon via the infiltration galleries and conveyed to an Intermediate Pump Station located adjacent to the existing SWRO Pump Station. Source water would be pumped from the Intermediate Pump Station to the existing SWRO Pump Station for conveyance to the desalination plant.

Heavy construction would be required along the lagoon shoreline for placement of the Intermediate Pump Station and associated piping. Similarly, heavy construction in the lagoon complex associated with construction of the infiltration galleries would result in temporary loss of the lagoon for recreation, permanent loss of aquaculture use, and conversion of up to 100 acres of subtidal mudflats to engineered fill and pipe galleries.

Brine from the CDP would be mixed with augmentation flow in the existing EPS discharge tunnel and ultimately be discharged to the Pacific Ocean. There would be no change in the receiving waterbody nor would the discharge plan require any structural modification to the existing EPS discharge pond or ocean outfall. A general schematic of the layout is provided in Figure 3.

Figure 2. Agua Hedionda Lagoon complex.

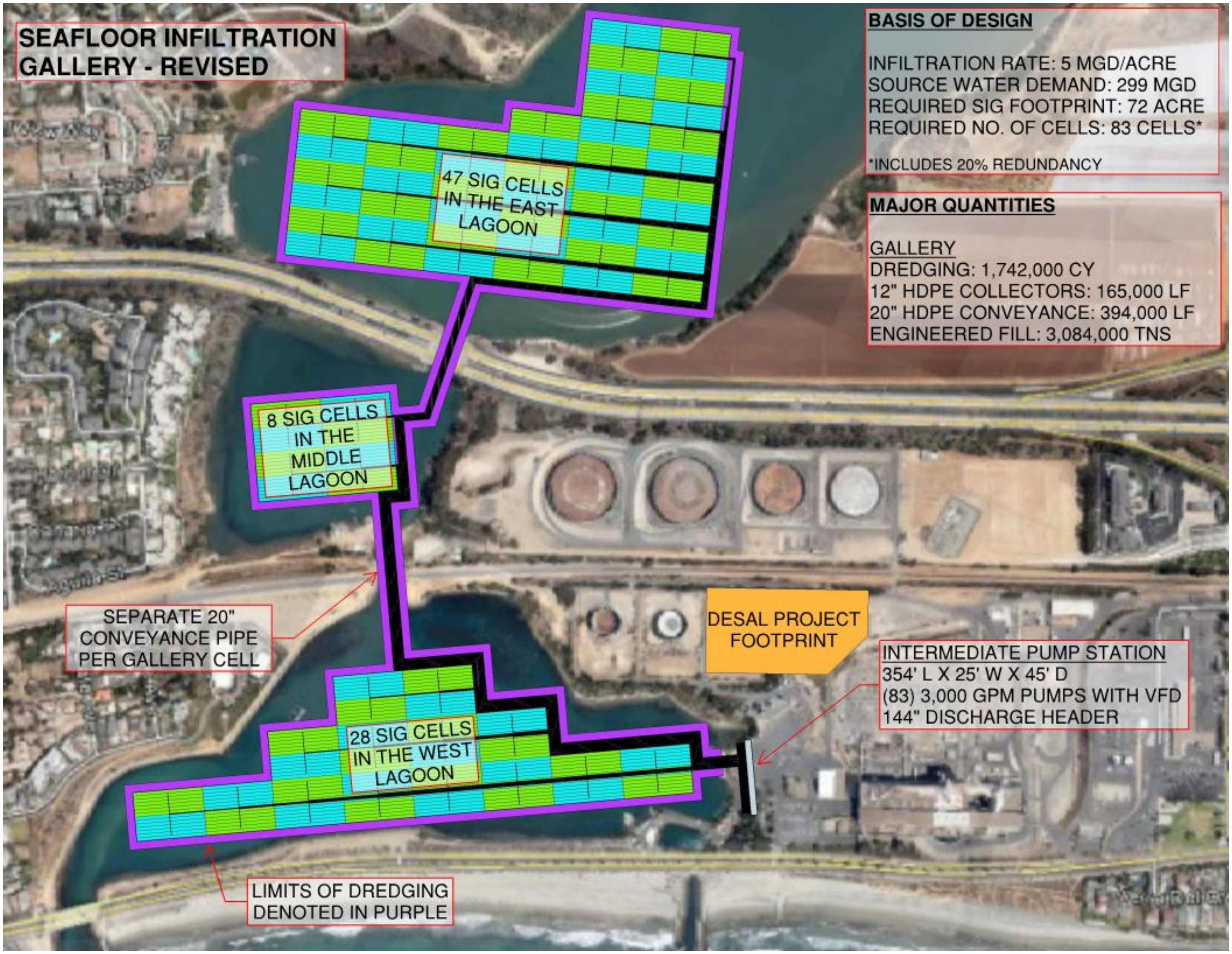


Figure 3. SIG design for discharge flow augmentation.

b. Design

A SIG consists of a submerged collector pipe system installed beneath the seafloor and buried under permeable engineered fill as shown in Figure 4 below.

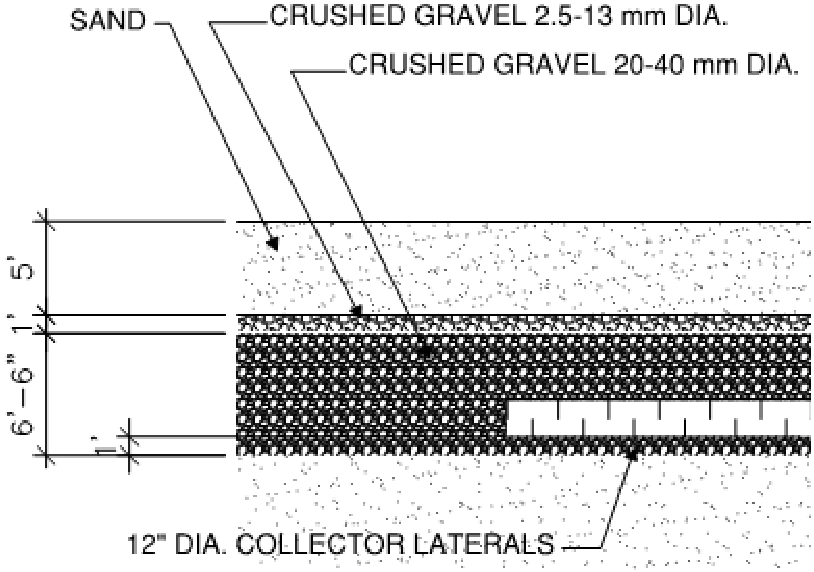


Figure 4. SIG profile.

A SIG is sized and configured using the same design criteria as a slow sand filter. A design loading rate (rate at which water will flow through permeable substrate) of 5 MGD / acre was selected based on recommendations from the Independent Science and Technical Advisory Panel (ISTAP) evaluating subsurface intakes for the proposed Huntington Beach Desalination Facility on behalf of Poseidon Water and the California Coastal Commission (Report of Waste Discharge Appendix U). In consideration of this loading rate, and an ISTAP recommended 20% redundancy factor, the implementation of a SIG intake with discharge flow augmentation requires approximately seventy-two (72) acres of gallery.

The seventy-two (72) acres of gallery would be divided into individual cells of 328 feet long by 115 feet wide by 12.5 feet deep, resulting in a total of eighty-three (83) cells. Per the ISTAP recommendations, each cell consists of twelve (12) inch perforated collector pipes and twenty (20) inch conveyance pipes (Figure 5). Collector pipes have been arranged to optimally reduce head loss differential across an individual cell. In addition, the depth of each cell has been designed to achieve optimal bed contact time between the source water and gallery media.

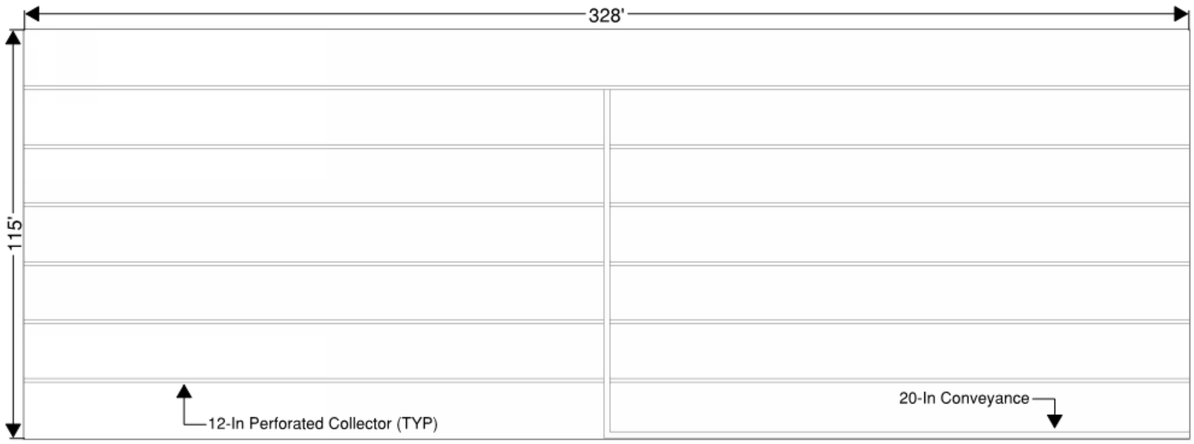


Figure 5. General arrangement of individual SIG cells.

Each of the eighty-three (83) cells is expected to foul (i.e., clog or plug) at different rates due to varying physical location, depth of water, quality of water, water currents, etc. Therefore, each cell has been designed with a stand-alone conveyance pipe to transmit water from the cell to the Intermediate Pump Station. At the Intermediate Pump Station, each cell is connected to a designated 3,000 gallons per minute (GPM) pump with variable frequency drive (VFD). The intent of stand-alone piping, pumps, and VFD is to guarantee consistent flow through each cell despite projected non-uniform fouling from cell to cell.

A depiction of the gallery, conveyance piping, and pump station is shown above in Figure 3.

c. Technology

A seafloor infiltration gallery (SIG), also known as a subsurface infiltration gallery or seabed infiltration gallery, is a subsurface intake technology. This technology is intended to passively exclude marine life from source water intake. Please see above for additional information related to implementation, layout, and design.

ii. Subsurface Intake (SIG) with Discharge Diffuser

a. Site

Please see above under *Subsurface (SIG) Intake with Discharge Flow Augmentation* for information regarding the Agua Hedionda Lagoon complex.

A new multiport diffuser system would be located approximately 4,000 ft offshore, 3,280 ft feet northwest of kelp beds. The diffuser system would be designed to maximize dilution, minimize the size of the brine mixing zone, minimize the suspension of benthic sediments, and minimize marine life mortality in accordance with the provisions of the Ocean Plan. A general schematic of the layout is provided in Figure 6 with additional detail of the terminus provided in Figure 7.

Figure 6. General schematic of the layout of the CDP with a screened intake and discharge diffuser.

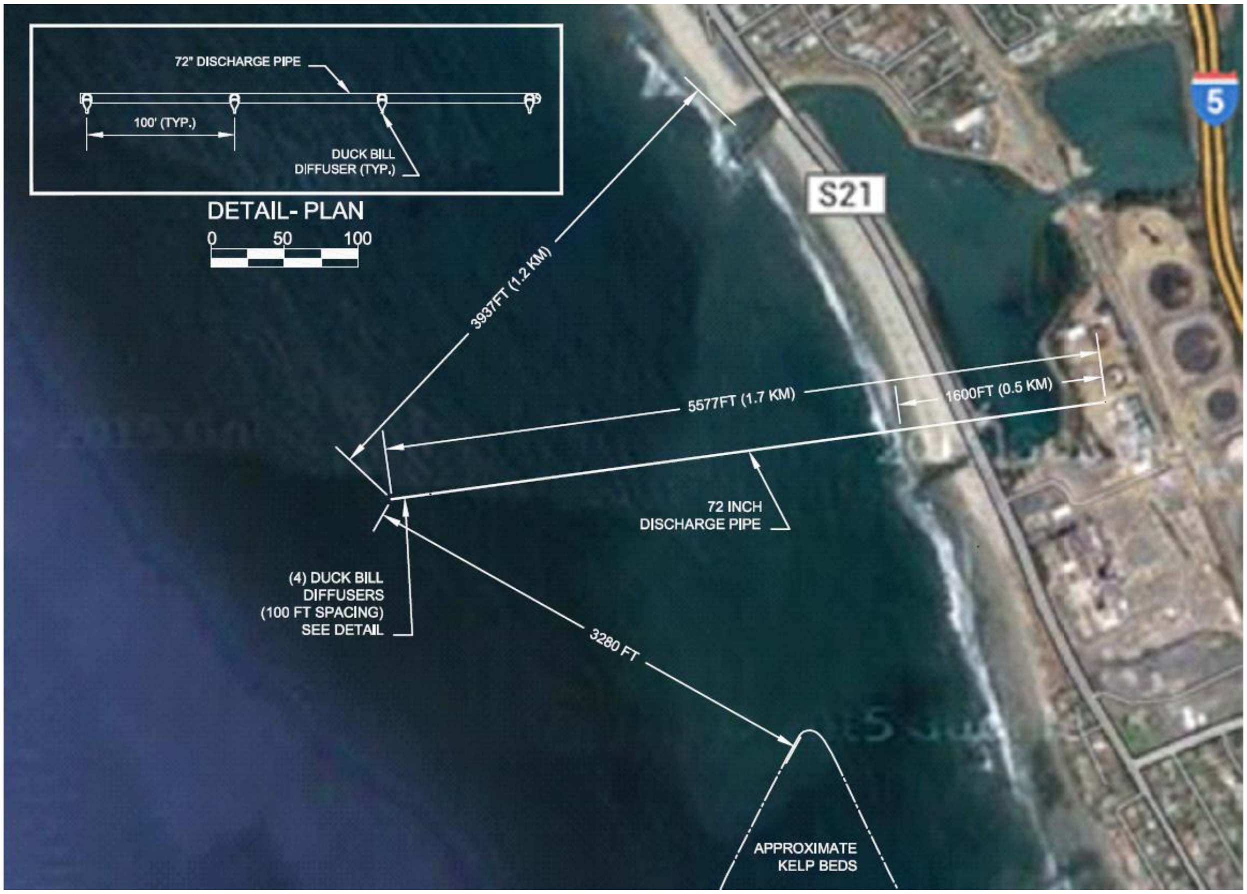


Figure 7. General schematic of the layout of the CDP discharge diffuser array.

Approximately 127.5 MGD of seawater would be withdrawn from the Lagoon -- 127 MGD for processing by the CDP and approximately 0.5 MGD for screen wash and fish return. Approximately 60 MGD of the diverted seawater would be converted to fresh water which would be piped to the San Diego County Water Authority delivery system in the City of San Marcos. The remaining flow (67 MGD) leaving the SWRO building would be discharged through a multiport diffuser system to the Pacific Ocean. The discharge would consist of brine produced by the reverse osmosis process (60 MGD) and treated backwash water from the pretreatment filters (7 MGD). The salinity of the discharge prior to dilution is approximately 65 ppt (67 ppt with no backwash water included) whereas the average salinity of the ambient seawater in the vicinity of the diffuser would be 33.5 ppt. As compared to the existing project operations described in Section 1.A.i, the CDP operations described above would achieve a 10% average annual increase in fresh drinking water production while reducing total quantity of seawater required.

The Desalination Amendment provides that the discharge shall not exceed a daily maximum of 2.0 parts per thousand (ppt) above natural background salinity measured at the edge of the brine mixing zone 100 meters (328 ft.) seaward of the end of the diffuser. Over the last 20 years, the natural background salinity at the closest reference site (Scripps Pier) has measured a minimum salinity of 30.4 ppt, maximum salinity of 34.2 ppt and an average salinity of 33.5 ppt. Therefore, under average conditions, the discharge shall not exceed a daily maximum of 35.5 ppt 100 meters (328 ft.) from the diffuser ports (the edge of the brine mixing zone).

b. Design

A SIG consists of a submerged collector pipe system installed beneath the seafloor and buried under permeable engineered fill as shown in Figure 4.

A SIG is sized and configured using the same design criteria as a slow sand filter. A design loading rate (rate at which water will flow through permeable substrate) of 5 MGD / acre was selected based on recommendations from the Independent Science and Technical Advisory Panel (ISTAP) evaluating subsurface intakes for the proposed Huntington Beach Desalination Facility on behalf of Poseidon Water and the California Coastal Commission (Report of Waste Discharge Appendix U). In consideration of this loading rate, and an ISTAP recommended 20% redundancy factor, the implementation of a SIG intake with discharge diffuser requires approximately thirty-two (32) acres of gallery.

The thirty-two (32) acres of gallery would be divided into individual cells of 328 feet long by 115 feet wide by 12.5 feet deep, resulting in a total of thirty-six (36) cells. Per the ISTAP recommendations, each cell consists of twelve (12) inch perforated collector pipes and twenty (20) inch conveyance pipes (Figure 5). Collector pipes have been arranged to optimally reduce head loss differential across an individual cell. In addition, the depth of each cell has been designed to achieve optimal bed contact time between the source water and gallery media.

Each of the thirty-six (36) cells is expected to foul (i.e., clog or plug) at different rates due to varying physical location, depth of water, quality of water, water currents, etc. Therefore, each cell has been designed with a stand-alone conveyance pipe to transmit water from the cell to the

Intermediate Pump Station. At the Intermediate Pump Station, each cell is connected to a designated 3,000 gallons per minute (GPM) pump with variable frequency drive (VFD). The intent of stand-alone piping, pumps, and VFD is to guarantee consistent flow through each cell despite projected non-uniform fouling from cell to cell.

A depiction of the gallery, conveyance piping, and pump station is shown below in Figure 8.

A 72" outfall pipeline extending approximately 4,000 feet offshore would convey the brine discharge from the SWRO building to the multiport diffuser system where four duck-bill diffuser ports spaced 100' ft. apart would eject the brine into the water column at a high velocity to promote rapid diffusion and dispersion. A general schematic of the outfall location with additional detail of the terminus is provided in Figure 7.

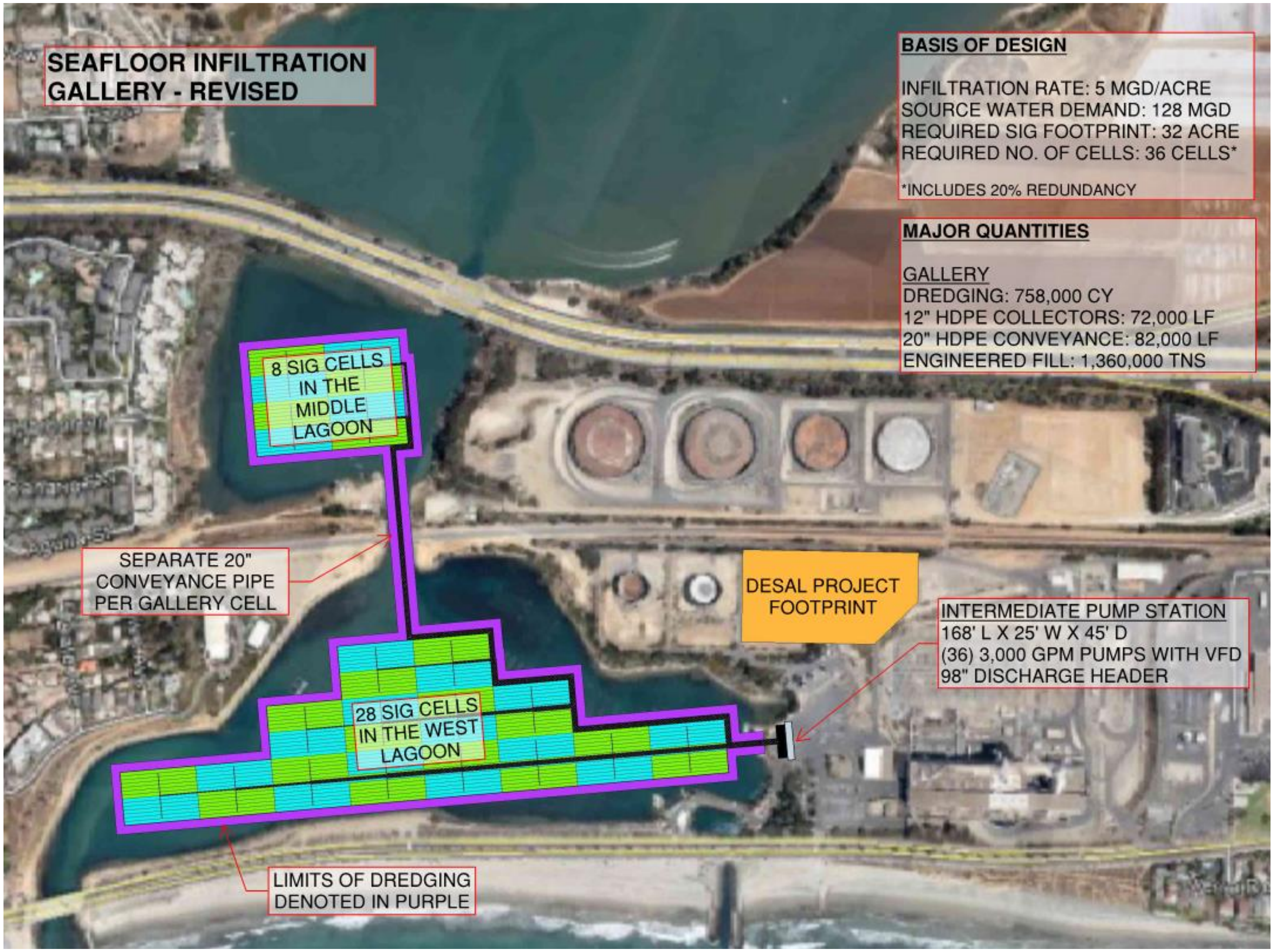


Figure 8. SIG design for discharge diffuser

c. Technology

A seafloor infiltration gallery (SIG), also known as a subsurface infiltration gallery or seabed infiltration gallery, is a subsurface intake technology. This technology is intended to passively exclude marine life from source water intake. Please see above for additional information related to implementation, layout, and design.

A new multiport diffuser system would be designed to maximize dilution, minimize the size of the brine mixing zone, minimize the suspension of benthic sediments, and minimize marine life mortality in accordance with the provisions of the Desalination Amendment. As provided in the Desalination Amendment, the brine mixing zone extends 100 m (328 ft) laterally from each of the points of discharge. As shown in Figure 7, the design features include:

- Tie-In to the exiting CDP brine outfall line
- Installation of 6000 linear feet (1000 feet onshore and 4,000 feet offshore of 72-inch conveyance tunnel
- Installation of four high pressure multiport diffusers spaced approximately 100 feet apart
- A brine mixing zone of approximately 14.4 acres.

D. Surface Intake/Discharge Alternatives – General Description

The Desalination Amendment requires the Regional Water Board conduct a Water Code section 13142.5(b) analysis of all new and expanded desalination facilities. A Water Code section 13142.5(b) analysis may include future expansions at the facility. The regional water board shall first analyze separately, as independent considerations, a range of feasible alternatives for the best available site, the best available design, the best available technology, and the best available mitigation measures to minimize intake and mortality of all forms of marine life. The Regional Water Board shall then consider the best available design, the best available technology, and the best available mitigation measures collectively and determine the best combination of feasible alternatives to minimize intake and mortality of all forms of marine life.

Poseidon has evaluated the various combinations of intake and discharge arrangements to provide a comprehensive review of all potential options. Each of these intake/discharge combinations is presented below in greater detail. The following sections describe the two surface intake/discharge alternatives that were evaluated (i.e., with flow augmentation and with an offshore diffuser).

i. Screened Intake with Discharge Flow Augmentation

a. Site

A new structure would be constructed to house the traveling water screens to be installed upstream of the SWRO Pump Station as well as the screens and pumps for the Flow Augmentation Pump Station (collectively the “New Screening/Fish-friendly Pumping

Structure”). The New Screening/Fish-friendly Pumping Structure would be located between the existing EPS intake tunnels to the east and the SWRO Pump Station to the west. Feedwater and flow augmentation water for the CDP would be withdrawn through the existing EPS trash rack structure in the Lagoon. There would be no change in the source waterbody nor would the new screening structure require any heavy shoreline construction in the Lagoon. Similarly, brine from the CDP would be mixed with augmentation flow in the existing EPS discharge tunnel and ultimately be discharged to the Pacific Ocean. There would be no change in the receiving waterbody nor would the discharge plan require any structural modification to the existing EPS discharge pond or ocean outfall. A general schematic of the layout is provided in Figure 9

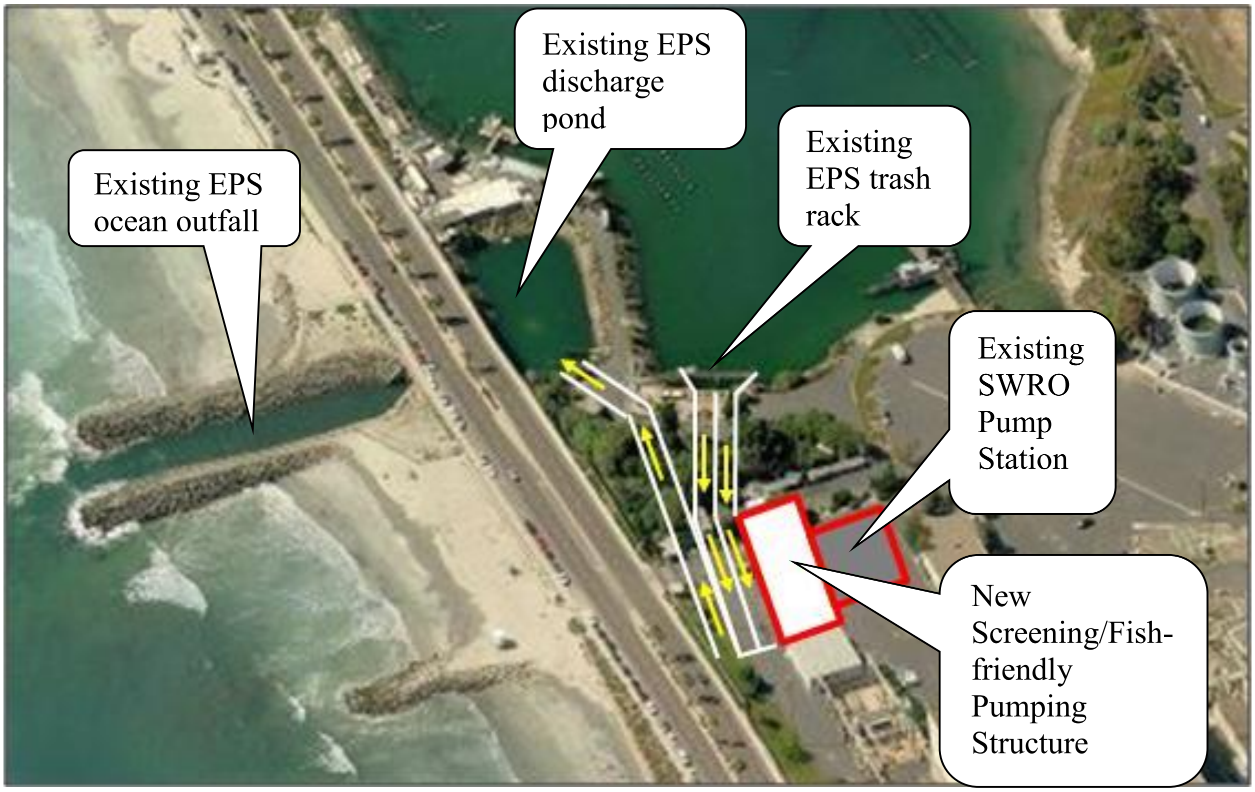


Figure 9. General schematic of the layout of the CDP with a screened intake and discharge flow augmentation.

Under this option, the source water for the seawater desalination plant and the seawater required brine dilution would be withdrawn through the existing intake on Agua Hedionda Lagoon. **Figure 10** provides a conceptual flow schematic of the layout of the CDP with a screened intake and discharge flow augmentation

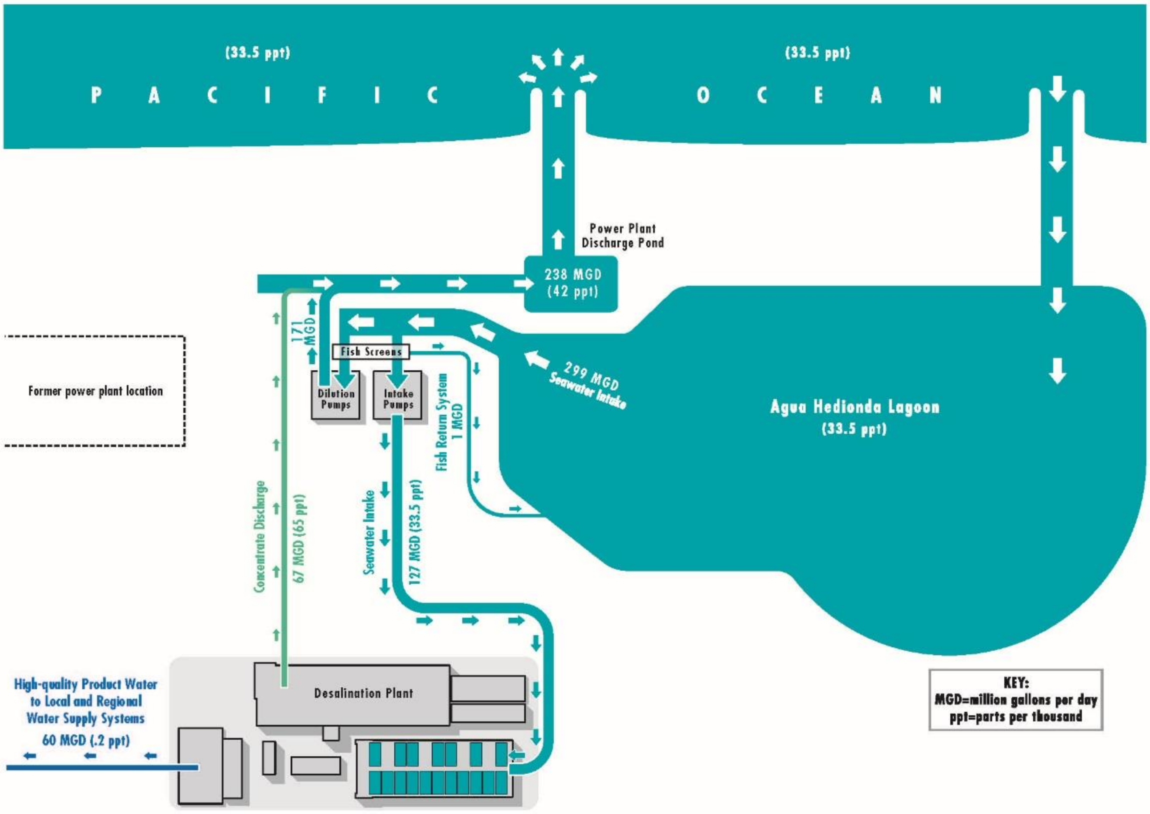


Figure 10. Conceptual schematic of the CDP with a screened intake and discharge flow augmentation.

Approximately 299 MGD of seawater would be withdrawn from the Lagoon -- 127 MGD for processing by the CDP, 171 MGD for brine dilution and approximately 1 MGD for screen wash and fish return. Approximately 60 MGD of the diverted seawater is converted to fresh water which is piped to the San Diego County Water Authority delivery system in the City of San Marcos. The remaining flow (67 MGD) is returned to the EPS discharge tunnel for blending with seawater prior to discharge to the Pacific Ocean. The discharge consists of brine produced by the reverse osmosis process (60 MGD) and treated backwash water from the pretreatment filters (7 MGD). The salinity of the discharge prior to dilution is approximately 65 ppt (67 ppt with no backwash water included), whereas the average salinity of the seawater in the vicinity of the discharge channel is 33.5 ppt. Poseidon is proposing an initial dilution of the brine to 42 ppt prior to discharge. This is accomplished by mixing the CDP discharge with 171 MGD of the seawater withdrawn from Agua Hedionda Lagoon. The combined CDP discharge and dilution water flow rate is 238 MGD. As compared to the existing project operations described in Section 1.A.i, the CDP operations described above would achieve a 10% average annual increase in fresh drinking water production while reducing total quantity of seawater required for processing and flow augmentation purposes.

The Desalination Amendment provides that the discharge shall not exceed a daily maximum of 2.0 parts per thousand (ppt) above natural background salinity measured at the edge of the brine mixing zone 200 meters (656 ft.) seaward of the end of the outfall channel. Over the last 20 years, the natural background salinity at the closest reference site (Scripps Pier) has measured a minimum salinity of 30.4 ppt, maximum salinity of 34.2 ppt, and an average salinity of 33.5 ppt. Therefore, under average conditions, the discharge shall not exceed a daily maximum of 35.5 ppt at the edge of the brine mixing zone (200 meter [656 ft] radius).

b. Design

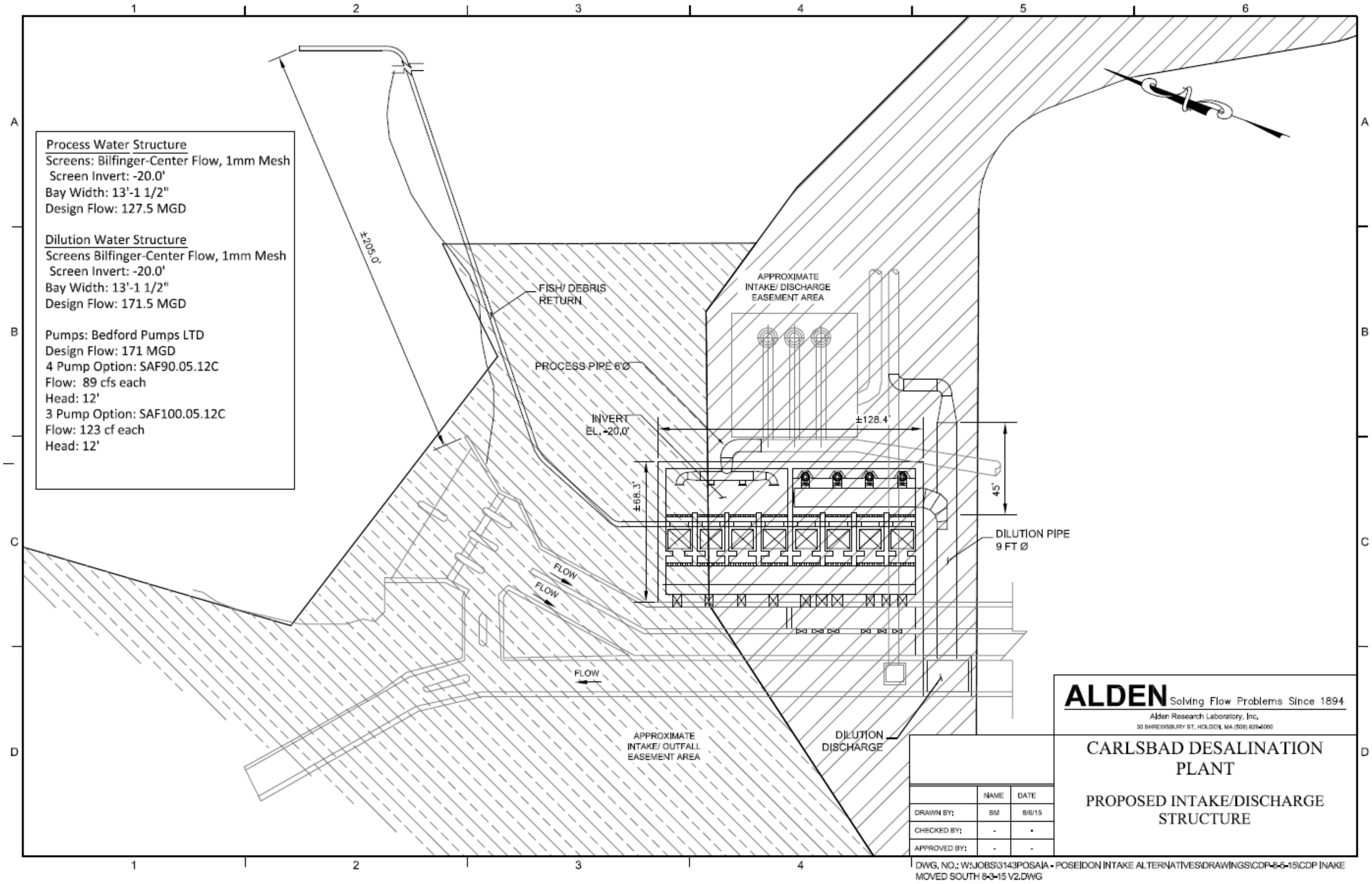
The New Screening/ Fish-friendly Pumping Structure would be located west of the SWRO Pump Station and east of the existing EPS intake tunnels. Intake flows would be withdrawn from the existing EPS intake tunnels after hydraulic connections have been established through the walls of the existing tunnel into the New Screening/Fish-friendly Pumping Structure forebay. The penetrations from the existing EPS intake tunnels to the new intake/discharge structure would be sized and spaced to provide optimal flow distribution to the screens.

The overall footprint of the New Screening/Fish-friendly Pumping Structure would be approximately 130 ft long and 65 ft wide with an invert of El. -20 ft. The overall structure would be divided into SWRO process water flow and augmentation flow. An average flow of 299 MGD would be withdrawn, 127 MGD through the process water intake, 171 MGD through the flow augmentation intake and approximately 1 MGD for screen washing and fish return. Each portion of the structure would have its own common plenum downstream of the screens. Figure 11 provides a plan view of the New Screening/Fish-friendly Pumping Structure.

After passing through the penetrations in the existing intake tunnels, the intake flow would enter a common plenum upstream of the screens. The invert of the plenum would step down from the tunnel invert of El. -15 ft, to an intermediate step at El. -17.5 ft to a bottom invert of El. -21 ft. The forebay invert is 1 ft lower than the invert of the screenbays (El. -20 ft) to create a sediment trap.

The portion of the screening structure devoted to the process water flow would be screened by four (three plus one redundant screen). The one redundant screen will be shared between the process water flow and the flow augmentation portion. Bilfinger Water Technologies (BWT) center-flow traveling water screens (or equal) with 1.0-mm mesh (Figure 11 and Figure 12). The screens would be modified with fish protection features (fish lifting buckets on each screen basket, low pressure spraywash, and fish return system). The process water intake is designed for a through-screen velocity of less than 0.5 ft/sec with only three screens in service and 15% fouling. If all four screens are in service, the through-screen velocity is well below 0.5 ft/sec. Each screen bay includes upstream and downstream stoplog slots to allow each bay to be dewatered and each screen isolated. All fish collected in the traveling screen fish buckets would be returned to Agua Hedionda Lagoon at a location that minimizes the potential for recirculation of organisms and debris. A Tee-shaped manifold with four inlets would convey flow from downstream of the screens to the SWRO Pump Station. Flow distributors are included upstream and downstream of the screens to create a more uniform flow through the screens and approaching the Tee-shaped manifold inlets.

The portion of the screening structure devoted to the augmentation flow would be screened by four BWT center-flow traveling water screens (or equal) with 1.0-mm mesh (Figure 11 and Figure 13). As with the process water screens, the augmentation flow screens would be equipped with fish protection features. The flow augmentation intake is designed for a through-screen velocity of less than 0.5 ft/sec with four screens in service and 15% fouling. The flow augmentation screen bays also include stoplogs to allow each bay to be dewatered and each screen isolated. As with the process water intake, all fish collected in the traveling screen fish buckets would be returned to Agua Hedionda Lagoon at a location that minimizes the potential for recirculation of organisms and debris. Flow distributors are included upstream and downstream of the screens to create a more uniform flow through the screens and approaching the flow augmentation pump bell intakes. The flow augmentation system would pump flow using four (three plus one redundant) fish-friendly, axial flow pumps (Bedford submersible or equal). This flow augmentation would be conveyed to a junction with the existing brine pipeline. The flows would mix at this junction and be discharged through a common vault into the existing EPS discharge tunnel. The combined brine and augmentation flows would mix further in transit to the existing EPS discharge pond and then to the ocean.



Process Water Structure
Screens: Bilfinger-Center Flow, 1mm Mesh
Screen Invert: -20.0'
Bay Width: 13'-1 1/2"
Design Flow: 127.5 MGD

Dilution Water Structure
Screens Bilfinger-Center Flow, 1mm Mesh
Screen Invert: -20.0'
Bay Width: 13'-1 1/2"
Design Flow: 171.5 MGD

Pumps: Bedford Pumps LTD
Design Flow: 171 MGD
4 Pump Option: SAF90.05.12C
Flow: 89 cfs each
Head: 12'
3 Pump Option: SAF100.05.12C
Flow: 123 cf each
Head: 12'

ALDEN Solving Flow Problems Since 1894
Alden Research Laboratory, Inc.
30 SHREWSBURY ST, HOLDEN, MA (508) 829-6000

CARLSBAD DESALINATION PLANT

PROPOSED INTAKE/DISCHARGE STRUCTURE

	NAME	DATE
DRAWN BY:	BM	8/6/15
CHECKED BY:	-	-
APPROVED BY:	-	-

DWG. NO.: W:\JOBS\3143POSAIA - POSEIDON INTAKE ALTERNATIVES\DRAWINGS\CDP-8-5-15\CDP INAKE MOVED SOUTH 8-3-15 V2.DWG

Figure 11. Screened intake/discharge structure, plan view.

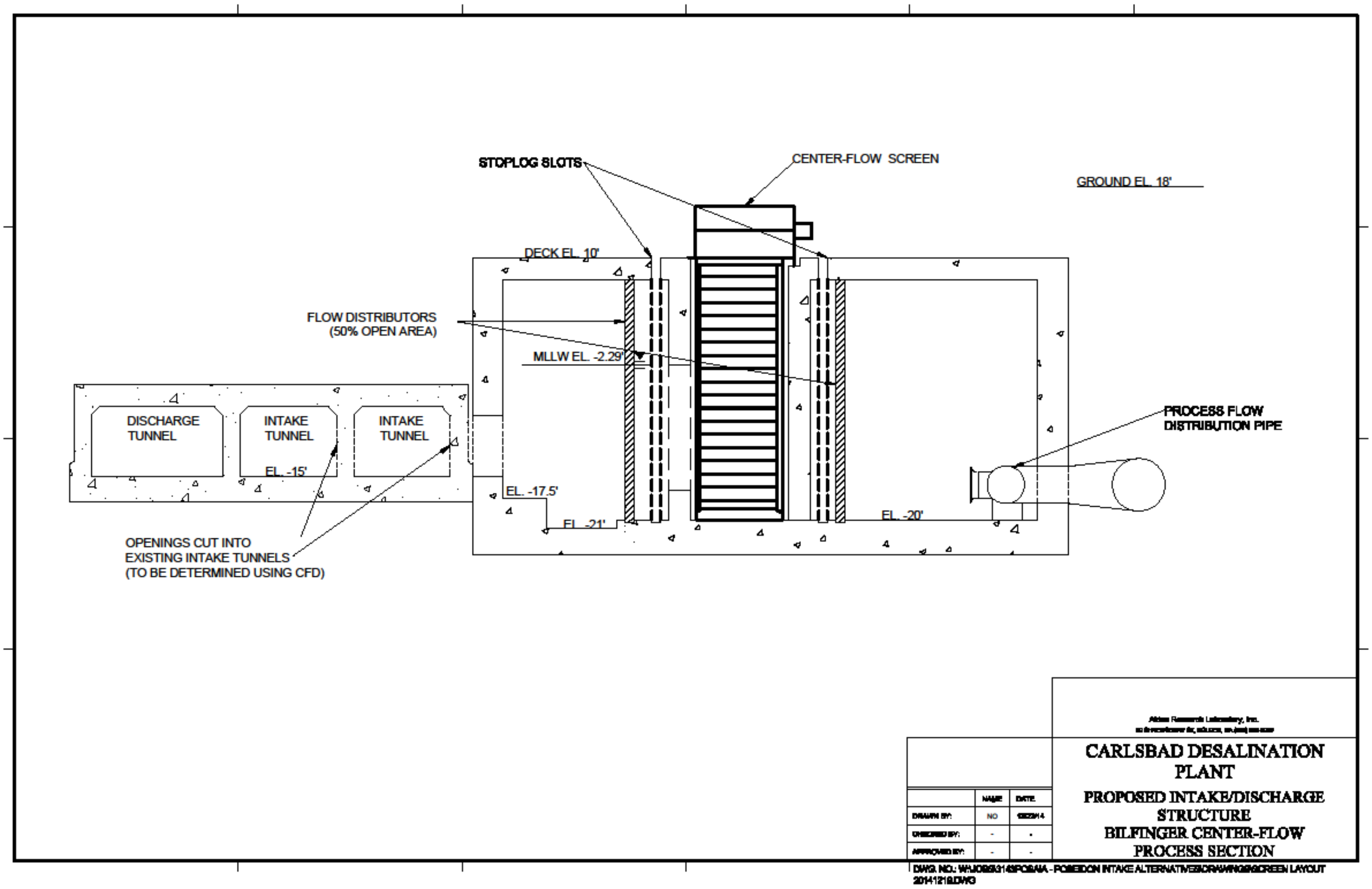


Figure 12. Screened process water intake, section view.

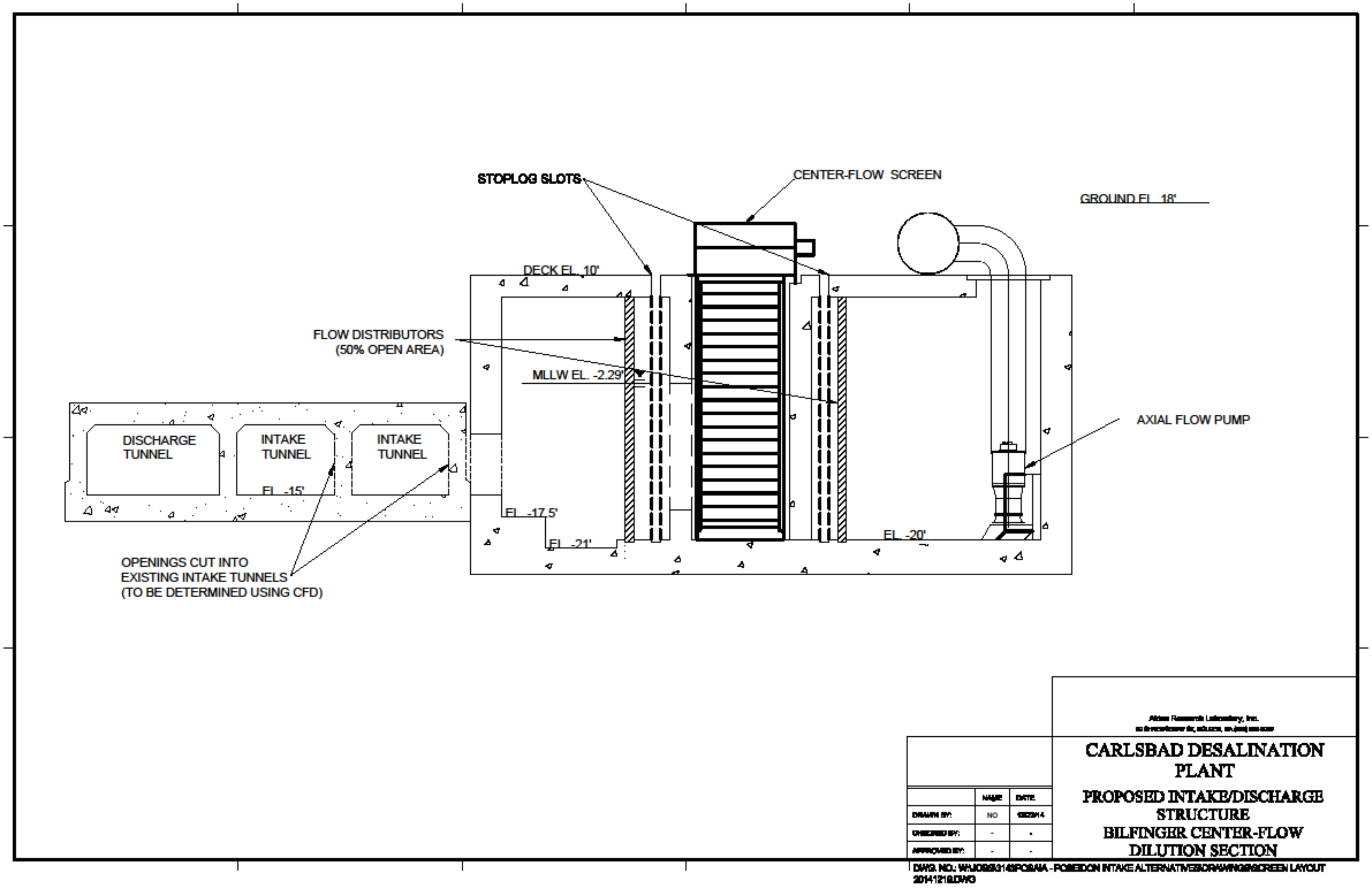


Figure 13. Screened flow augmentation intake, section view.

c. *Technology*

Intake Screening Technology

The intake screening technology selected for the screened intake with discharge flow augmentation is the BWT center-flow traveling water screen (Figure 14). This screen type is oriented perpendicular to the flow and both the ascending and descending sides of the screen provide screening area. The increased screening area represents a distinct advantage over traditional through-flow screens in which only the ascending side provides screening area. In addition, the potential for carryover of debris is greatly reduced with this type of screen.

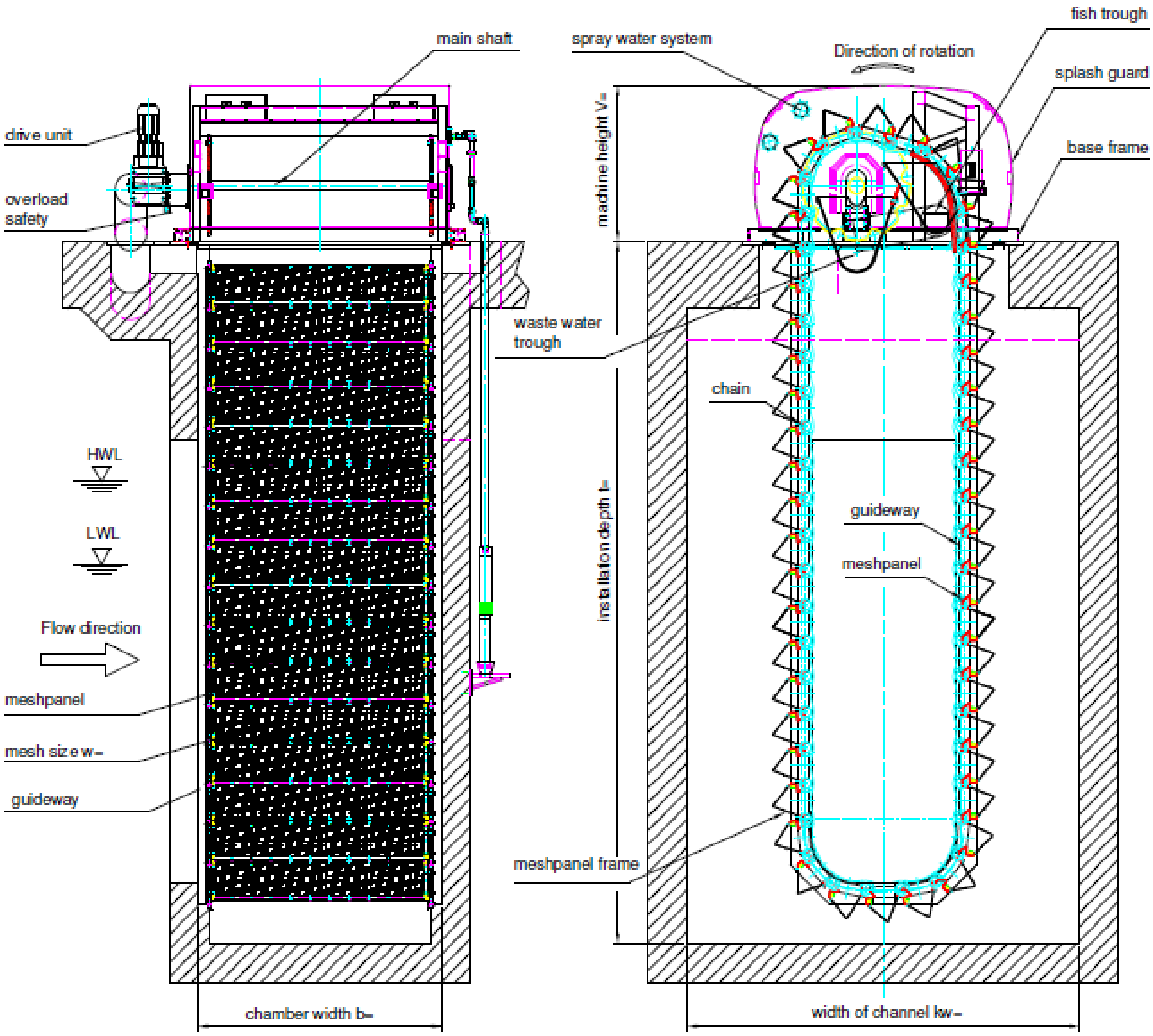


Figure 14. Sample profile and section view of a typical BWT center-flow traveling water screen (courtesy Bilfinger Water Technologies).

Operational Principle

As shown in Figure 15, the BWT center-flow traveling screen is designed to draw water into the center of the screen and out through both the ascending and descending screen faces, resulting in two flows leaving the screen and coalescing downstream. Center-flow traveling screens are widely used throughout Europe, but less so in the U.S. They offer a number of substantial advantages over standard through-flow and even dual-flow designs. BWT center-flow screens prevent carryover of debris by keeping all filtered debris on the upstream side of the screen. Also, the in-to-out flow pattern is unique in that it prevents the potential for uncollected debris from becoming jammed on the descending side of the screen (as can be the case in dual-flow screens with an out-to-in flow pattern.

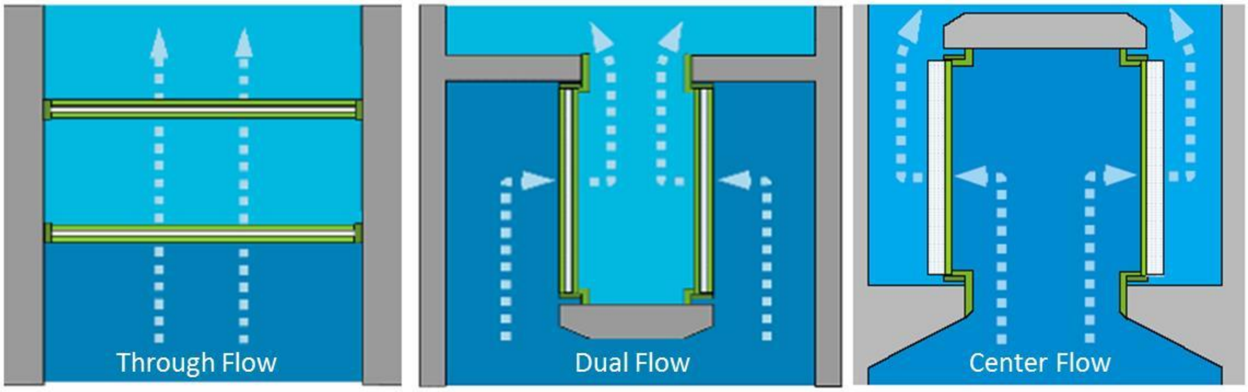


Figure 15. Schematic of the flow patterns through various traveling water screen types (courtesy Bilfinger Water Technologies).

Mesh Size

Screening mesh size directly impacts the size of the screening structure. For the same design flow, an intake utilizing smaller mesh would require a larger footprint to keep the through-screen velocity constant. The new intake/discharge structure required for the long term stand-alone CDP utilizes screens with 1.0-mm mesh on both the SWRO Pump Station side and the Flow Augmentation Pump Station side to minimize intake and mortality of marine life.

It is important to note that not just the mesh size, but also the panel shape can affect hydraulic capacity. As shown in Figure 16, the BWT center-flow traveling screen uses v-shaped, instead of flat, screen panels. This v-shape increases overall screening area by approximately 40%, reducing the overall footprint of the installation.

Fish-Friendly Screen -Features

Fish-friendly traveling water screens are also referred to as "modified" and "Ristroph" traveling water screens. Screens modified for fish protection purposes share a number of common features, each of which is listed below with a description of those features included on the BWT center-flow traveling screens specified for the CDP.

Screen mesh type

Fish-friendly screens use a mesh with a smooth surface to minimize the risk of scale loss during the impingement process. The fish-friendly mesh on the BWT screens for the CDP would be fabricated of woven stainless steel wire as shown in Figure 16.

Figure 16. Example of BWT center-flow traveling screen panel mesh (courtesy Bilfinger Water Technologies).

Fish lifting buckets

Fish-friendly screens have fish lifting buckets attached to the lower section of each screen panel. The buckets provide a sheltered area for organisms that cannot escape the intake flow to congregate and prevent them from becoming trapped against the screen mesh. The buckets are also designed to hold water to minimize air exposure during the collection and return process. The BWT screens would have fish lifting buckets as shown in Figure 17.

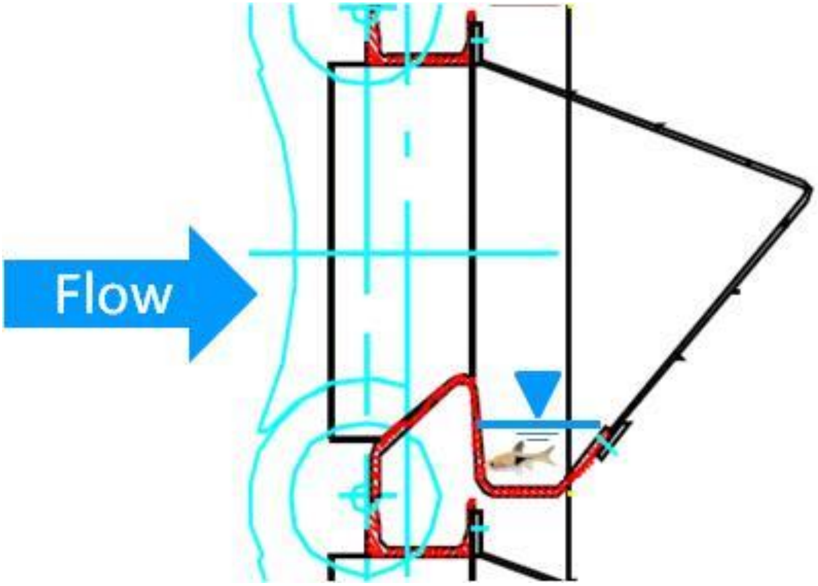


Figure 17. Example of BWT center-flow traveling screen fish lifting bucket (modified from a Bilfinger Water Technologies figure).

Low-pressure spraywash

Fish-friendly screens have low pressure spraywash system (in addition to the standard high-pressure one used to clean the screen of debris) to gently rinse collected fish from the screen into a fish return system. The spraywash pressure is typically below 20 psi and the location and orientation of the nozzles is optimized for best performance. The BWT screens would have a low-pressure spraywash to gently rinse marine organisms into the fish return trough.

Rotation speed

Fish-friendly screens are designed to operate continuously in comparison to standard traveling water screens that typically rotate on a schedule or a set pressure differential. The BWT screens would be designed to operate continuously.

Fish return system

Fish-friendly screens require fish return systems to safely transport collected organisms from the screen back to the source waterbody. The fish return design must minimize abrasion, turbulence, shear, and velocity for transported fish. It is critical that the fish return have sufficient water depth to transport organisms, sufficient velocity to flush organisms towards the discharge point, a means of protection from avian and/or terrestrial predators, and a discharge point that minimizes the risk of recirculating organisms back to the intake. The fish return for the BWT screens is designed to meet all of these considerations (Figure 18).

Once organisms are removed from the BWT center-flow traveling screens, they must be safely returned back to the Agua Hedionda Lagoon. The current design includes a single new combined fish and debris return trough. Fish and debris removed by both the low- and high-pressure spray washes, respectively, would combine into a single pipe before being returned to the Lagoon approximately 205 ft north east of the existing intake structure (Figure 11). The fish return discharges into a quiescent area in the southeast corner of the Lagoon which is separated from the deep channel that connects the intake to the Pacific Ocean, thereby minimizing the potential for recirculation of returned organisms into the intake flow (Figure 19 and Figure 20).

A combined trough provides another opportunity for safe passage for organisms that may not have been dislodged by the low-pressure wash and allows for a greater volume of wash water associated with the high-pressure spray wash system to maintain proper flow in the return system. The flows used to size the fish return are based on the spray wash capacity of each screen (114.5 gpm) or 916 gpm for all eight screens (4 – 1-mm screens in front of SWRO pumps, 4 – 1.0-mm screens in front of the Fish-friendly pumps).

Within the new structure, the combined return trough would be mounted to the intake deck on the downstream side of the screens. A 2.0-ft diameter half-round trough with a slope of 1/16 inch per ft was chosen for this stage of design.

After leaving the screening structure, the return trough would transition into a 2.0-ft diameter pipe that continues for a run of 382 ft. The velocity in this section would be approximately 7ft/sec with a flow depth of 4.0 inches. Except for a short section adjacent to the screening structure, the fish return would be buried. Two cleanouts would be located along its length to facilitate cleaning and inspection of the return pipe. From El. 0.0 ft to below the low water level, the fish return would be an open trough to ensure that organisms are returned to the Lagoon during all anticipated water levels. The discharge location would extend out into the Lagoon to ensure sufficient water depth during low water. Depending on the final arrangement, this section could either be anchored directly to the seafloor, supported by small piles, or attached to the piers supporting the existing dock.

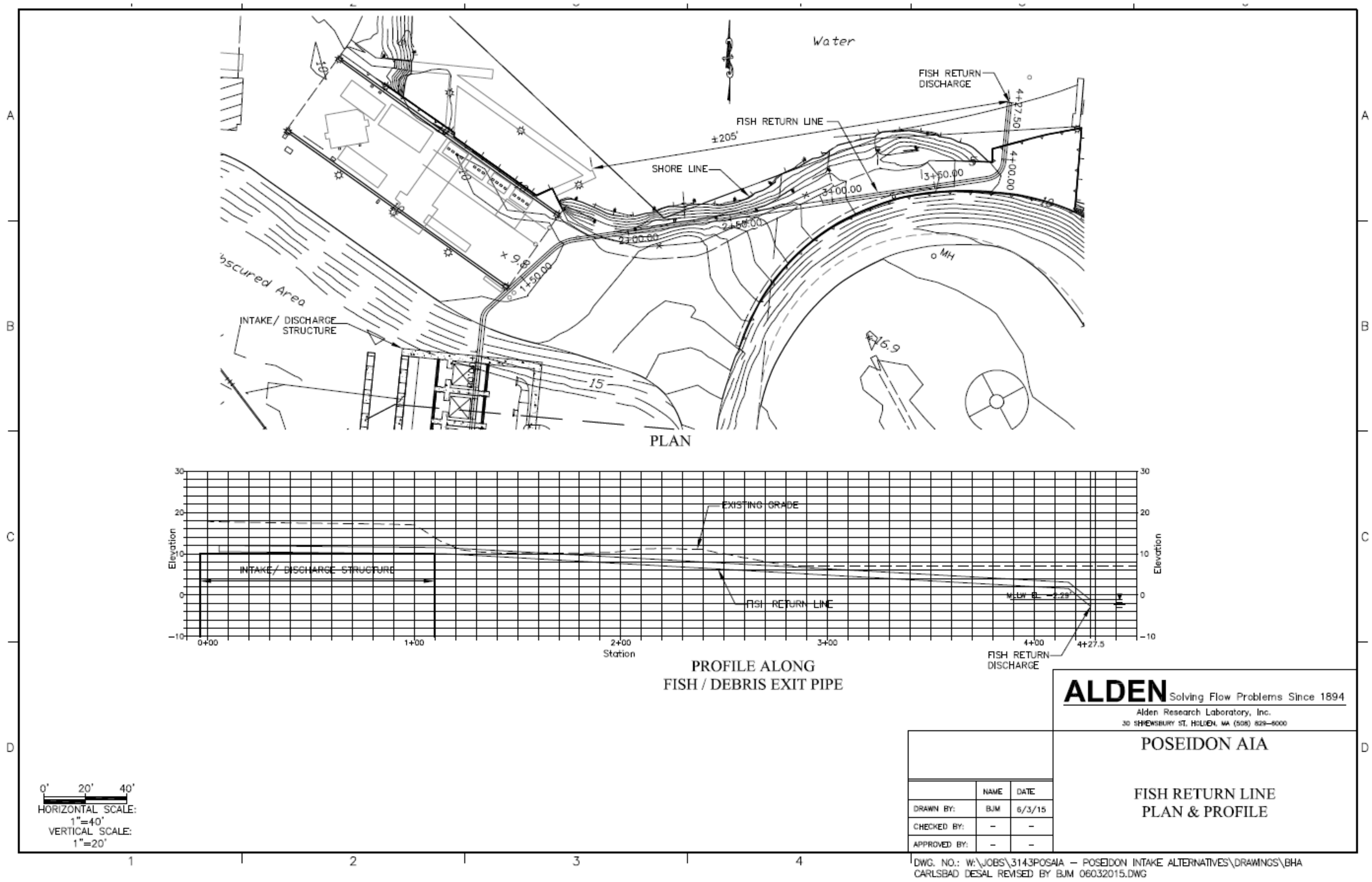


Figure 18. Preliminary design of the fish return system for the CDP.

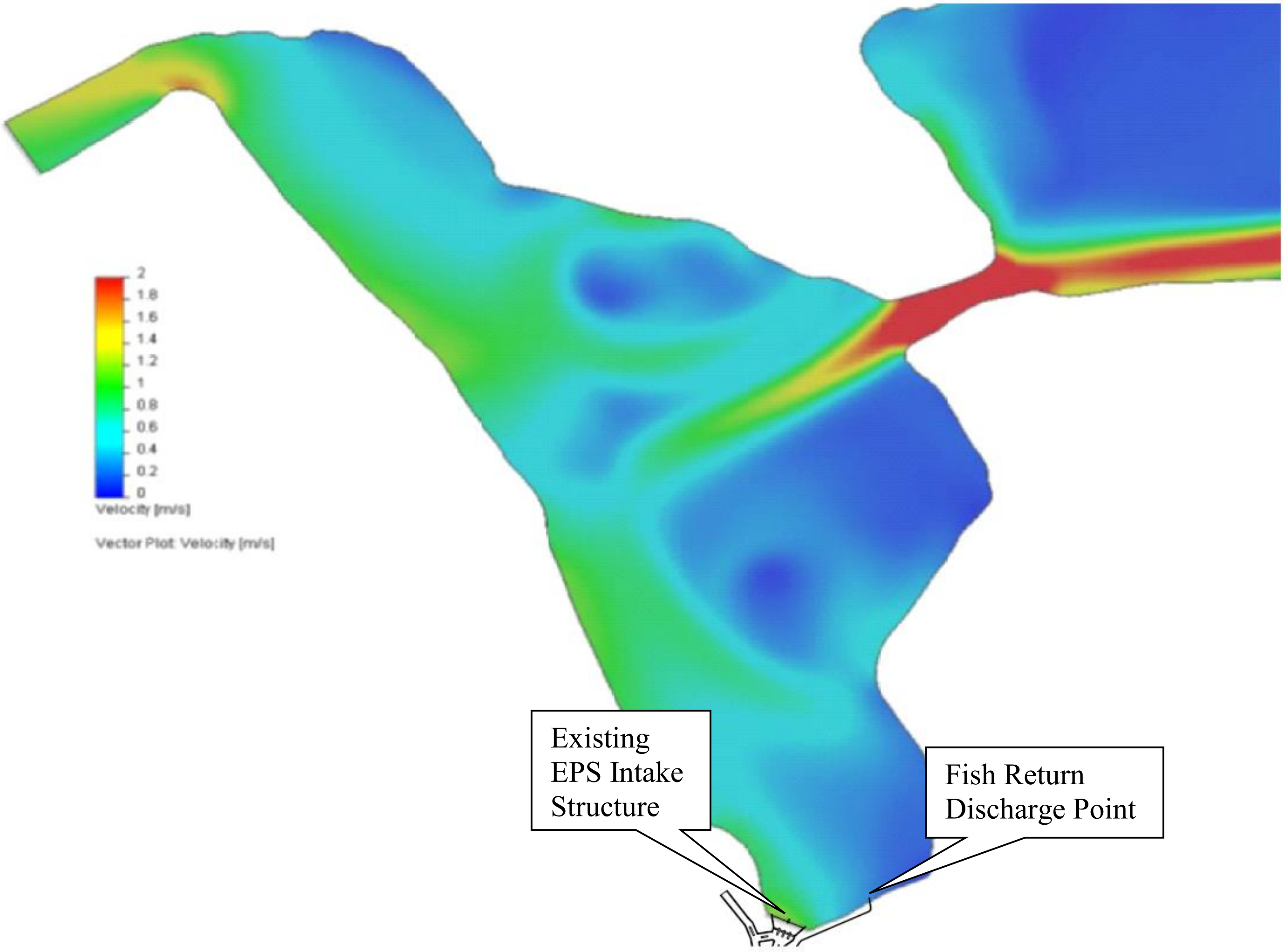


Figure 19. Velocity contours for maximum ebb tide during Spring tide, plant inflow rate 300 MGD. Existing EPS intake structure and proposed fish return line indicated.

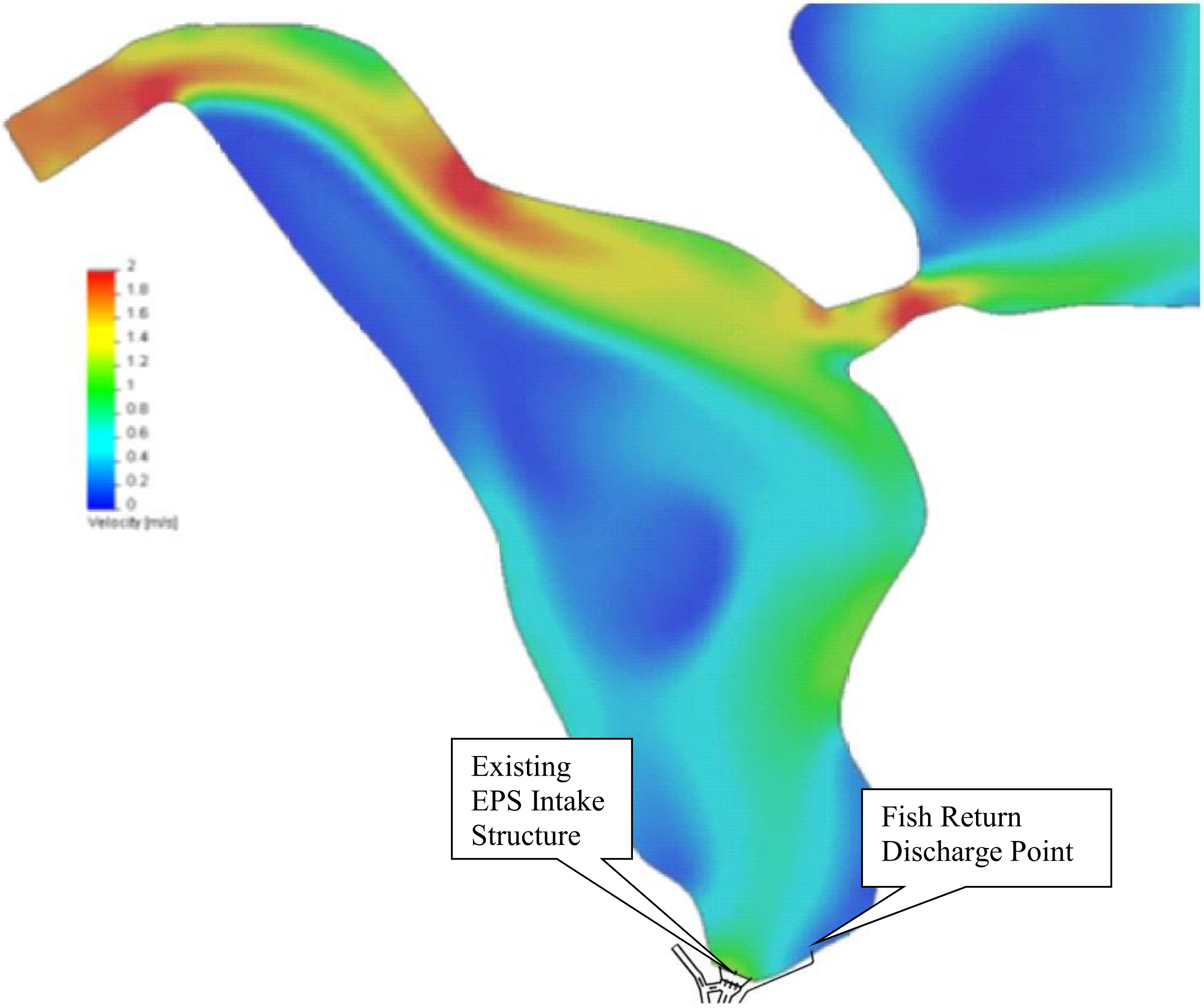


Figure 20. Velocity contour for maximum flood tide during Spring tide, plant inflow rate 300 MGD. Existing intake structure and proposed fish return line indicated.

Discharge Flow Augmentation Technologies

Flow augmentation at the CDP would be accomplished by pumping additional flow from the intake tunnels to mix with the brine flow generated by the SWRO process. Poseidon has committed to using fish-friendly flow augmentation pumps to minimize entrainment mortality. Fish-friendly pumps were originally designed for transferring fish in the aquaculture industry. Such pumps have demonstrated the capacity to transfer fish with little or no injury. Since their inception, fish-friendly pumps have been used in fish passage and protection facilities to convey fish to a safe release location. There are several types of fish-friendly pumps available, each designed with the common goal of safely transferring live fish. Each fish-friendly pump type employs certain fundamental principles that reduce the potential injury and mortality to fish. To varying degrees, fish-friendly pump designs limit fish exposure to stressors, such as pressure, shear, and impeller blade strike. More specifically, fish-friendly pumps limit fish exposure to:

- dramatic pressure differentials and high rates of pressure change;
- shear forces caused by rapid flow acceleration or deceleration;
- potential for blade strike by limiting the number of blades on the impeller and/or increasing blade thickness; and
- other sources of mechanical injury (e.g., pinching in gaps between the impeller and housing)

Poseidon has evaluated fish-friendly Archimedes screw pumps, fish-friendly centrifugal pumps, and fish-friendly axial flow pumps. Fish-friendly axial flow pumps have the greatest advantages for the CDP site and are described in greater detail below.

Fish-friendly Axial Flow Pumps

The Bedford Pumps fish-friendly axial flow pump consists of a propeller within a pipe driven by a sealed motor (Figure 21). These pumps are smaller in dimension than many conventional pumps and are designed for low heads and high flows. The low head design of the pumps (approximately 5 psi) should minimize the potential for pressure-related injuries. These pumps have been designed and used to safely pass live fish for pumping applications worldwide.

The pump specified for this application has a two-bladed impellor, a pumping capacity of 57 MGD, and is fully submersible. A total of four pumps would be installed with three in service and one as a backup. The model of pump specified for the CDP underwent independent fish survival testing in 2012 and demonstrated that survival was very good (Vis and Kemper 2012).

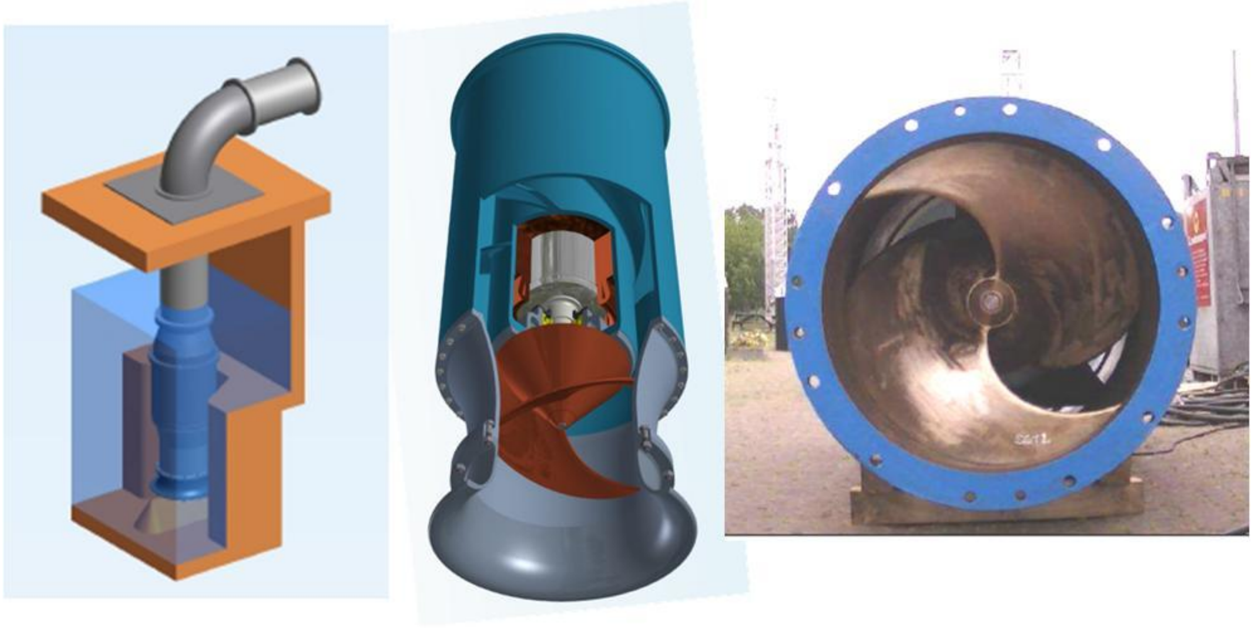


Figure 21. Bedford Pumps axial flow submersible pump: left: general installation arrangement similar to the approach at the CDP, middle: cutaway of the pump, right: photo of pump impellor (courtesy Bedford Pumps and VisAdvies Ecological Consultancy and Research).

ii. Screened Intake with Discharge Diffuser

a. Site

The new intake screening structure would be located between the existing EPS intake tunnels to the east and the SWRO Pump Station to the west (Figure 22). Feedwater for the CDP would be withdrawn through the existing EPS trash rack structure in the Lagoon. There would be no change in the source waterbody nor would the new screening structure require any heavy shoreline construction in the Lagoon.

A new multiport diffuser system would be located approximately 4,000 ft offshore, approximately 3,280 feet northwest of kelp beds. The diffuser system would be designed to maximize dilution, minimize the size of the brine mixing zone, minimize the suspension of benthic sediments, and minimize marine life mortality in accordance with the provisions of the Ocean Plan. A general schematic of the layout is provided in Figure 22 with additional detail of the terminus provided in Figure 23.

Figure 22. General schematic of the layout of the CDP with a screened intake and discharge diffuser.

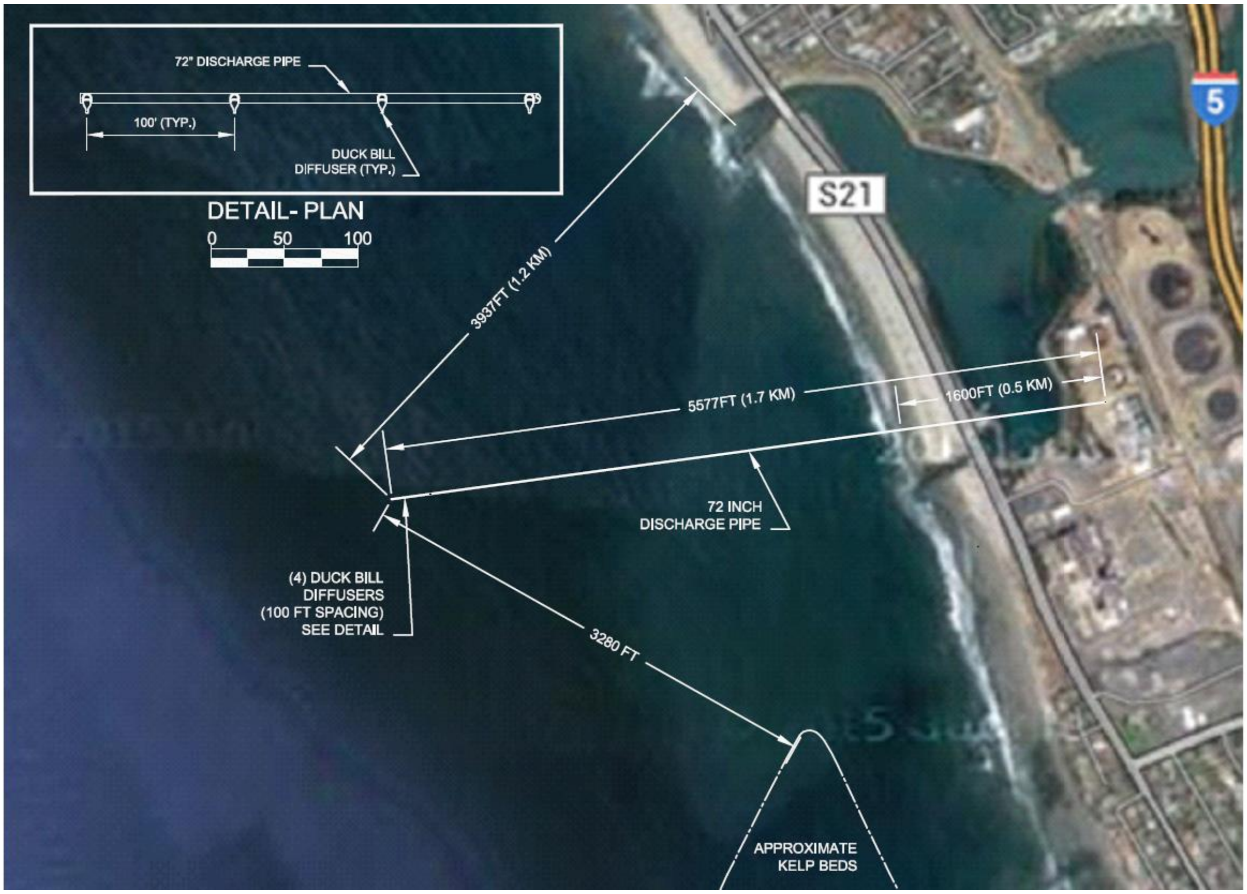


Figure 23. General schematic of the layout of the CDP discharge diffuser array.

Approximately 127.5 MGD of seawater would be withdrawn from the Lagoon: 127 MGD for processing by the CDP and approximately 0.5 MGD for screen wash and fish return. Approximately 60 MGD of the diverted seawater would be converted to fresh water which would be piped to the San Diego County Water Authority delivery system in the City of San Marcos. The remaining flow (67 MGD) leaving the SWRO building would be discharged through a multiport diffuser system to the Pacific Ocean. The discharge would consist of brine produced by the reverse osmosis process (60 MGD) and treated backwash water from the pretreatment filters (7 MGD). The salinity of the discharge prior to dilution would be approximately 65 ppt (67 ppt with no backwash water included), whereas the average salinity of the ambient seawater in the vicinity of the diffuser is 33.5 ppt. As compared to the existing project operations described in Section 1.A.i., the CDP operations described above would achieve a 10% average annual increase in fresh drinking water production while reducing total quantity of seawater required.

The Desalination Amendment provides that the discharge shall not exceed a daily maximum of 2.0 parts per thousand (ppt) above natural background salinity measured at the edge of the brine mixing zone 100 meters (328 ft.) from the diffuser. Over the last 20 years, the natural background salinity at the closest reference site (Scripps Pier) has measured a minimum salinity of 30.4 ppt, maximum salinity of 34.2 ppt and an average salinity of 33.5 ppt. Therefore, under average conditions, the discharge shall not exceed a daily maximum of 35.5 ppt at 100 meters (328 ft) from the diffuser ports (at the edge of the brine mixing zone).

b. Design

The new screening structure would be located west of the SWRO Pump Station and east of the existing EPS intake tunnels. Intake flows would be withdrawn from the existing EPS intake tunnels after hydraulic connections have been established through the walls of the existing tunnel into the new intake screening forebay. The penetrations from the existing EPS intake tunnels to the new intake structure would be sized and spaced to provide optimal flow distribution to the screens.

The overall footprint of the new intake screening structure would be approximately 67 ft long and 65 ft wide with an invert of El. -20 ft. An average flow of 127.5 MGD would be withdrawn, 127 MGD for processing by the CDP and approximately 0.5 MGD for screen wash and fish return. All flow would be withdrawn through the screens into a common plenum. Figure 24 provides a plan view of the new intake screening structure.

After passing through the penetrations in the existing intake tunnels, the intake flow would enter a common plenum upstream of the screens. The invert of the plenum would step down from the tunnel invert of El. -15 ft, to an intermediate step at El. -17.5 ft to a bottom invert of El. -21ft. The bottom invert is 1 ft lower than the invert of the screenbays (El. -20 ft) to create a sediment trap.

The new intake screening structure would be screened by four (three plus one redundant) Bilfinger Water Technologies (BWT) center-flow traveling water screens with 1.0-mm mesh (Figure 24). The screens would be modified with fish protection features (fish lifting buckets on each screen basket, low pressure spray wash, and fish return system). The intake would be designed for a through-screen velocity of less than 0.5 ft/sec with only three screens in service and 15% fouling. If all four screens are in service, the through-screen velocity would be well below 0.5 ft/sec. Each screen bay includes upstream and downstream stoplog slots to allow each bay to be dewatered and each screen isolated. All fish collected in the traveling screens fish buckets would be returned to Agua Hedionda Lagoon at a location that minimizes the potential recirculation of organisms and debris. A Tee-shaped manifold with four inlets would convey flow from downstream of the screens to the SWRO Pump Station. Flow distributors are included upstream to create a more uniform flow through the screens and approaching the Tee- shaped manifold inlets.

A 72” outfall pipeline extending approximately 4,000 feet offshore would convey the brine discharge from the SWRO building to the multiport diffuser system where four duck-bill diffuser ports spaced 100 ft apart would eject the brine into the water column at a high velocity to promote rapid diffusion and dispersion (Figure 23).

Installation of the outfall pipeline will require tunneling and pipeline placement under the existing EPS site, Carlsbad Boulevard, and approximately 4,000 linear feet of seafloor. Anchoring of the outfall pipeline to the seafloor would be coordinated to minimize impacts to the local reef and kelp beds offshore of the desalination plant. The spacing, number, and orientation of the four diffuser heads has been designed to maximize brine mixing in accordance with the provisions of the Desalination Amendment.

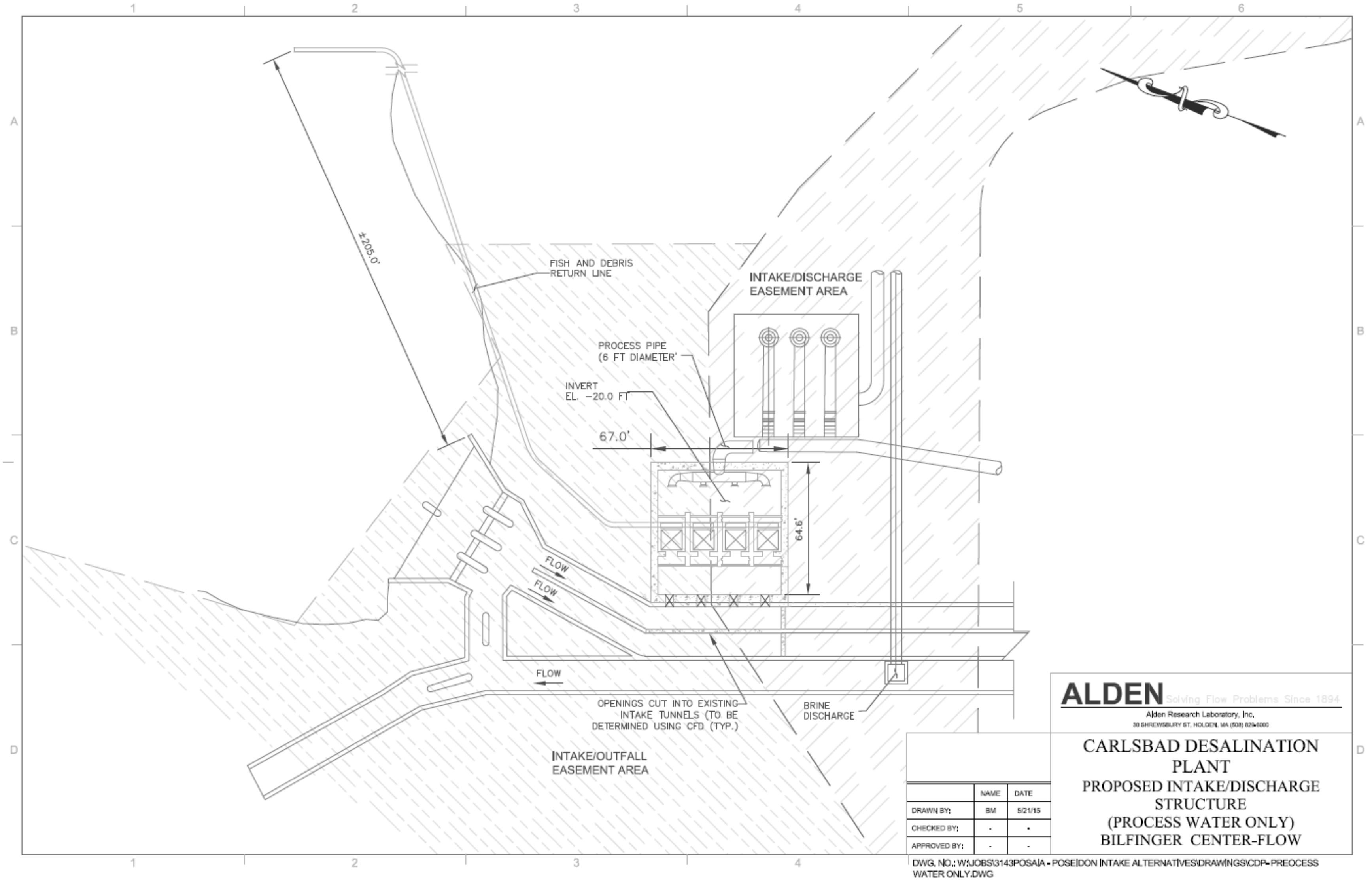


Figure 24. Screened intake structure, plan view.

c. Technology

Intake Screening Technology

The intake screening technology selected for the screened intake with discharge diffuser is the BWT center-flow traveling water screen (Figure 14). This screen type is oriented perpendicular to the flow and both the ascending and descending sides of the screen provide screening area. The increased screening area represents a distinct advantage over traditional through-flow screens in which only the ascending side provides screening area. In addition, the potential for carryover of debris is greatly reduced with this type of screen.

Operational Principle

As shown in Figure 15, the BWT center-flow traveling screen is designed to draw water into the center of the screen and out through both the ascending and descending screen faces, resulting in two flows leaving the screen and coalescing downstream. Center-flow traveling screens are widely used throughout Europe, but less so in the U.S. They offer a number of substantial advantages over standard through-flow and even dual flow designs. BWT center-flow traveling screens prevent carryover of debris by keeping all filtered debris on the upstream side of the screen. Also, the in-to-out flow pattern is unique in that it prevents the potential for uncollected debris from becoming jammed on the descending side of the screen (as can be the case in dual-flow screens with an out-to-in flow pattern.

Mesh Size

Screening mesh size directly impacts the size of the screening structure. For the same design flow, an intake utilizing smaller mesh would require a larger footprint to keep the through-screen velocity constant. The new intake screen structure required for the SWRO Pump Station operating in long term stand-alone mode would have screens with 1.0-mm mesh to minimize the potential entrainment of early life stages of marine organisms.

It is important to note that not just the mesh size, but also the panel shape, can affect hydraulic capacity. As shown in Figure 16, the BWT center-flow traveling screen uses v-shaped, instead of flat, screen panels. This v-shape increases overall screening area by approximately 40%, reducing the overall footprint of the installation.

Fish-Friendly Features

Fish-friendly traveling water screens are also referred to as “modified” and “Ristroph” traveling water screens. Screens modified for fish protection purposes share a number of common features, each of which is listed below with a description of those features included on the BWT center-flow traveling screens specified for the CDP.

Screen mesh type

Fish-friendly screens use a mesh with a smooth surface to minimize the risk of scale loss during the impingement process. The fish-friendly mesh on the BWT screens for the CDP would be fabricated of woven stainless steel wire as shown in Figure 16).

Fish lifting buckets

Fish-friendly screens have fish lifting buckets attached to the lower section of each screen panel. The buckets provide a sheltered area for organisms that cannot escape the intake flow to congregate and prevent them from becoming trapped against the screen mesh. The buckets are also designed to hold water to minimize air exposure during the collection and return process. The BWT screens would have fish lifting buckets as shown in Figure 17.

Low-pressure spraywash

Fish-friendly screens have low pressure spraywash system (in addition to the standard high-pressure one used to clean the screen of debris) to gently rinse collected fish from the screen into a fish return system. The spraywash pressure is typically below 20 psi and the location and orientation of the nozzles is optimized for best performance. The BWT screens would have a low-pressure spraywash to gently rinse marine organisms into the fish return trough.

Rotation speed

Fish-friendly screens are designed to operate continuously in comparison to standard traveling water screens that typically rotate on a schedule or a set pressure differential. The BWT screens would be designed to operate continuously.

Fish return system

Fish-friendly screens require fish return systems to safely transport collected organisms from the screen back to the source waterbody. The fish return design must minimize abrasion, turbulence, shear, and velocity for transported fish. It is critical that the fish return have sufficient water depth to transport organisms, sufficient velocity to flush organisms towards the discharge point, a means of protection from avian and/or terrestrial predators, and a discharge point that minimizes the risk of recirculating organisms back to the intake. The fish return for the BWT screens is designed to meet all of these considerations (Figure 18).

Once organisms are removed from the BWT center-flow traveling screens, they must be safely returned back to the Agua Hedionda Lagoon. The current design includes a single new combined fish and debris return trough. Fish and debris removed by both the low- and high-pressure spray washes,, would combine into a single pipe before being returned to the Lagoon approximately 205 ft north east of the existing intake structure (Figure 11). The fish return discharges into a quiescent area in the southeast corner of the Lagoon which is separated from the deep channel that connects the intake to the Pacific Ocean, thereby minimizing the potential for recirculation of returned organisms into the intake flow (Figure 19 and Figure 20).

A combined trough provides another opportunity for safe passage for organisms that may not have been dislodged by the low-pressure wash and allows for a greater volume of wash water associated with the high-pressure spray wash system to maintain proper flow in the return system. The flows used to size the fish return are based on the spray wash capacity of each screen (114.5 gpm) or 458.0 gpm for all four screens. Within the new structure, the combined return trough would be mounted to the intake deck on the downstream side of the screens. A 2.0-ft diameter half-round trough with a slope of 1/16 inch per ft was chosen for this stage of design.

After leaving the screening structure, the return trough would transition into a 2.0-ft diameter pipe that continues for a run of 382 ft. The velocity in this section would be approximately 7 ft/sec with a flow depth of 4.0 inches. Except for a short section adjacent to the screening structure, the fish return would be buried. Two cleanouts would be located along its length to facilitate cleaning and inspection of the return pipe. From El. 0.0 ft to below the low water level, the fish return would be an open trough to assure that organisms are returned to the Lagoon during all anticipated water levels. The discharge location would extend out into the Lagoon to ensure sufficient water depth during low water. Depending on the final arrangement, this section could either be anchored directly to the seafloor, supported by small piles, or attached to the piers supporting the existing dock.

Discharge Diffuser Technology

A new multiport diffuser system would be designed to maximize dilution, minimize the size of the brine mixing zone, minimize the suspension of benthic sediments, and minimize marine life mortality in accordance with the provisions of the Desalination Amendment. As provided in the Desalination Amendment, the brine mixing zone extends 100 m (328 ft) laterally from each of the points of discharge. As shown in Figure 23 the design features include:

- Tie-In to the exiting CDP brine outfall line
- Installation of 5,600 linear feet (1,600 feet onshore and 4,000 feet offshore) of 72-inch conveyance tunnel
- Installation of four high pressure multiport diffusers spaced approximately 100 feet apart
- Elevating the multiport diffusers off the seafloor and orienting the diffusers so to minimize suspension of benthic sediments
- A brine mixing zone of approximately 14.4 acres.

3. Feasibility Analysis

The feasibility analysis of the intake/discharge alternatives presented below was conducted in accordance with the definition of feasible included in the Desalination Amendment:

> *Feasible means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors.*

A. Technical

i. SIG Intake with Discharge Flow Augmentation

The technical aspects of the SIG intake with discharge flow augmentation are analyzed in greater detail below.

a. Site Constraints

The physical placement of a SIG is governed by the required design acreage and the Agua Hedionda Lagoon complex. The Agua Hedionda Lagoon complex is divided into three bodies of water herein referred to as the “west lagoon”, “middle lagoon”, and “east lagoon”. The required design acreage surpasses that available in any one of the three lagoon sections, thereby requiring the placement of SIG cells in all three lagoon sections for implementation of a SIG intake with discharge flow augmentation (see Figure 3). Although all three sections of the lagoon are hydraulically connected, it is expected that variations in water quality and sediment transport across the three lagoon sections will create variations in cell fouling and maintenance.

The placement of SIG cells in all three sections of the lagoon complex also creates engineering and construction challenges. From an engineering perspective, cells placed in the west lagoon are significantly closer to the Intermediate Pump Station as compared to cells in the east lagoon. Specifically, the cell located furthest away from the Intermediate Pump Station is located approx. 7,000 linear feet away while the closest cell is located approx. 500 linear feet away. Although each of these two cells would be hydraulically managed by stand-alone pump and VFD as described previously, this difference in linear feet of conveyance piping creates a large difference in expected head losses between the two cells. The depth and inlet elevations for the Intermediate Pump Station will ultimately be governed by the head losses of the cells located the furthest distance away. From a construction perspective, the placement of conveyance piping spanning the east lagoon to the Intermediate Pump Station requires the placement of conveyance piping underneath the rail road and I-5 freeway overpasses. Placement of conveyance piping through these overpass sections must not undermine or otherwise cause adverse effects to the overpass footings. Similarly, construction easements / approvals must be obtained as required for the construction of conveyance piping under these overpasses as required.

As described previously, the Intermediate Pump Station required for implementation of a SIG with discharge flow augmentation measures 354 feet long by 25 feet long by 45 feet deep and would require significant construction at and near the lagoon shoreline. The discharge piping associated with this pump station would be approx. 144-in diameter.

ii. SIG Intake with Discharge Diffuser

The technical aspects of the SIG intake with a discharge diffuser are analyzed in greater detail below.

a. Site Constraints

The physical placement of a SIG is governed by the required design acreage and the geometry of the Agua Hedionda Lagoon complex. The Agua Hedionda Lagoon complex is divided into three bodies of water herein referred to as the “west lagoon”, “middle lagoon”, and “east lagoon”. The required design acreage surpasses that available in any one of the three lagoon sections, thereby requiring the placement of SIG cells in two lagoon sections for implementation of a SIG intake with discharge diffuser. Although these two sections of the lagoon are hydraulically connected, it is expected that variations in water quality and sediment transport across these sections will create variations in cell fouling and maintenance.

The placement of SIG cells in two sections of the lagoon complex also creates engineering and construction challenges. From an engineering perspective, cells placed in the west lagoon are significantly closer to the Intermediate Pump Station as compared to cells in the middle lagoon. Specifically, the cell located furthest away from the Intermediate Pump Station is located approx. 4,000 linear feet away while the closest cell is located approx. 500 linear feet away. Although each of these two cells would be hydraulically managed by stand-alone pump and VFD as described previously, this difference in linear feet of conveyance piping creates a large difference in expected head losses between the two cells. The depth and inlet elevations for the Intermediate Pump Station will ultimately be governed by the head losses of the cells located the furthest distance away. From a construction perspective, the placement of conveyance piping spanning the middle lagoon to the Intermediate Pump Station requires the placement of conveyance piping underneath the rail road overpass. Placement of conveyance piping through this overpass section must not undermine or otherwise cause adverse effects to the overpass footings. Similarly, construction easements / approvals must be obtained as required for the construction of conveyance piping under the overpass as required.

As described previously, the Intermediate Pump Station required for implementation of a SIG with discharge flow augmentation measures 168 feet long by 25 feet long by 45 feet deep. The discharge piping associated with this pump station would be approx. 98-in diameter and would require significant construction at and near the lagoon shoreline.

iii. Screened Intake with Discharge Flow Augmentation

The technical aspects of the screened intake with discharge flow augmentation are analyzed in greater detail below.

a. Site Constraints

The footprint available for the New Screening/Fish-friendly Pumping Structure is limited given that all existing EPS structures are still in service and would have to remain so during construction of the long term stand-alone CDP structures. However, iterative conceptual design efforts indicate that sufficient space is available to keep all eight screens in-line in one location by using a lower invert elevation (and longer screens).

Site constraints associated with a retrofitted screening structure also typically limit the hydraulic optimization of the approach flow. However, at the tie-in point for water withdrawal under long term stand-alone CDP operation, a novel technique would make use of the existing EPS intake tunnel walls as a flow distribution tool for providing the proper approach flow hydraulics to the screens.

A single fish return system would be sufficient for all eight screens in the New Screening/Fish-friendly Pumping Structure. The majority of the fish return pipe would be buried (Figure 18) and would minimize aesthetic concerns. The terminus of the fish return pipe would be located approximately 205 feet from the existing EPS intake.

b. Equipment

The screening equipment required to construct a new long term stand-alone CDP New Screening/Fish-friendly Pumping Structure is commercially available and Poseidon has received a preliminary cost estimate for the screens. The BWT center-flow traveling water screen is a proven technology used widely throughout the world for screening large seawater flows. The equipment materials specified are marine grade to minimize corrosion and are designed with cleaning features to keep them clear of debris. The BWT screen design has numerous advantages over other fish-friendly traveling water screen designs including increased screening area associated with the two screening faces and the v-shaped screen baskets, elimination of debris carryover, and large screen height available to accommodate the increased invert elevation of the specified design.

The Bedford fish-friendly flow augmentation pumps are also commercially available and Poseidon has received preliminary cost estimates for them. The submersible pump specified for this application would be constructed of solid brass to withstand the rigors of pumping seawater. The pump model specified for this application has been proven to be fish-friendly (see Appendix A).

iv. Screened Intake with Discharge Diffuser

The technical aspects of the New Screening Structure with discharge diffuser are analyzed in greater detail below.

a. Site Constraints

The footprint available for the New Screening Structure is limited given that all existing EPS structures are still in service and would have to remain so during construction of the long term stand-alone CDP structures. However, iterative conceptual design efforts indicate that sufficient space is available to keep all four screens in-line in one location by using a lower invert elevation (and longer screens).

Site constraints associated with a retrofitted screening structure also typically limit the hydraulic optimization of the approach flow. However, at the tie-in point for water withdrawal under long term stand-alone CDP operation, a novel technique would make use of the existing EPS intake tunnel walls as a flow distribution tool for providing the proper approach flow hydraulics to the screens.

A single fish return system would be sufficient for all four screens in the New Screening Structure. The majority of the fish return pipe would be buried (Figure 18) and would minimize aesthetic concerns. The terminus of the fish return pipe would be located approximately 205 feet from the existing EPS intake.

b. Equipment

The screening equipment required to construct a new long term stand-alone CDP intake screening structure is commercially available and Poseidon has received a preliminary cost estimate for the screens. The BWT center-flow traveling water screen is a proven technology used widely throughout the world for screening large seawater flows. The equipment materials specified are marine grade to minimize corrosion and are designed with cleaning features to keep them clear of debris. The BWT screen design has numerous advantages over other fish-friendly traveling water screen designs including increased screening area associated with the two screening faces and the v-shaped screen baskets, elimination of debris carryover, and large screen height available to accommodate the increased invert elevation of the specified design.

The multiport diffuser system is typically custom-designed for each application. The pipeline leading to the offshore diffusers for the long term stand-alone CDP would be approximately 5,600 feet long (total of 4,000 feet offshore) and 72 inches in diameter. Consideration must be given to the impacts associated with the construction of a large offshore structure on benthic habitat. Impacts would be specific to the method of construction with tunneling having relatively fewer impacts than the “trench and fill” approach.

B. Economic

A detailed analysis of the life-cycle cost for the Expanded CDP subsurface intake/discharge alternatives is presented in Appendix N. The findings of this analysis are included in Table 1. The life cycle costs provide a relative comparison of the net incremental cost and savings of each of the alternatives. Costs considered include permitting, design, land acquisition, financing, construction, operations, maintenance, mitigation, equipment replacement, insurance, taxes, management, and energy consumption over the lifetime of the facility. Savings considered include construction and operating allowances provided for in the WPA that are applicable to each of the alternatives and operational savings due reduced chemical consumption, extended membrane life, and reduced membrane cleaning frequency that is applicable to the subsurface intake alternatives.

Table 1. Expanded CDP intake/discharge alternatives net incremental annual life-cycle cost/(savings) ($/year).

Annual Cost	Surface Intake with Flow Augmentation	Surface Intake with Multiport Diffuser	Subsurface Intake with Flow Augmentation	Subsurface Intake with Multiport Diffuser
Capital Charge	$3,806,058	$34,314,716	$107,982,781	$60,209,040
O&M Charge	$2,897,960	$1,690,000	$8,868,050	$5,477,125
Other Charges	$391,997	$4,880,500	$10,720,844	$8,198,981
Total Annual Cost	$7,096,016	$40,642,836	$127,571,675	$73,885,146
WPA O&M Offset	($2,759,512)	($2,759,512)	($2,759,512)	($2,759,512)
WPA Capital Offset	($1,897,879)	($1,968,003)	($2,134,297)	($1,994,291)
Total Annual Expense	$2,438,626	$35,915,322	$122,677,866	$69,131,344

The findings of this analysis indicate that $73,885,146 would need to be added to the annual operating budget of the CDP to pay for the capital and operating costs associated with SIG with the multiport diffuser alternative and $127,571,675 would need to be added to the annual operating budget of the CDP to pay for the capital and operating costs associated with the SIG with flow augmentation alternative

Chapter III.M provides the following guidance for assessing the feasibility of subsurface intakes:

> *Subsurface intakes shall not be determined to be economically infeasible solely because subsurface intakes may be more expensive than surface intakes. Subsurface intakes may be determined to be economically infeasible if the additional costs or lost profitability associated with subsurface intakes, as compared to surface intakes, would render the desalination facility not economically viable.*

Thus, the Regional Water Board's determination of the economic feasibility of the SIG alternatives turns on the basis of whether the additional costs or lost profitability associated with these alternatives would render the desalination facility not economically viable. One measure of economic viability is whether the anticipated plant revenues would cover cost of one or both of the SIG alternatives.

The Water Authority entered into a 30-year Water Purchase Agreement (the "WPA") with Poseidon. Under the terms of the WPA, all of the output of the CDP is to be made available to the Water Authority at a predetermined price. Thus, one consideration for determining the feasibility of the SIG alternatives is whether the amount the Water Authority is obligated to pay for the water would be adequate to cover additional cost of the SIG alternatives for the duration of the 30-year operating life of the project when the SIG is put into operation.

The WPA pricing terms provide for recovery of a predetermined dollar amount for intake retrofit capital and operating costs incurred due to the retirement of the EPS. The net annual costs of $69 million per year for the subsurface intake with a multiport diffuser and $123 million per year for the subsurface intake with flow augmentation are net of the maximum allowance provided under the WPA. Therefore, absent an additional source of revenue, the SIG alternatives are economically infeasible.

C. Schedule

Each intake and outfall technology features unique engineering and constructability characteristics which will impact the individual project schedules for each. Alternatives including the SIG, for example, will require longer construction periods. Table 2 below presents a summary of the schedules for each of the intake/discharge alternatives considered.

Table 2. Summary of permitting, construction, and operating terms for the intake/discharge alternatives considered.

Project Duration	Surface Intake with Flow Augmentation	Surface Intake with Multiport Diffuser	Subsurface Intake with Flow Augmentation	Subsurface Intake with Multiport Diffuser
Permitting Term (yrs)	1.5	3.0	3.0	3.0
Construction Term (yrs)	2.0	3.0	7.2	3.8
Total Duration	3.5	6.0	10.2	6.8
Operating Term (yrs)	26.5	24.0	19.8	23.2
Total Term	30.0	30.0	30.0	30.0

Per the schedule provided in Table 2, based on a 30-year term, the surface intake with flow augmentation alternative has the longest operating period, resulting in the lowest unit water costs. This operating period results primarily from the contracted construction schedule when compared to the SIG alternatives.

D. Environmental

The most significant impacts to aquatic organisms caused by desalination intake structures are broadly categorized into: 1) operational impacts (impingement and entrainment), and 2) construction impacts. Operational impacts represent an interaction between the organisms in the source waterbody and the screening technology and each is dependent on organism and screen mesh size. Construction impacts relate to the temporary and permanent disturbances to the benthos. A discussion follows that describes each of these impacts in greater detail for each intake/discharge alternative evaluated.

i. SIG Intake with Discharge Flow Augmentation

a. Impingement

Impingement is the pinning of larger organisms against the screen mesh by the flow of the withdrawn water. The magnitude of impingement losses for any species from intake operation is a function of the involvement of the species with the intake (number or proportion impinged) and the subsequent mortality of those organisms (referred to as impingement mortality or IM).

Intake velocity is commonly accepted to be the strongest predictor of impingement. Furthermore, a through-screen velocity of 0.5 ft/sec or less has been identified for being protective of impingeable sized fish. A SIG is commonly-accepted to eliminate impingement since the velocity through the infiltration medium is minimized to the extent that it is biologically negligible. As such, a SIG would not impinge any marine organisms and would comply with the Desalination Amendment prescription at 2.d.(1)(a) that the regional board shall require subsurface intakes unless determined to be infeasible.

b. Entrainment

Entrainment is the passage of smaller organisms through the screening mesh. The magnitude of entrainment losses for any species from intake operation is a function of the involvement of the species with the intake (number or proportion entrained) and the subsequent mortality of those organisms as they pass through the process equipment (referred to as entrainment mortality).

A SIG is commonly-accepted to eliminate entrainment since the rate of withdrawal of seawater per unit area of SIG surface is extremely slow and the pore sizes through the infiltration medium are too small to allow the physical passage of marine organisms. As such, a SIG would not entrain any marine organisms and would comply with the Desalination Amendment prescription at 2.d.(1)(a) that the regional board shall require subsurface intakes unless determined to be infeasible.

c. Brine Mixing Zone

The brine mixing zone (BMZ), for the CDP is a 200 meter (656 ft) semi-circle originating from the terminus of the discharge channel in the ocean. Outside of the BMZ, salinity cannot exceed 2 ppt over ambient background salinity. Within the BMZ, entrained organisms will experience elevated salinity. The benthic area encompassed by the brine mixing zone would be approximately 15.5 acres.

d. Habitat Loss

The SIG alternative under consideration would be located in the lagoon. RO feedwater and flow augmentation water would be withdrawn beneath the floor of the lagoon. The lagoon based SIG would avoid impacts to sensitive habitats and sensitive species. However, construction of the

SIG would result in the permanent destruction of approximately 72 acres of fish habitat, as the SIG would require a large footprint to provide the total plant flow (299 MGD) (Figure 3).

Heavy construction would be required along the lagoon shoreline for placement of the Intermediate Pump Station and associated piping. Similarly, heavy construction in the lagoon complex associated with construction of the infiltration gallery will result in temporary loss of the lagoon for recreational, permanent loss of aquaculture use, and conversion of 72 acres of subtidal habitat to engineered fill.

A recognized advantage of a SIG is its ability to withdraw seawater without impinging or entraining marine life. However, in this instance, construction and operation of the SIG would replace a significant portion of the habitat of the most abundant larval fish species identified in the CDP entrainment study. Over ninety percent of the fish larvae that are expected be entrained by the Expanded CDP using a surface intake are CIQ goby, combtooth blennies and Garibaldi (see Appendix K, Carlsbad Desalination Facility Discharge Options Entrainment Analysis, MBC, July 27, 2015). These species' habitats include 49 acres of mudflat/tidal channel, 253 acres of open water, and the rocky areas adjacent to the power plant intake. Depending on which SIG alternative is selected, construction and operation of the subsurface (SIG) intake in Agua Hedionda Lagoon would effectively eliminate a substantial portion of the CIQ goby habitat on the floor of the lagoon and replace it with engineered fill. The combtooth blennies live primarily in the shell fish racks in the west lagoon. The aquaculture operation would not be compatible with construction and operational maintenance required for the SIG. Therefore, both SIG alternatives would require removal of the combtooth blennie habitat in the lagoon. Garibaldi live in the rocks adjacent to the power plant intake structure. Garibaldi are found in greater numbers at this location than comparable habitat in the pristine environments of Coronado, San Clemente, and Santa Catalina Islands. The reason for the high concentrations is that the power plant intake operations provide a source of food for the Garibaldi. If the intake were to be permanently decommissioned, the Garibaldi would likely abandon this area of the lagoon.

The construction and operation of this SIG alternative has environmental effects on the marine ecology that must be considered by the Regional Water Board in assessing the feasibility of subsurface intakes. The expected impacts to the CIQ goby are similar to those of the open intake, whereas the SIG is expected to have a greater impact on the combtooth blennie and Garibaldi populations than the Expanded CDP using an open intake

ii. SIG Intake with Discharge Diffuser

a. Impingement

Impingement is the pinning of larger organisms against the screen mesh by the flow of the withdrawn water. The magnitude of impingement losses for any species from intake operation is a function of the involvement of the species with the intake (number or proportion impinged) and the subsequent mortality of those organisms (referred to as impingement mortality or IM).

Intake velocity is commonly accepted to be the strongest predictor of impingement. Furthermore, a through-screen velocity of 0.5 ft/sec or less has been identified for being protective of impingeable sized fish. A SIG is commonly-accepted to eliminate impingement since the velocity through the infiltration medium is minimized to the extent that it is biologically negligible. As such, a SIG would not impinge any marine organisms and would comply with the Desalination Amendment prescription at 2.d.(1)(a) that the regional board shall require subsurface intakes unless determined to be infeasible.

b. Entrainment

Entrainment is the passage of smaller organisms through the screening mesh. The magnitude of entrainment losses for any species from intake operation is a function of the involvement of the species with the intake (number or proportion entrained) and the subsequent mortality of those organisms as they pass through the process equipment (referred to as entrainment mortality).

A SIG is commonly-accepted to eliminate entrainment since the rate of withdrawal of seawater per unit area of SIG surface is extremely slow and the pore sizes through the infiltration medium are too small to allow the physical passage of marine organisms. As such, a SIG would not entrain any marine organisms and would comply with the Desalination Amendment prescription at 2.d.(1)(a) that the regional board shall require subsurface intakes unless determined to be infeasible.

Entrainment relative to a discharge diffuser refers to secondary entrainment of ambient organisms in the ocean water entrained into the diffuser jets. The Substitute Environmental Documentation (SED) included with the Desalination Amendment states in section 8.6.2.2.1 that "organisms that are entrained into the brine discharge may experience high levels of shear stress for short durations, which is thought to cause some mortality." In addition to shear stress, the ambient organisms would be exposed to osmotic stress associated with the higher salinity brine plume. Each of these factors that could potentially contribute to entrainment mortality in the discharge diffuser system is discussed in the section below.

Shear and Turbulence

As cited in the SED, modeling results from Foster et al. (2013) indicated that "*23 percent of the total entrained volume of dilution water may be exposed to lethal turbulence*." and more specifically, the SWRCB (2014) states in the SED that "*we assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence*".

Under long term stand-alone operation, the diffuser would discharge 67 MGD of effluent (60 MGD brine and 7 MGD treated backwash water from the pretreatment filters) into the receiving water. The salinity of the effluent would be 65 ppt. In order to dilute the 67 MGD (at 65 ppt) to the receiving water limit of 35.5 ppt (2 ppt above background of 33.5 ppt), 945 MGD of dilution water would be entrained ((60 MGD x 67 ppt) + (945 MGD x 33.5 ppt))/(60 MGD + 945 MGD) = 35.5 ppt. Of the total dilution flow entrained, 23% (or 217 MGD) would expose ambient ichthyoplankton to lethal levels of shear. The duration of exposure to lethal shear in the CDP discharge diffuser plume is short: 10-50 seconds (per section 8.5.1.2 of the SED). Since there are no empirical data available on mortality caused by the diffuser jet, the SED states that "*until additional data are available, we assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence.*"

Based on the APF methodology set forth in Appendix E of the OPA staff report, 67 acres would be required to mitigate for the loss of organisms due to entrainment in the diffuser jet (Report of Waste Discharge Appendix K).

Osmotic Stress

Osmotic stress results from the exposure of organisms to elevated salinity. The critical measure of risk for an open-ocean diffuser system is the exposure profile: the duration of exposure and the area within which salinity is above critical thresholds for key indicator species. The duration of exposure and a salinity map can be estimated through modeling. Relative to the Screened Intake with Discharge Flow Augmentation alternative presented below, the duration of exposure for organisms entrained in the discharge plume would be less than that of organisms entrained through the flow augmentation system.

c. Brine Mixing Zone

The brine mixing zone (BMZ), for the CDP is a circle with a radius of 100 meters (328 ft) originating from the discharge diffuser ports in the ocean. The discharge diffuser system will be comprised of four duckbill diffuser spaced approximately 100 feet apart (Figure 7). Outside of the BMZ, salinity cannot exceed 2 ppt over ambient background salinity. Within the BMZ, entrained organisms will experience elevated salinity. The BMZ would extend 100 meters (328 ft) out from each of the four discharge points with the combined area inside the BMZ covering 14.4 acres. The benthic area encompassed by the brine mixing zone would be approximately 14.4 acres.

d. Habitat Loss

The SIG alternative under consideration would be located in the lagoon. RO feedwater would be withdrawn beneath the floor of the lagoon. The lagoon based SIG would avoid impacts to sensitive habitats and sensitive species. However, construction of the SIG and the diffuser would result in the permanent destruction of approximately 33 acres of fish habitat, as the SIG would require a large footprint to provide the total plant flow (128 MGD) (Figure 8).

Heavy construction would be required along the lagoon shoreline for placement of the Intermediate Pump Station and associated piping. Similarly, heavy construction in the lagoon complex associated with construction of the infiltration gallery will result in temporary loss of the lagoon for recreational, permanent loss of aquaculture use, and conversion of 33 acres of subtidal habitat to engineered fill.

A recognized advantage of a SIG is its ability to withdraw seawater without impinging or entraining marine life. However, in this instance, construction and operation of the SIG would replace a significant portion of the habitat of the most abundant larval fish species identified in the CDP entrainment study. Over ninety percent of the fish larvae that are expected be entrained by the Expanded CDP using a surface intake are CIQ goby, combtooth blennies and Garibaldi (see Appendix K, Carlsbad Desalination Facility Discharge Options Entrainment Analysis, MBC, July 27, 2015). These species' habitats include 49 acres of mudflat/tidal channel, 253 acres of open water, and the rocky areas adjacent to the power plant intake. Depending on which SIG alternative is selected, construction and operation of the subsurface (SIG) intake in Agua Hedionda Lagoon would effectively eliminate a substantial portion of the CIQ goby habitat on the floor of the lagoon and replace it with engineered fill. The combtooth blennies live primarily in the shell fish racks in the west lagoon. The aquaculture operation would not be compatible with construction and operational maintenance required for the SIG. Therefore, both SIG alternatives would require removal of the combtooth blennie habitat in the lagoon. Garibaldi live in the rocks adjacent to the power plant intake structure. Garibaldi are found in greater numbers at this location than comparable habitat in the pristine environments of Coronado, San Clemente, and Santa Catalina Islands. The reason for the high concentrations is that the power plant intake operations provide a source of food for the Garibaldi. If the intake were to be permanently decommissioned, the Garibaldi would likely abandon this area of the lagoon.

The construction and operation of this SIG alternative has environmental effects on the marine ecology that must be considered by the Regional Water Board in assessing the feasibility of subsurface intakes. The expected impacts to the CIQ goby are similar to those of the open intake, whereas the SIG is expected to have a greater impact on the combtooth blennie and Garibaldi populations than the Expanded CDP using an open intake

iii. Screened Intake with Discharge Flow Augmentation

The Desalination Amendment provides that Poseidon may submit a proposal to the Regional Water Board for flow augmentation as an alternative brine discharge technology. Poseidon must demonstrate to the Regional Water Board that flow augmentation provides a comparable level of intake and mortality of all forms of marine life as multiport diffusers since wastewater dilution is not available. Poseidon must evaluate all of the individual and cumulative effects of flow augmentation on the intake and mortality of all forms of marine life, including (where applicable):

- Intake-related entrainment impacts using an ETM/APF approach;
- Estimate degradation of all forms of marine life from elevated salinity within the brine mixing zone, including osmotic stresses, the size of the impacted area, and the duration that all forms of marine life are exposed to the toxic conditions;
- Estimate intake and mortality of all forms of marine life that occurs as a result of water conveyance, in-plant turbulence or mixing and shearing stress at the point of discharge.

The Desalination Amendment provides that the owner or operator of a desalination facility that proposes flow augmentation using a surface water intake may submit a proposal to the Regional Water Board for approval of an alternative brine mixing zone not to exceed 200 meters (656 ft.) laterally from the discharge structure. Poseidon must demonstrate, in accordance with the criteria listed above, that the combination of the alternative brine mixing zone and flow augmentation using a surface water intake provide a comparable level of intake and mortality of all forms of marine life as the combination of the multiport diffuser and the brine mixing zone required for the multiport diffuser (100 meters (328 ft.) laterally from the points of discharge). In addition to the analysis described above, Poseidon must also evaluate the individual and cumulative effects of the alternative brine mixing zone on the intake and mortality of all forms of marine life.

The screened surface intake under consideration would be located adjacent to the Agua Hedionda Lagoon. Feedwater for the Expanded CDP, and brine dilution water, would be withdrawn through the existing EPS intake structure located in the south west corner of Agua Hedionda Lagoon. There would be no change in the source waterbody, and no significant construction in the lagoon. The habitats potentially impacted by the surface water intake include those areas occupied by the three most commonly entrained lagoon fish larvae (90% of the fish larvae that would be entrained by the Expanded CDP using a surface intake are CIQ goby, combtooth blennies and Garibaldi). These habitats include 49 acres of mudflat/tidal channel and 253 acres of open water. The continued use of the EPS intake would avoid impacts to pelagic fishes commonly reported in the nearshore water-column habitat, including some species important to the commercial and sport fishing industries.

a. Impingement

Impingement is the pinning of larger organisms against the screen mesh by the flow of the withdrawn water. The magnitude of impingement losses for any species from intake operation is a function of the involvement of the species with the intake (number or proportion impinged) and the subsequent mortality of those organisms (referred to as impingement mortality or IM).

Intake velocity is commonly accepted to be the strongest predictor of impingement. Furthermore, a through-screen velocity of 0.5 ft/sec or less has been identified for being protective of impingeable sized fish. Per the Desalination Amendment language at 2.d.(1)(c)iv., the SWRCB has prescribed a through-screen velocity of 0.5 ft/sec in order to minimize impingement at surface water desalination intakes.

The screens for the long term stand-alone CDP intake/discharge structure are designed for less than 0.5 ft/sec through-screen velocity and would therefore meet the Desalination Amendment requirement for minimizing impingement at the New Screening/Fish-friendly Pumping Structure for the CDP.

b. Entrainment

Entrainment is the passage of smaller organisms through the screening mesh. The magnitude of entrainment losses for any species from intake operation is a function of the involvement of the species with the intake (number or proportion entrained) and the subsequent mortality of those organisms as they pass through the process equipment (referred to as entrainment mortality).

Per the Desalination Amendment language at 2.d.(1)(c)ii., the SWRCB has prescribed screens with 1.0-mm mesh in order to reduce entrainment at surface water desalination intakes. In accordance with the Desalination Amendment, Poseidon has selected 1.0-mm screens for both the process and flow augmentation sides of the intake/discharge structure.

Based on intake-related entrainment through the process water screens (128 MGD), the calculated APF associated with the operation of the screen intake serving the SWRO process is 36 acres and 48 acres for the 171 MGD in the flow augmentation system (assuming 100% mortality), for a total of 84 acres using the methodology set forth in Appendix E of the Staff Report for the Desalination Amendment.

Each of the factors that could potentially contribute to entrainment mortality in the flow augmentation system is discussed in the sections below.

Pump Passage (Pressure and Blade Strike)

Entrained organisms would be exposed to hydraulic- and mechanical-related stresses passing through the flow augmentation pumps. In general, the stresses associated with pump passage include pressure changes (magnitude and rate), blade strike, mechanical grinding and shear. Most of the information on the effects of these stresses on fishes is from the hydropower industry.

Regarding pressure, gas-filled cavities within fish can be susceptible to pressure-induced damage (barotrauma). However, the low head design of the pumps (12 ft) should minimize the risk of barotrauma. This low head equates to a change in pressure of approximately 5.2 psi.

The low lift pumps specified for the CDP flow augmentation system would be fish-friendly axial flow Bedford pumps. These pumps have been designed and used to safely pass live fish for pumping applications worldwide. The pump specified for the CDP has been tested with juvenile and adult fish at a full scale for fish-friendliness (Vis and Kemper 2012). A total of 373 fish were passed through the pump operating at 330 rpm discharging 1.3m^3/sec (46 ft^3/sec) and survival was 100%. Only minor injuries (e.g., descaling, hemorrhage) were noted in the study results. Given the favorable performance for larger fish, smaller life stages are also presumed to fare well during pump passage.

Shear and Turbulence

Shear and turbulence are forces to which organisms entrained in the dilution flow would be exposed. These forces exist where water velocities change over a given distance; therefore, the greatest shear forces are likely to be encountered during pump passage and during mixing of the brine and dilution flows. The flow augmentation pumps would be operated at approximately 500 rpm to lift water approximately 12 feet. The location of entrained organisms within the pump passage would affect whether they would be exposed to the areas of high shear (typically near solid surfaces in a pump impellor). The low lift fish-friendly axial flow Bedford pumps are designed to minimize these impacts. Similarly, the location of entrained organisms when the dilution and brine flows are mixed would affect whether they would be exposed to areas of high shear in the discharge tunnel. The mixing point is being designed to minimize the creation of high shear zones while still promoting efficient mixing of the two flows. Therefore, pending results of ongoing modeling efforts (Appendix L), we expect that shear will not be a major contributor to injury and mortality in the flow augmentation system.

Osmotic Stress

Osmotic stress results from the exposure of organisms to elevated salinity. The critical measure of risk is the exposure profile: the duration of exposure and the magnitude of increased salinity. The duration of exposure to elevated salinity in the CDP in-plant dilution system has been modeled and biological assays have been conducted by Poseidon to evaluate salinity tolerances for various key indicator species. Each effort is described in more detail below.

Hydrodynamic and CFD Modeling

Hydrodynamic modeling was conducted by Dr. Scott Jenkins (Report of Waste Discharge Appendix C) and CFD modeling was conducted by Alden Research Laboratory (Report of Waste Discharge Appendix L) to determine the duration of larval exposure to elevated salinity. Table 3 presents the matrix of durations based on varying flows at the CDP during average ocean conditions. These exposure durations formed the basis of the biological assays conducted during Nautilus' salinity tolerance testing discussed below.

Table 3. Ichthyoplankton exposure durations.

Total Discharge Flow Rate	Total Discharge Salinity Level	Time Exposure for Salinity in Discharge Tunnel	Mean Time Exposure for Salinity in Discharge Pond[1]	Time Exposure for Salinity from Discharge Pond to BMZ (35.5 ppt)	Time Exposure for Salinity from BMZ (35.5 ppt) to Average Ambient Ocean (33.5 ppt)
238 MGD	42 ppt	2.2 min	5.5 min	26.9 min	24.5 min

[1] Residence time in the discharge pond ranges from less than one minute to ten minutes, with a median residence time of 5.5 minutes.

Salinity Tolerance Testing

Poseidon contracted with Nautilus Environmental (Nautilus) (Report of Waste Discharge Appendix I) to assess the potential effects of varying salinity levels on sensitive larval-stage marine organisms. The study design was focused on potential effects due to salinity fluctuations on organisms traveling into the intake from ambient seawater salinity in the receiving environment, through the brine dilution systems of the CDP, and then being discharged back into the receiving water. Species and endpoints evaluated for this study included red abalone (*Haliotis rufescens*) development and purple sea urchin (*Strongylocentrotus purpuratus*) development. These species were identified as two of the most sensitive to elevated salinity levels relative to other accepted monitoring species in the Ocean Plan, based on previous studies using standard EPA whole effluent toxicity (WET) tests (Philips et al., 2012).

The goal of this study was to determine the salinity- induced adverse effects to these organisms as they travel through the brine dilution system. The study was designed to assess several potential operating scenarios involving differing salinity levels and residence times that were within the plant's operational capabilities. Procedures were established to simulate the salinity fluctuations an organism might experience as it moves through the brine dilution system, encountering elevated salinity as the brine discharge is mixed with seawater from the flow augmentation system then a reduction in salinity to 35.5 ppt as it travels through the discharge system to the edge of the brine mixing zone (BMZ), and finally a reduction from 35.5 ppt to ambient salinity.

There were three distinct phases common to each exposure scenario; only the maximum salinity and duration of each phase were varied:

- Phase 1 consisted of simulation of initial brine mixing with seawater from the flow augmentation system. The salinity was raised from ambient seawater (33.5 ppt) by adding 67 ppt brine at a rate calculated to reach the desired salinity within approximately one minute, and then held there for a specified amount of time depending on the scenario being tested.
- Phase 2 involved simulation of the dilution that occurs in the BMZ technology. Continuous addition of ambient seawater at a rate calculated to reach 35.5 ppt within a specified period.
- Phase 3 represents the return to ambient seawater salinity from 35.5 ppt, with the rate of return varied according to specification.

Results of the bench-top exposure trials are presented below in Table 4.

Table 4. Summary of results for bench-top exposure scenarios.

Scenario #	Scenario Description	Test Date	Species Tested	Mean Normal Development			
				Sample	Phase 1	Phase 2	Phase 3
1	P1: 44 ppt for 2.8 minutes; P2: 39 min.; P3: 30 min.	2/6/15	Abalone Development	Control	83.8	77.7	80.5
				Brine Exposure	76.7*	79.1	78.8
1	P1: 44 ppt for 2.8 min.; P2: 39 min.; P3: 30 min.	2/17/15	Urchin Development	Control	93.7	92.0	89.3
				Brine Exposure	91.3	90.3	91.3
2	P1: 42 ppt for 2.2 min.; P2: 36 min.; P3: 30 min.	1/30/15	Abalone Development	Control	94.0	93.7	94.3
				Brine Exposure	95.7	92.7	91.7
3	P1: 40 ppt for 1.7 min.; P2: 34 min.; P3: 30 min.	1/22/15	Abalone Development[a]	Control[a]	66.0	61.0	67.3
				Brine Exposure	68.5	67.0	60.3

P1, P2, P3 = Phase 1, 2, and 3

* An asterisk indicates a statistically significant decrease compared to the control ($p < 0.05$)

[a] The abalone test Scenario #3 conducted on January 22 did not meet the 80% test acceptability criterion for normal development in the control..

In summary, the brine dilution toxicity study focused on the species that is most sensitive to elevated salinity and concluded that these species experienced no significant toxic effects after being exposed elevated salinity conditions similar those that would exist during transit through proposed flow augmentation system offshore to the location where the salinity of the discharge would be match the surrounding seawater.

Notwithstanding the expected high rate of survival of all forms of marine life exposed to the cumulative effects of the flow augmentation system, for the purposes of demonstrating to the Regional Water Board that this technology provides a comparable level of intake and mortality of all forms of marine life to that of the multiport diffusers, Poseidon has conservatively assumed the worst case outcome -- 100% mortality of all organisms passing through the flow augmentation system. Flow augmentation is expected to require 171 MGD of seawater for brine dilution purposes. Therefore, 171 MGD represents the volume of water, and associated ichtyoplankton, that Poseidon has assumed would be subject to 100% mortality. The calculated APF associated with the operation of the flow augmentation system is 48 acres using the methodology set forth in Appendix E of the OPA staff report (Report of Waste Discharge Appendix K).

c. *Brine Mixing Zone*

The brine mixing zone (BMZ), for the CDP is a 200 meter (656 ft) semi-circle originating from the terminus of the discharge channel in the ocean. Outside of the BMZ, salinity cannot exceed 2 ppt over ambient background salinity. Within the BMZ, entrained organisms will experience elevated salinity. The benthic area encompassed by the brine mixing zone would be approximately 15.5 acres.

iv. Screened Intake with Discharge Diffuser

The screened surface intake under consideration would be located adjacent to the Agua Hedionda Lagoon. Feedwater for the Expanded CDP would be withdrawn through the existing EPS intake structure located in the south west corner of Agua Hedionda Lagoon. There would be no change in the source waterbody, and no significant construction in the lagoon. The habitats potentially impacted by the surface water intake include those areas occupied by the three most commonly entrained lagoon fish larvae (90% of the fish larvae that would be entrained by the Expanded CDP using a surface intake are CIQ goby, combtooth blennies and Garibaldi). These habitats include 49 acres of mudflat/tidal channel and 253 acres of open water. The continued use of the EPS intake would avoid impacts to pelagic fishes commonly reported in the nearshore water-column habitat, including some species important to the commercial and sport fishing industries.

a. *Impingement*

Impingement is the pinning of larger organisms against the screen mesh by the flow of the withdrawn water. The magnitude of impingement losses for any species from intake operation is a function of the involvement of the species with the intake (number or proportion impinged) and the subsequent mortality of those organisms (referred to as impingement mortality or IM).

Intake velocity is commonly accepted to be the strongest predictor of impingement. Furthermore, a through-screen velocity of 0.5 ft/sec or less has been identified for being protective of impingeable sized fish. Per the Desalination Amendment language at 2.d.(1)(c)iv., the SWRCB has prescribed a through-screen velocity of 0.5 ft/sec in order to minimize impingement at surface water desalination intakes.

The screens for the long term stand-alone CDP intake/discharge structure are designed for less than 0.5 ft/sec through-screen velocity and therefore meet the Desalination Amendment requirement for minimizing impingement at the New Screening/Fish-friendly Pumping Structure for the CDP.

b. *Entrainment*

Entrainment is the passage of smaller organisms through the screening mesh. The magnitude of entrainment losses for any species from intake operation is a function of the involvement of the species with the intake (number or proportion entrained) and the subsequent mortality of those organisms as they pass through the process equipment (referred to as entrainment mortality).

Entrainment relative to the process water intake would be as described above for the Screened Intake with Discharge Flow Augmentation alternative. The process water screens use 1.0-mm mesh and therefore comply with the Desalination Amendment prescription for reducing entrainment. Despite the small screen mesh size, however, some early life stages will be entrained.

Entrainment relative to a discharge diffuser refers to secondary entrainment of ambient organisms in the ocean water entrained into the diffuser jets. The Substitute Environmental Documentation (SED) states in section 8.6.2.2.1 that "*organisms that are entrained into the brine discharge may experience high levels of shear stress for short durations, which is thought to cause some mortality.*" In addition to shear stress, the ambient organisms would be exposed to osmotic stress associated with the higher salinity brine plume. Each of these factors that could potentially contribute to entrainment mortality in the discharge diffuser system is discussed in the section below.

Shear and Turbulence

As cited in the SED, modeling results from Foster et al. (2013) indicated that "*23 percent of the total entrained volume of dilution water may be exposed to lethal turbulence*." and more specifically, the SWRCB (2014) states in the SED that "*we assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence*".

Under long term stand-alone operation, the diffuser would discharge 67 MGD of effluent (60 MGD brine and 7 MGD treated backwash water from the pretreatment filters) into the receiving water. The salinity of the effluent would be 65 ppt. In order to dilute the 67 MGD (at 65 ppt) to the receiving water limit of 35.5 ppt (2 ppt above background of 33.5 ppt), 945 MGD of dilution water would be entrained. Of the total dilution flow entrained, 23% (or 217 MGD) would expose ambient ichthyoplankton to lethal levels of shear. The duration of exposure to lethal shear in the CDP discharge diffuser plume is short: 10-50 seconds (per section 8.5.1.2 of the SED). Since there are no empirical data available on mortality caused by the diffuser jet, the SED states that "*until additional data are available, we assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence.*"

Based on intake-related entrainment through the process water screens (128 MGD), the calculated APF associated with the operation of the screen intake serving the SWRO process is 36 acres and 67 acres for the entrainment impacts associated with the multiport diffuser, for a total of 103 acres using the methodology set forth in Appendix E of the Staff Report for the Desalination Amendment.

Osmotic Stress

Osmotic stress results from the exposure of organisms to elevated salinity. The critical measure of risk for an open-ocean diffuser system is the exposure profile: the duration of exposure and the area within which salinity is above critical thresholds for key indicator species. The duration of exposure and a salinity map can be estimated through modeling. Relative to the Screened Intake with Discharge Flow Augmentation alternative presented above, the duration of exposure for organisms entrained in the discharge plume would be less than that of organisms entrained through the flow augmentation system.

c. Brine Mixing Zone

The brine mixing zone BMZ, for the CDP is a circle with a radius of 100 meters (328 ft) originating from the discharge diffuser ports in the ocean. The discharge diffuser system will be comprised of four duckbill diffuser spaced approximately 100 feet apart (Figure 7). Outside of the BMZ, salinity cannot exceed 2 ppt over ambient background salinity. Within the BMZ, entrained organisms will experience elevated salinity. The BMZ would extend 100 meters (328 ft) out from each of the four discharge points with the combined area inside the BMZ covering 14.4 acres. The benthic area encompassed by the brine mixing zone would be approximately 14.4 acres.

d. Habitat Loss

Construction of the discharge diffuser would result in habitat loss equivalent to approximately 1 acre.

E. Social

i. SIG Intake with Discharge Flow Augmentation

a. Desalination Plant Operations

Starting Fall 2015, the CDP will provide the San Diego region with up to 10% of its water supply. Cabrillo intends to discontinue the operation of once-through-cooling pumps serving the EPS and CDP as early as June 1, 2017. The improvements needed for the transition to long term stand-alone operation need to be in place in advance of the retirement of the EPS so to minimize the interruption in the output from the CDP. If the SIG intake with discharge flow augmentation alternative were to be selected, the CDP could be out of service for five to eight years waiting for the SIG to be completed. During this period, the San Diego County Water Authority's (the "Water Authority") would need to find an alternative water supply, and the owner of the CDP would be unable to make debt service payments on the CDP construction bonds.

b. Recreational

YMCA Camp H2O

Located in the middle lagoon, Camp H2O is a summer camp that offers seven to 12-year olds affordable day camp activities, including swimming, kayaking, paddleboards, rowboats and fishing. The camp plays an important role in educating youth about the precious marine environment and the need to preserve the lagoon for future generations. These activities would not be compatible with construction of either of the SIG alternatives. Depending on the alternative selected, Camp H2O would be closed for four to seven years.

Recreational Boating.

Recreational boating is allowed in the east lagoon and is one of the most popular lagoon activities for residents and visitors. California Water Sports offers boating lessons and rents a variety of boats, jet skis, paddle board, kayaks, canoes, and peddle craft to the general public. California Water Sports operations would not be compatible with construction of the larger of the SIG alternatives because construction of the SIG would require exclusive access to the area of the east lagoon designated for use by the water craft. Therefore, if the SIG with flow augmentation alternative is selected, California Water Sports would be closed for seven years.

c. Commercial

In addition to the lost recreation associated with construction of the SIG, many of the foregone activities also result in lost commercial opportunities for the business that serve the recreating public. So, in addition to the commercial aspect of recreation that is lost, other businesses could be impacted. The lagoon is home to the thriving Carlsbad Aquafarm where mussels and oysters are harvested and sold to seafood vendors and restaurants. The Aquafarm has 20 employees and helps reduce the toll that over-fishing takes on the ocean by providing high-quality farmed seafood. Aquafarm operations would not be compatible with construction and operation of either of the SIG alternatives because construction of the SIG, and ongoing maintenance dredging associated with the SIG operations, would require unobstructed access to the entire west lagoon. Therefore, the Aquafarm would be closed if either SIG alternative is selected.

ii. SIG Intake with Discharge Diffuser

a. Desalination Plant Operations

Starting Fall 2015, the CDP will provide the San Diego region with up to 10% of its water supply. Cabrillo intends to discontinue the operation of once-through-cooling pumps serving the EPS and CDP as early as June 1, 2017. The improvements needed for the transition to long term stand-alone operation need to be in place in advance of the retirement of the EPS so to minimize the interruption in the output from the CDP. If the SIG alternative with discharge diffuser were to be selected, the CDP could be out of service for five to eight years waiting for the SIG to be completed. During this period, the San Diego County Water Authority's (the “Water Authority”) would need to find an alternative water supply, and the owner of the CDP would be unable to make debt service payments on the CDP construction bonds.

b. Recreational

YMCA Camp H2O

Located in the middle lagoon, Camp H2O is a summer camp that offers seven to 12-year olds affordable day camp activities, including swimming, kayaking, paddleboards, rowboats and fishing. The camp plays an important role in educating youth about the precious marine environment and the need to preserve the lagoon for future generations. These activities would not be compatible with construction of either of the SIG alternatives. Depending on the alternative selected, Camp H2O would be closed for four to seven years.

Warm Water Jetties Surf Break

The EPS discharge acts as a manmade river mouth that delivers sand to the end of the jetties that form the discharge channel, creating a man-made sandbar. The result is a popular surfing break. Should the SIG with the multiport discharge diffuser be selected, the Expanded CDP discharge would be relocated offshore, thereby eliminating a significant source of sand replenishment for the sandbar. Additionally, per the terms of the CDP's State Lands Commission Lease, the jetties must be removed if the existing discharge channel is decommissioned. Thus, if the SIG with the multiport diffuser is selected, an important recreational asset would be lost.

c. Commercial

In addition to the lost recreation associated with construction of the SIG, many of the foregone activities also result in lost commercial opportunities for the business that serve the recreating public. So, in addition to the commercial aspect of recreation that is lost, other businesses could be impacted. The lagoon is home to the thriving Carlsbad Aquafarm where mussels and oysters are harvested and sold to seafood vendors and restaurants. The Aquafarm has 20 employees and helps reduce the toll that over-fishing takes on the ocean by providing high-quality farmed seafood. Aquafarm operations would not be compatible with construction and operation of either of the SIG alternatives because construction of the SIG, and ongoing maintenance dredging associated with the SIG operations, would require unobstructed access to the entire west, lagoon. Therefore, the Aquafarm would be closed if either SIG alternative is selected.

iii. Screened Intake with Discharge Flow Augmentation

There are no social impacts associated with this alternative.

iv. Screened Intake with Discharge Diffuser

There are limited social impacts associated with this alternative.

a. Recreational

Warm Water Jetties Surf Break

The EPS discharge acts as a manmade river mouth that delivers sand to the end of the jetties that form the discharge channel, creating a man-made sandbar. The result is a popular surfing break. Should the screened intake with the multiport diffuser be selected, the Expanded CDP discharge would be relocated offshore, thereby eliminating a significant source of sand replenishment for the sandbar. Additionally, per the terms of the CDP's State Lands Commission Lease, the jetties must be removed if the existing discharge channel is decommissioned. Thus, if the screened intake with the multiport diffuser is selected, an important recreational asset would be lost.

4. Mitigation

This section describes the impacted area subject to mitigation required for each of the four alternatives evaluated. Per section III.M.2.e of the Desalination Amendment, the impacts that require mitigation are associated with the construction and/or operation of the intake and discharge structures after having first minimized intake and mortality of all forms of marine life through best available site, design, and technology. Table 5 summarizes the individual and cumulative mitigation acreage required for each alternative evaluated.

Table 5. Comparison of impacted area subject to mitigation for each intake/discharge alternative evaluated.

	Mitigation (Acreage) Required for Each Intake/Discharge Alternative			
Impacts	**Screened intake with flow augmentation**	**Screened intake with discharge diffuser**	**SIG with flow augmentation**	**SIG with discharge diffuser**
Intake Entrainment APF	36	36	NA	NA
Diffuser Entrainment APF	48	67	NA	67
Brine Mixing Zone	15.5	14.4	15.5	14.4
Habitat Loss	0	1	72	33
Cumulative	**99.5**	**118.4**	**87.5**	**114.4**

5. Recommended Alternative

Poseidon has prepared this feasibility study to determine the best methods and technologies to comply with the requirements set forth in the Desalination Amendment. This analysis indicates that the screened intake with discharge flow augmentation is the best alternative for the CDP when it begins long term stand-alone operation. The BWT center-flow traveling screens specified for the new intake/discharge structure are considered state-of-the-art for minimizing impingement mortality. The use of 1.0-mm mesh on the BWT screens would reduce the potential for entrainment and complies with the screen mesh size requirement in the Desalination Amendment. The screened intake alternatives also utilize existing infrastructure and have comparatively less impact on the fish habitat in and shoreline of the Agua Hedionda Lagoon complex. In particular, the screened intake with discharge flow augmentation alternative can be constructed fully within the existing industrial footprint, unlike the options that consider multiport diffusers or subsurface intakes which would result in substantial disturbance of the benthos in the Pacific Ocean and/or Agua Hedionda Lagoon. In addition, although Poseidon has conservatively assumed 100% mortality of all organisms entrained through the flow augmentation system, the system has been designed to minimize the risk of injury or mortality through the use of fish-friendly pumps, low shear/turbulence transitions.

The life cycle cost analysis presented in Appendix N provides a relative comparison of the net incremental cost and savings of each of the alternatives. The findings indicate that $73,885,146 would need to be added to the annual operating budget of the CDP to pay for the capital and operating costs associated with SIG with the multiport diffuser alternative and $127,571,675 would need to be added to the annual operating budget of the CDP to pay for the capital and operating costs associated with the SIG with flow augmentation alternative.

The WPA pricing terms provide for recovery of a predetermined dollar amount for intake retrofit capital and operating costs incurred due to the retirement of the EPS. The incremental annual life-cycle costs exceed the maximum allowance provided under the WPA by $69,131,344 to $122,677,866 depending on which SIG alternative selected. Therefore, absent a source of additional revenue, the SIG alternatives are not economically feasible (per the guidance provided in Chapter III.M for assessing the feasibility of subsurface intakes).

The data that were compiled in evaluating the feasibility of each alternative are given in Table 6. This table summarizes the direct and indirect effects on all forms of marine life resulting from various alternatives under consideration for the Expanded CDP.

Table 6. Comparison of environmental, schedule, and cost impacts of the CDP intake/discharge alternatives.

Carlsbad Desalination Project Intake and Discharge Altermatives Comparison of Environmental, Schedule and Cost Impacts				
Alternative	**1**	**2**	**3**	**4**
Intake/Discharge Configuration	**Surface Screened Intake with Flow Augmentation**	**Surface Screened Intake with Multiport Diffuser**	**Subsurface Intake with Flow Augmentation**	**Subsurface Intake with Multiport Diffuser**
Intake Water Potentially Exposed to 100% Mortality	128 MGD	128 MGD	0 MGD	0 MGD
Flow Augmentation Water Potentially Exposed to 100% Mortality	171 MGD	0 MGD	0 MGD	0 MGD
Diffuser Water Potentially Exposed to 23% Mortality	0 MGD	217 MGD	0 MGD	217 MGD
Total Water Potentially Exposed to Mortality	299 MGD	345 MGD	0 MGD	217 MGD
Area of Production Foregone	84 Acres[1]	103 Acres[1]	0 Acres	67 Acres[1]
Brine Mixing Zone @ 35.5 ppt	15.5 Acres[2]	14.4 Acres[2]	15.5 Acres[2]	14.4 Acres[2]
Permanent Construction Impacts to Marine Environment	0 Acres	1 Acre[2]	72 Acres[2]	33 Acres[2]
Total Area Impacted Entrainment, Brine Mixing Zone and Construction	99.5 Acres	118.4 Acres	87.5 Acres	114.4 Acres
Permitting Schedule	1.5 Years	3.0 Years	3.0 Years	3.0 Years
Construction Schedule	2.0 Years	3.0 Years	7.2 Years	3.8 Years
Total Duration	3.5 Years[3]	6.0 Years[3]	10.2 Years[3]	6.8 Years[3]
Total Project Cost	$47,108,597[4]	$425,024,742[4]	$1,308,495,000[4]	$745,549,704[4]

[1] Area of Production Foregone is calculated as described in Appendix E of the Staff Report for Amendment to the Water Quality Control Plan for Ocean Waters of California Addressing Desalination Facility Intakes, Brine Discharges, and the Incorporation of other Non-substantive Changes (hereafter, "Appendix E of the Staff Report"). See Report of Waste Discharge Appendix K, Carlsbad Desalination Facility Entrainment Analysis for Dilution and Discharge Options Entrainment Analysis, MBC, July 27, 2015.

[2] Brine Mixing Zone is calculated as described in Section 3.D.

[3] See Appendix Y for project schedule.

[4] See Appendix N and Appendix X for detailed cost estimates.

6. References

Foster, M.S., G.M. Cailliet, J. Callaway, K.M. Vetter, P. Raimondi, and P.J.W. Roberts. 2013. Desalination Plant Entrainment Impacts and Mitigation. Expert Review Panel III. http://www.swrcb.ca.gov/water_issues/programs/ocean/desalination/docs/erp_final.pdf

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Vis, H. and J.H. Kemper. 2012. Test Fish Survivability Bedfor Pumps SAF.90.05.12 Pump at 330 rpm (1.3m^3/s). VisAdvies BV, Nieuwegein, the Netherland. Project number VA2011_28, 17 pg.

Appendix A - Test Fish Survivability Bedford Pumps SAF.90.05.12 Pump at 330 rpm (1.3m^3/s). VisAdvies BV, Nieuwegein, the Netherland. Project number VA2011_28, 17 pg.

VisAdvies

Test fish survivability Bedford Pumps SAF.90.05.12 pump at 330 rpm (1.3 m^3/s)

Report: VA2011_28

Prepared on behalf of:

Bedford Pumps Ltd

July 2012

Authors:

Vis H. & J.H. Kemper

Test fish survivability Bedford Pumps SAF.90.05.12 pump at 330 rpm (1.3 m^3/s)

Report: VA2011_28

Prepared on behalf of:

Bedford Pumps Ltd

July 2012

Authors:

Vis H. & J.H. Kemper

Statuspage

Title:	Test fish survivability Bedford pumps SAF.90.05.12 pump at 330 rpm (1.3 m^3/s)
Summary:	VisAdvies BV
Address:	PO box 2744 3430 GC Nieuwegein
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Homepage:	http://www.VisAdvies.nl
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Number of pages:	17
Keywords:	fish survivability, pump, fish friendly, delayed mortality
Project number:	VA2011_28
Date:	July 2012
Version:	final

Bibliographic reference:

Vis H. & J.H. Kemper, 2012. Test fish survivability Bedford Pumps SAF.90.05.12 pump at 330 rpm (1.3 m^3/s). VisAdvies BV, Nieuwegein, the Netherlands. Project number VA2011_28, 17 pag.

Content

Summary

For the past few decades the welfare of fish in their natural habitat has become a serious issue. For this reason, fish must be able to pass pumping station pumps ("pumps" in short), relatively unharmed.

On June 12th 2012 Bedford Pumps SAF.90.05.12 pump was tested for its ability to let fish pass the motor without being injured. Bedford Pumps SAF pump has been especially designed to be fish friendly. The test known as "the fish survivability test", was performed in a dry dock in the Netherlands. For this test, three representative fish groups in two different size classes were forced to flow through the pump. The groups are:

- *Percidae (perch-like species, mainly perch and ruff),*
- *Cyprinidae (carp-like species, mainly roach and bream) and*
- *Anguillidae (European eel).*

The score is based on the amount of fish that pass the pump and survive without lethal injuries. The final rating of the pump is related to the score of other pumps of the same type.

In total 373 fish were exposed to the pump at a rotation speed of 330 rpm and a discharge of approx. 1.3 m^3*/sec. Except for a few large bream, all fish survived the test and no lethal injuries were observed. Therefore Bedford Pumps SAF pump can be rated as excellent for the rotation speed and discharge as mentioned above.*

1 Introduction

1.1 General

Pumping station pumps (pumps: in short) play a central role in water management and flood control. Common types of such pumps are screw pumps (also called axial pumps) and centrifugal pumps. Besides water, debris and fish are carried along through the pump. Fish passage can partly be avoided by means of a debris grill, so damage and mortality can be reduced. But at the same time, it prevents fish from reaching their spawning grounds. For eels it is an absolute necessity to reach the sea on their way to the spawning grounds in the Sargasso Sea. Moreover, it is a species which is protected by EU regulations and has therefore special priorities.

In recent years fish survival, fish damage and delayed mortality was tested for several types of pumps. The survival, damage and delayed mortality rates due to pump passages vary widely. The fish survival rate can be as low as 0%. In the context of fish welfare, manufacturers like Bedford Pumps Ltd., focus on the development of fish survivable pumps.

At the request of Bedford Pumps Ltd VisAdvies BV performed a test on their fish friendly Axial Flow pump SAF.90.05.12 at a rotation speed of 330 rpm (approx. 1.3 m^3/sec.) With this test the fish survivability of the pump was evaluated. The test was carried out to the protocol and classifying method, developed by VisAdvies BV.

1.2 Aim of the study

The aim of the study is to rate Bedford Pumps SAF.90.05.12 pump in the sense of fish survivability. The rating is based on:

1. The percentage of fish that survive the passage through the pump.
2. The type of injuries.
3. The percentage of (non lethal) injuries
4. The reference to other pumps that are tested on fish survivability.

1.3 Pump description

The pump that was tested was Bedford Pumps SAF.90.05.12 (table 1.1 & figure 1.1).

table 1.1 *Specifications Bedford Pumps SAF.90.05.12 pump.*

Weight	3856 kg
Electrical supply	50 Hz / 400 V / 3 pH
Nominal running speed	585 rpm
Motor rating required (max)	166 kW
Full l load current (166 kW)	307 A
Pump set inertia (166 kW)	13.09 kg/m^2

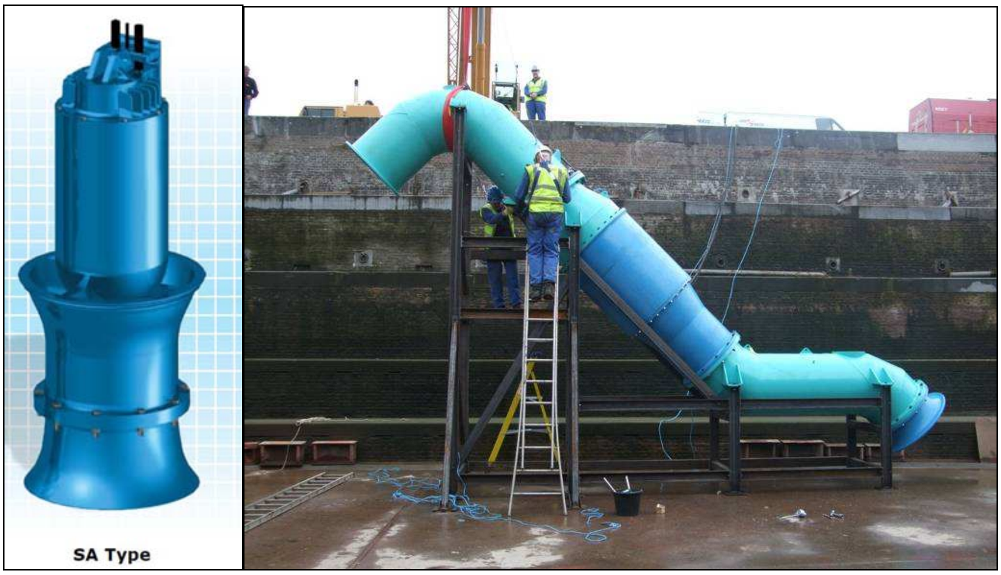

figure 1.1 *Drawing (left) and picture (right) of Bedford Pumps submersible axial pump SAF.90.05.12. Right: the pump with in- and outlet pipes, mounted on the rig.*

A complete overview of the pump specifications is shown in appendix I. The pump with its impellor is shown in figure 1.2.

figure 1.2 *Impeller of Bedford Pumps SAF.90.05.12 pump.*

2 Field test approach

2.1 Experimental animals

In order to test new ‘fish friendly’ pumps on their fish survivability, before the pump is actually released onto the market, a unique test on its fish survivability is required by a so called forced exposure of fish to the running pump (in a controlled environment).

The experimental animals used in this study belong to three families of fish that are very common in European waters. Within each family a target species is chosen that is considered to be representative for the European fish fauna:

- *Anguillidae* (eel-like): **eel** (*Anguilla anguilla*);
- *Cyprinidae* (carp-like): **bream and roach** (*Abramis brama, Rutilus rutilus*);
- *Percidae* (perch-like): **perch and ruff** (*Perca fluviatilis, Gymnocephalus cernua*).

Two representative length classes for each group were used for each of the tests:

Eel:	size group 1: ≤ 45 cm; size group 2 > 45 cm.
Cyprinids:	size group 1: ≤ 15 cm; size group 2 > 15 cm
Percids:	size group 1: ≤ 15 cm; size group 2 > 15 cm

For each group and length class of fish, preferably fifty individuals were exposed to the running pump. (table 4.1).

The reasons for the selection of the groups are:

- They are representative for the most common fish.
- They are representative for the <u>more</u> (cyprinids) and <u>less</u> (percids) vulnerable fish groups, due to fish passage through pumps.
- Eel is of special interest because of its cathadromous[1] migration pattern, which makes it a necessity to pass all pumping stations and hydro power plants on their way, to reach its spawning ground.

The percids and cyprinids were wild caught specimens, provided by a commercial fisherman (Bram van Wijk, Visserij Service Nederland). The eel are obtained from a commercial eel farm in the Netherlands (Nijvis BV, Nijmegen).

For each fish species and length class an amount of fish will be exposed, such that the desired confidence interval is accomplished (see also § 2.3).

The use of experimental animals is authorized by the Animal Experimental committee Dier Experimenten Commissie, DEC) of the Central Veterinary Institute of Wageningen University and Research Centre (see appendix II). All personnel involved in the experiments were authorized by the Animal Experimental committee (cf. Article 9 authorized officer WOD (J.H. Kemper and I.L.Y. Spierts) and cf. Article 12 authorized

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[1] Fish that spend most of their lives in fresh water and migrate to the sea to breed.

officer WOD (H. Vis)) under the guidance of Drs P.S. Kroon of the Central Veterinary Institute (cf. authorized officer with Article 14 WOD).

2.2 Field setup and fish handling

The experiments were carried out on the 12th of June 2012 in the dry dock 'Jan Blanken' in Hellevoetsluis, the Netherlands (figure 2.1).

figure 2.1 *Dry dock 'Jan Blanken' (left) and pump in dock (right).*

The essence of the set up is that the fish are inserted in the pump in such a way, that escapement from the device is impossible. In figure 2.2 the forced exposure of the fish is shown. A net was positioned over the inlet pipe, through which fish entered the pump. After passing the pump, fish were caught in a knot less Norwegian life net (4x4x3,5 m), as shown in figure 2.2 and subsequently 'forced' to swim in the direction of a fyke, positioned directly behind the life net. Immediately after each test run was finished, fish were taken out of the fyke and checked for survival and damages. In this check four classes were distinguished:

- no damage;
- scale damage;
- cuts;
- immediate death.

figure 2.2 *Forced exposure of fish to the running pump.*

The SAF.90.05.12 was tested at a rotation speed of 330 rpm and a discharge of approx. 1.3 m^3/sec.

Fish that pass the pump alive and without any noticeable damage, can still have invisible damages or even die after some time as a result from internal damages. In order to determine if this was the case, all fish that passed the pump and had no damages were stored for the duration of 48 h

figure 2.3 *Fish storage tanks for delayed mortality study.*

in four large fish tanks (1000-1500 l each, see figure 2.3). After this time fish were again thoroughly checked for any damage. After the experiments fish that were alive were released in the water, and dead fish were discharged.

Special attention was paid to eel that showed internal haemorrhages and irregularities in their spinal column (figure 2.4 & figure 2.5). Eel that showed these signs, but did survive the 48 h storage period, were killed and examined internally. These eels were classified as dead (“delayed mortality”) in the analysis. Eel with haemorrhages as a result of muscle bruises were considered as survivable. Although eel with fracture (s) in their spinal column, can survive for quit some time, it is assumed that these fish are not able to reach their spawning grounds in the Sargasso Sea, eventually.

figure 2.4 *Eel with blood stained ventral fin (under). Eel with no haemorrhage (top).*

figure 2.5 *Dissected eel with internal haemorrhage.*

2.3 Statistical evaluation

From the results not only an estimate of the chance of survival of fish is being determined, also the borders between which this chance of survival exactly lies is given, the so-called confidence interval. The estimated chance of survival is equal to the number of fish that survived divided by the total number of fish that passed the pump. The variance in the number of fish that survived is then estimated by:

$$s^2(n) = N\hat{p}(1 - \hat{p})$$

Where s2 (n) the estimated variance in the number of survived fish, n and $N\hat{p}$ the number of survived fish, N is the total number of fish and $\hat{p}$ the estimated probability of survival. A rough estimate of the 95% confidence interval of the number of survived fish is given by n ± 2s (n). By dividing these values by the number of observations we obtain the confidence interval of the chance. The confidence interval can be determined more precisely, where the most conservative results are obtained with the so-called exact method, which directly uses the properties of the binomial distribution (Wikipedia). The reliability are calculated using a confidence interval calculator on the Internet.
(http://statpages.org/confint.html#Binomial

3 Fish survivability score

3.1 Calculation

Fish survivability of a pump is determined on the basis of the number of fish that passed the pump and survived, by group and by length class. The determination of fish survivability of a pump is based on fish which, after passage through a pump, are classified in the category ‘survive’, in which:

Percentage survival = total amount of fish that survived / total amount of fish passed, and,

total amount of fish that survived = sum of all fish that survived the pump passage.

Fish that pass a pump alive and without any visible damage can still die after a while as a result of internal damage. To understand to what extent this is the case with the pump to be tested, also the delayed mortality is included in the total number of fish that did not pass the pump alive. For each fish group and length class the total amount of fish that survived will be expressed as a percentage of the total amount of fish in that particular group (length and specie) that were exposed to the pump by force. In the end this will result in six survival rates (three fish groups and two length classes per specie).

3.2 Evaluation

For each tested pump the evaluation results in a score between 0 and 1, with which the fish survivability of a pump is determined. A final score of 0 means that a pump has minimal fish survivability, a final score of 1 means optimal survivability.

The determination of the degree of fish survivability of a certain pump, i.e. the final fish survivability score, is structured as follows. Each test group is classified into two length categories (table 3.1). For each length category a survival rate will be determined by the forced exposure test. The resulting survival rates are then divided into four possible classes of survivability (coloured columns in table 3.1).

table 3.1 *Structure final score fish survivability.*

	Group	**Length class (cm)**	**Weighing factor**	**Survivability classes (%)**			
				Excellent	**Good**	**Insuffi-cient**	**Bad**
1	**Eel**	0-45	0.15	99-100	95-98	90-94	0-89
2		>45	0.25	99-100	95-98	90-94	0-89
3	**Cypr.**	0-15	0.1	97.5-100	90-97.4	80-89	0-79
4		>15	0.2	95-100	90-94	75-89	0-74
5	**Perc.**	0-15	0.1	99-100	97.5-98	92.5-97.4	0-92.4
6		>15	0.2	99-100	95-98	90-94	0-89
Score % survival				**0.75-1**	**0.5-0.75**	**0.25-0.5**	**0.0-0.25**

The classification of these four classes is entirely based on the results of the survival rates (per group and length class) for pumps whose test results were available (see Appendix III, only in Dutch). The classification of the fish survivability is shown in table 3.1. The individual survival rates for each category (group and length class) of the pump to be tested will subsequently be compared with the average individual survival rates of the pumps already tested.

Each group has for each length class a separate weighing factor (fourth column table 3.1). The total weighting factor for eel is higher (0.4 out of 1) than for cyprinids (0.3 out of 1) and for percids (0.3 out of 1). This is due to the great need for migration of this species, and the (low) degree of occurrence. All groups have a higher weighting factor for larger fish than for smaller fish because: 1) the greater likelihood of being hit by the pump, and 2) the importance of larger specimens of each group for the conservation of the species.

The sub score per group and length class (six in total) is calculated as follows:

Sub score group1, length class 1 = weighing factor X score % survival.

table 3.2 *Classification end score fish survivability.*

Score	**Classification**	**Colour code**
0.75-1	Excellent	🟩
0.5-0.75	Good	🟩
0.25 -0.5	Insufficient	🟪
0.0-0.25	Bad	🟥

Finally, the end score of the pump to be tested is the sum of all six sub scores. A pump with score 1 will have a score for fish survivability that is comparable with the best pumps tested until yet, and a pump with score 0 will have a score for fish survivability that is compared with the worst pumps tested until yet (table 3.2).

The individual sub scores per category are however also important to notice in the final evaluation of a pump.

4 Results

4.1 Fish data

table 4.1 *# Fish used for each fish category.*

	Group	Length class (cm)	(N)	Confidential interval
1	**Eel**	0-45	52	0.069
2		>45	56	0.064
3	**Cypr.**	0-15	133	0.027
4		>15	38	0.093
5	**Perc.**	0-15	68	0.053
6		>15	26	0.13
Total			**373**	

table 4.2 *Mean TL ± stdev of all used fish.*

	Group	Length class (cm)	(N)
1	**Eel**	0-45	36±3.1
2		>45	54±4,4
3	**Cypr.**	0-15	11±1,8
4		>15	19±5,9
5	**Perc.**	0-15	10±1,6
6		>15	16±3,8

All fish that were used in the experiment were in perfect condition before the start of the experiment. In total 373 fish passed the pump: 108 eel; 171 cyprinids and 94 percids (table 4.1). The fish passed the pump well and were properly caught in the Norwegian life net. The mean TL ± stdev of all fish categories and test scenario's are shown in 0. As is shown in table 4.1 it is clear that the borders between which the chance of survival exactly lie for all groups (confidential intervals) are very small.

In appendix IV all length frequency diagrams are shown for all fish categories, separately.

4.2 Survival rates

All of the 253 small fish and 120 big fish that were exposed to the running pump survived their way through the pump (so 100% survival, figure 4.1). The most severe damage to the cyprinids and percids was scale loss, but no cuts (decapitation or dividing) were observed. This descaling however was not due to the forced exposure to the running pump and the impeller itself, but was caused by: 1) the heavy impact of the fish on the water when they left the outlet pipe of the pump (see also figure 2.2 right picture), and 2) the contact with the Norwegian life net in which the fish where captured after the exposure. It is clear that cyprinids and percids (in a lesser extend), are vulnerable to excessive skin contact. The fish that were used in these experiments were firstly cached, secondly brought into the inlet pipe of the pump, and thirdly caught in the Norwegian life net. This amount of contact is inevitable in these kind of experiments, but it does explain the occurring descaling of the skin.

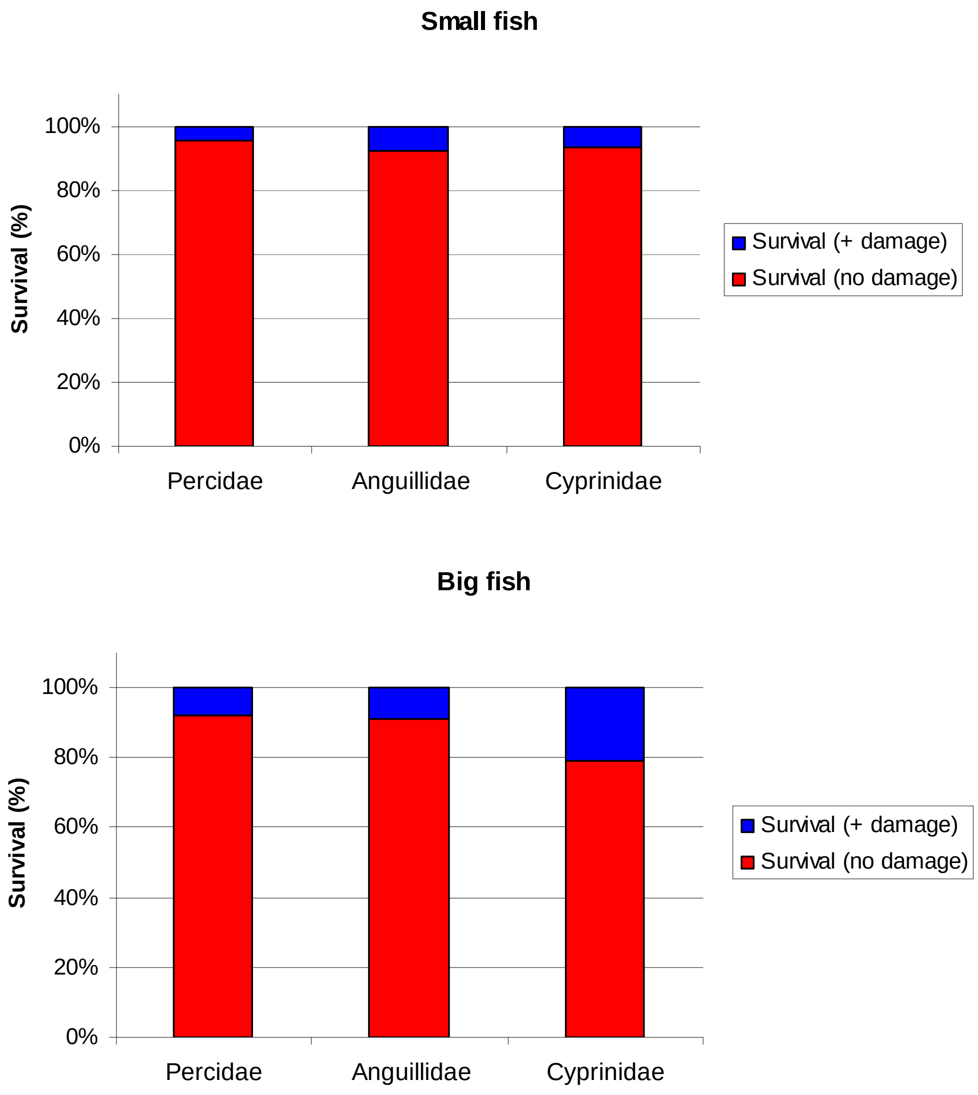


figure 4.1 *Overview survival rates of three fish groups for small (above) and big fish (below).*

Except for the big cyprinids (bream) more than 90% of all other fish classes had passed the running pump completely undamaged (see also appendix V). It is also interesting to notice that there was not a large difference (again except for the big bream) in direct damage between the small and the big fish that where exposed to the running pump. No eel was cut and the most severe damage that was observed was red staining of the ventral fins (belly side), which indicates an internal haemorrhage. These fish were internally examined, and no injuries due to the pump passage were observed. Especially for the big eel this is an interesting outcome, as these fish had a mean TL of 54±4.4 cm.

4.3 Delayed mortality

Cyprinids and percids

After being exposed to the running pump, the cyprinids and percids were kept for 48 hours in large fish tanks in order check them for delayed mortality. Although there

was no delayed mortality within 48 h after the experiment, still 10-15% of the cyprinids and percids eventually died after the 48 h period.
These death can however not be attributed to the passage of the pump itself. There are several causes: 1) handling of the fish before the experiment (catching them, inserting them into the inlet pipe); 2) the constant contact with nets, prior to the experiment and after the experiment; 3) the hitting of the water when leaving the outlet pipe of the pump, 4) the higher water temperature at the moment of storage and testing, and 5) the storage itself. No fish likes being confined for 48 h, swimming freely is always a better solution. It is therefore that these delayed mortalities are mentioned, but are not included in the group of fish that did not survive the pump passage itself.

Eel
Compared with other fish species, eel are in general physically stronger. All eel responded well to the circumstances they were exposed to during the test. Five small and four big eel showed minor skin damages. There was no delayed mortality amongst the eel.

4.4 Fish survivability scores

In table 4.3 the survival rates are shown for all fish categories that passed the running pump at 330 rpm, 1.3 m^3/s). The mortality amongst fish that passed the pump consists of both direct as well as delayed mortality after 48 h. In all categories the pump passage resulted in 100 % fish survival.

table 4.3 *Results survival rates Bedford Pumps SAF.90.05.12 pump.*

	Group	Length class (cm)	Weighing factor	Survivability classes (%)			
				Excellent	**Good**	**Insuffi-cient**	**Bad**
1	**Eel**	0-45	0.15	100			
2		>45	0.25	100			
3	**Cypr.**	0-15	0.1	100			
4		>15	0.2	100			
5	**Perc.**	0-15	0.1	100			
6		>15	0.2	100			
Score % survival				**0.75-1**	**0.5-0.75**	**0.25-0.5**	**0.0-0.25**

In figure 4.2 the sub- and end scores for each separate fish category are shown. It is obvious that Bedford Pumps SAF.90.05.12 pump scores the maximum score in all classes. so also in the end score. which is 1. This makes Bedford Pumps SAF.90.05.12 pump an excellent pump for fish survivability when constantly running at 330 rpm (1.3 m^3/s) with a water elevating height of 2.9 m.

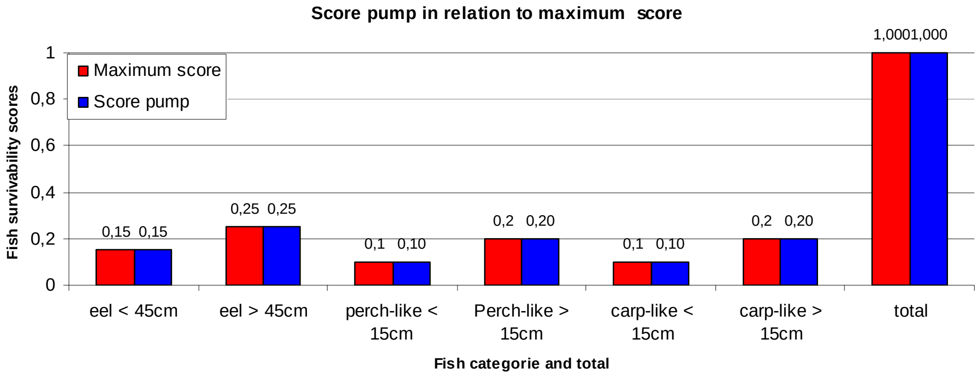


figure 4.2 *Sub- and end score fish survivability Bedford Pumps SAF.90.05.12 pump test (the scores are shown above the bars).*

The results of the mean fish survivability scores for the most common existing pumps in the Netherlands (see appendix III) show large difference between different types of pumps. In table 4.4 the mean end score fish survivability for different pump types is given. Only those pumps were included. that actually were tested under exactly the same conditions and with exactly the same fish group and length classes as described in this particular study. In the first column of table 4.4 is (between brackets) shown how many pumps were used to calculate the mean fish survivability. Needless to say is that the score runs from 0 (bad) to 1 (excellent). The mean end scores fish survivability of existing pumps are calculated by using the mean survival rates per group and per length class for each type of pump shown in appendix III.
It is obvious that mortars on average score the best. whereas closed screw pumps score the worst. It is good to notice that these end scores are just a indication and give a rough picture of fish survivability of different pump types. In the last row of the graph the excellent score of Bedford Pumps SAF.90.05.12 pump is shown. With its end score of 1 for fish survivability, it is the best pump on the market concerning this subject!

table 4.4 *Rough indication of the mean fish survivability end scores per pump type. Between brackets: the amount of pumps tested for calculating the score: --: Too little data available from these pump types to calculate an end score fish survivability. Bottom line: end result of the test with Bedford Pumps SAF pump in this study.*

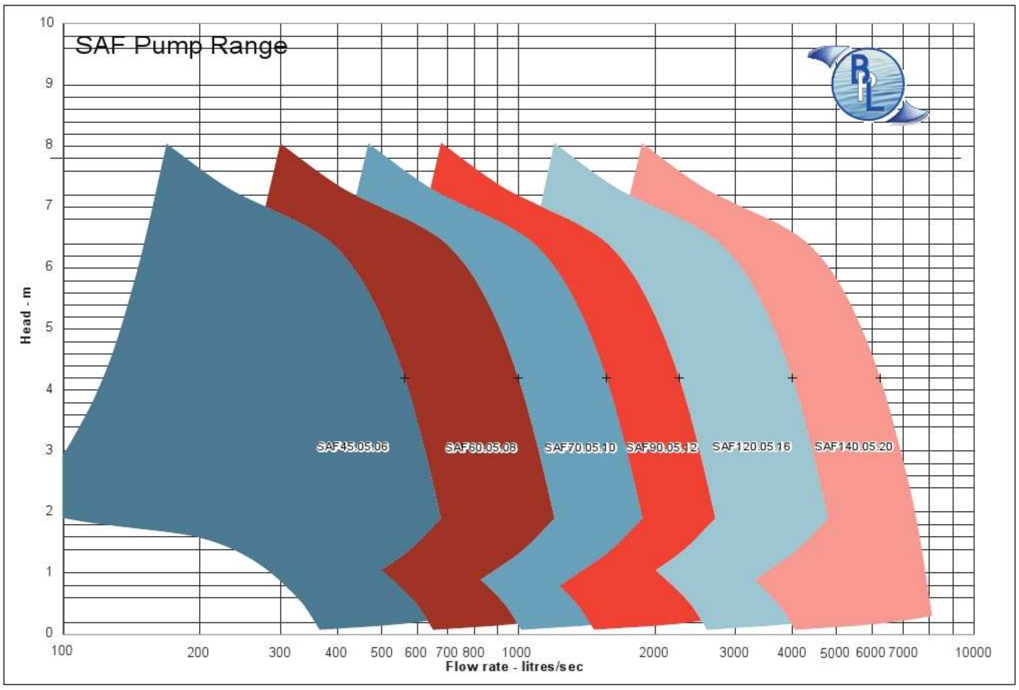
Pump type	**Mean end scores fish survivability (0-1)**
Turbine auger	--
Centrifugal pump	--
Mortar (5)	0.90
Screw centrifugal pump (5)	0.73
Hidrostal pump	--
Closed screw pump (2)	0.28
Open screw pump (2)	0.31
Closed screw compact (2)	0.30
Bedford Pumps submersible axial pump SAF.90.05.12.	**1**

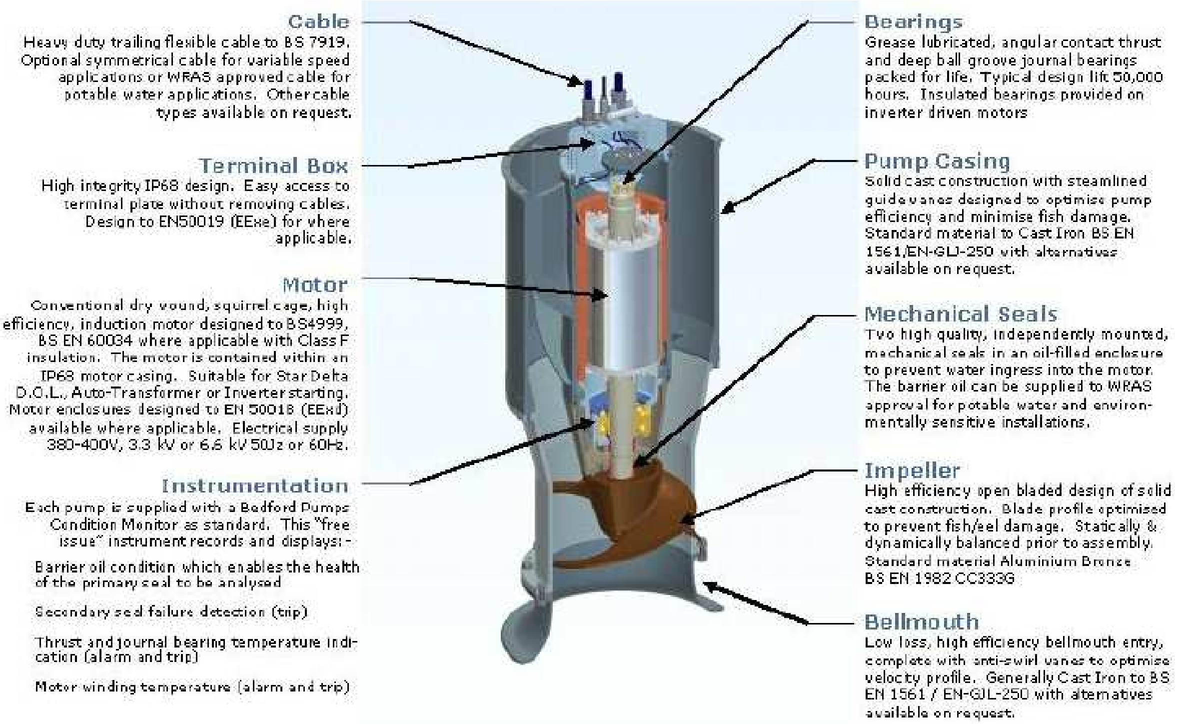
5 Conclusions

1. Concerning the fish survivability score Bedford Pumps SAF.90.05.12 pump scores the maximum score in all fish classes and also in the end score. which is 1. This makes Bedford Pumps SAF.90.05.12 pump an excellent pump for fish survivability operating at a rotation speed of 330 rpm (1.3 m^3/s) with a water elevating height of 2.9 m.
2. All of the 253 small fish and 120 big fish that were exposed to the running pump survived their way through the pump (100% survival).
3. Except for the big cyprinids more than 90% of all other fish classes had passed the running pump completely undamaged.
4. No eel was cut and the most severe damage that was observed was red staining of the ventral fins (belly side). which indicates an internal haemorrhage.
5. The descaling of the cyprinids and percids during the experiment (and later their delayed mortality) was not due to the forced exposure to the running pump and the impeller itself. but was caused by: 1) the heavy impact of the fish on the water when they left the outlet pipe of the pump. 2) the contact with both the net to guide the fish into the inlet pipe of the pump and the Norwegian life net in which the fish where captured after the exposure. and 3) the storage of the fish during 48 h. the higher water temperatures. The 10-15% delayed mortality amongst this group can therefore not be attributed to the pump passage itself.
6. It is important to mention that at the top of the outlet pipe an inspection hatch was present. The hatch however was constructed in such a way. that passing fish could get hurt. It is however unclear to what extend this inspection hatch contributed to damaged or even dead fish. An improvement of this hatch would solve this problem.

Appendices

Appendix I Detailed specifications Bedford pumps SAF range





Cable
Heavy duty trailing flexible cable to BS 7919. Optional symmetrical cable for variable speed applications or WRAS approved cable for potable water applications. Other cable types available on request.

Terminal Box
High integrity IP68 design. Easy access to terminal plate without removing cables. Design to EN50019 (EExe) for where applicable.

Motor
Conventional dry wound, squirrel cage, high efficiency, induction motor designed to BS4999, BS EN 60034 where applicable with Class F insulation. The motor is contained within an IP68 motor casing. Suitable for Star Delta D.O.L., Auto-Transformer or Inverter starting. Motor enclosures designed to EN 50018 (EExd) available where applicable. Electrical supply 380-400V, 3.3 kV or 6.6 kV 50Jz or 60Hz.

Instrumentation
Each pump is supplied with a Bedford Pumps Condition Monitor as standard. This "free issue" instrument records and displays:-

Barrier oil condition which enables the health of the primary seal to be analysed

Secondary seal failure detection (trip)

Thrust and journal bearing temperature indication (alarm and trip)

Motor winding temperature (alarm and trip)

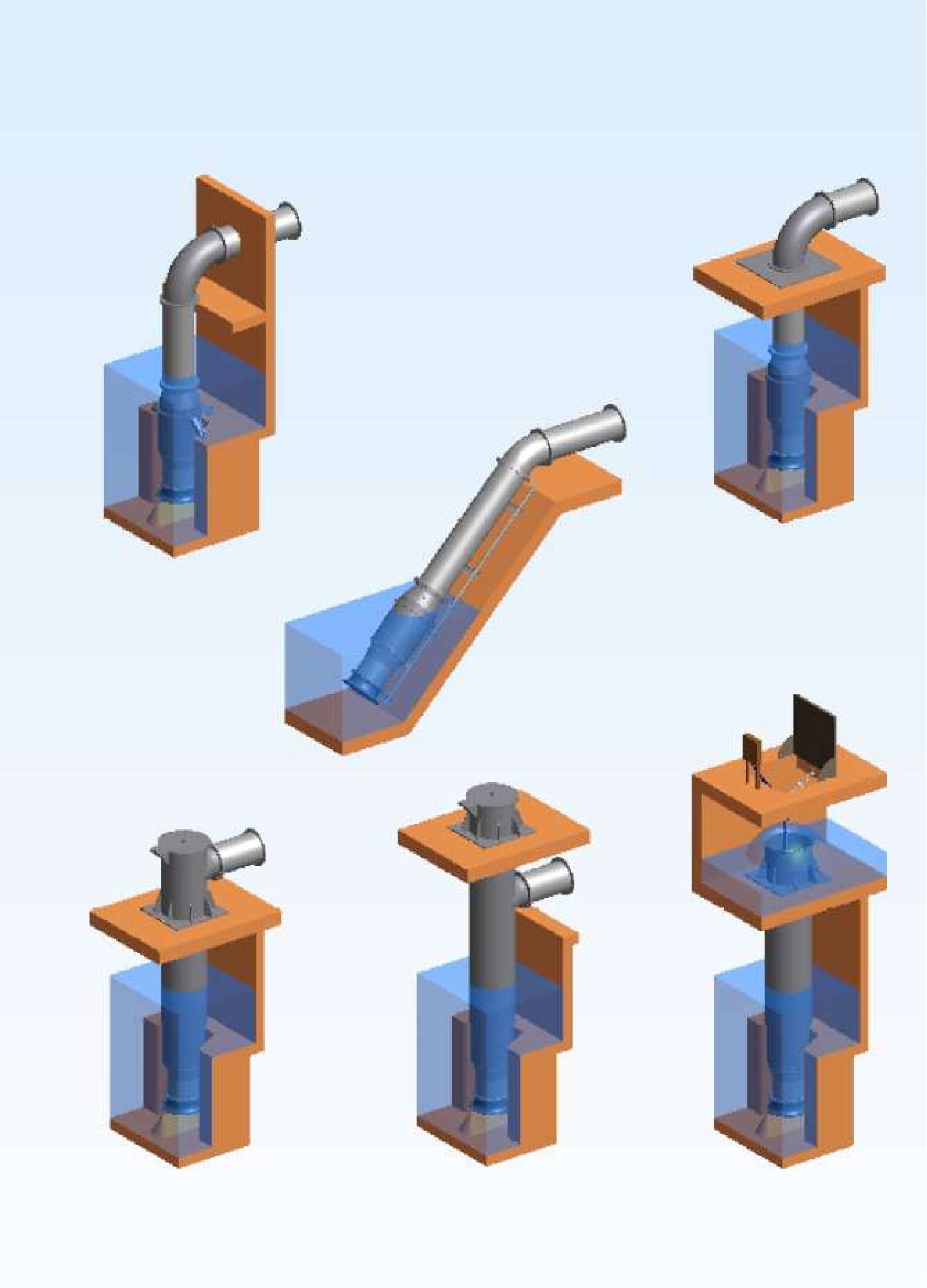
Bearings
Grease lubricated, angular contact thrust and deep ball groove journal bearings packed for life. Typical design lift 50,000 hours. Insulated bearings provided on inverter driven motors

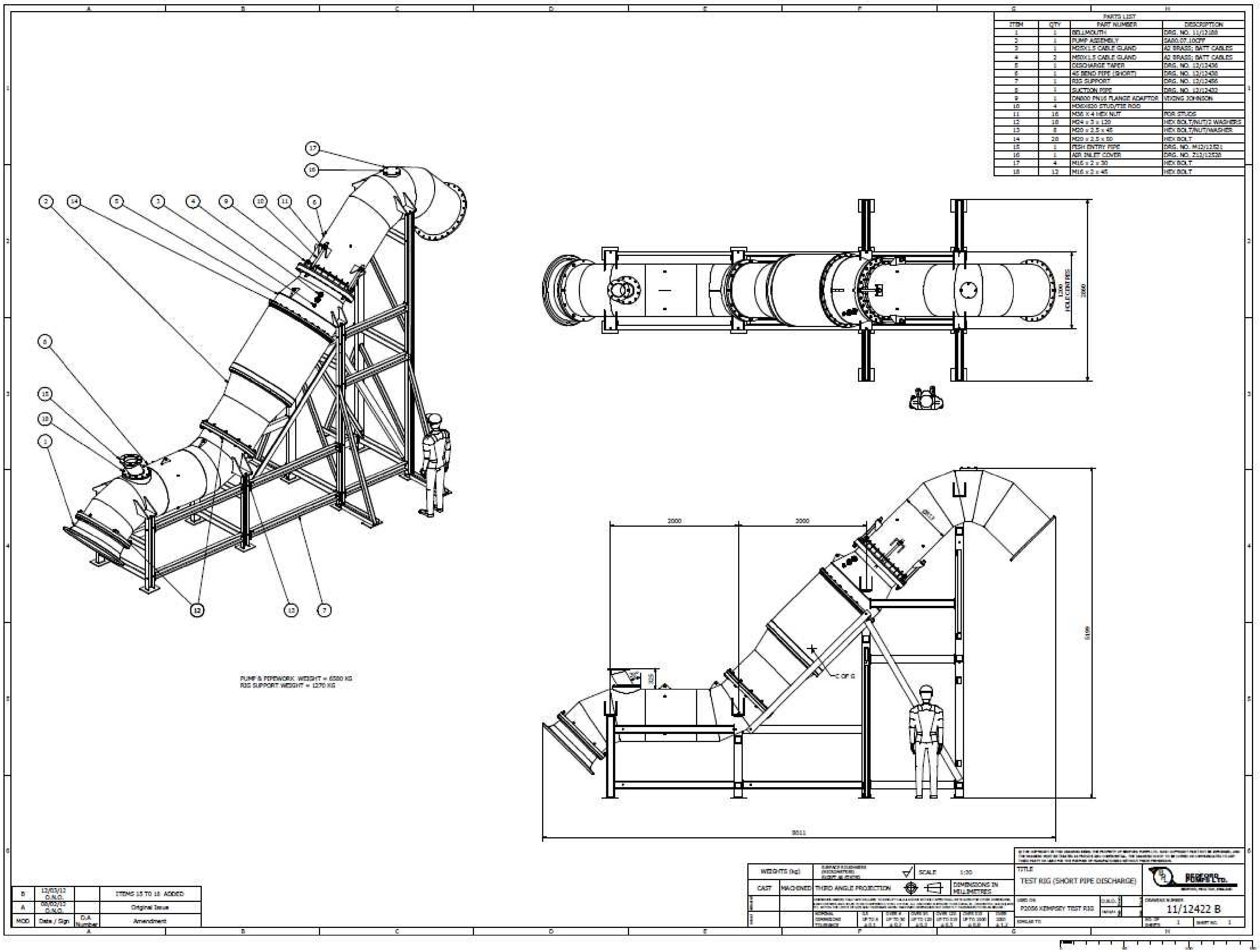
Pump Casing
Solid cast construction with steamlined guide vanes designed to optimise pump efficiency and minimise fish damage. Standard material to Cast Iron BS EN 1561/EN-GJJ-250 with alternatives available on request.

Mechanical Seals
Two high quality, independently mounted, mechanical seals in an oil-filled enclosure to prevent water ingress into the motor. The barrier oil can be supplied to WRAS approval for potable water and environmentally sensitive installations.

Impeller
High efficiency open bladed design of solid cast construction. Blade profile optimised to prevent fish/eel damage. Statically & dynamically balanced prior to assembly. Standard material Aluminium Bronze BS EN 1982 CC333G

Bellmouth
Low loss, high efficiency bellmouth entry, complete with anti-swirl vanes to optimise velocity profile. Generally Cast Iron to BS EN 1561 / EN-GJL-250 with alternatives available on request.





PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	BELLMOUTH	DRG. NO. 11/12188
2	1	PUMP ASSEMBLY	SA80.07.10CFF
3	1	M25X1.5 CABLE GLAND	A2 BRASS; BATT CABLES
4	2	M50X1.5 CABLE GLAND	A2 BRASS; BATT CABLES
5	1	DISCHARGE TAPER	DRG. NO. 12/12436
6	1	45 BEND PIPE (SHORT)	DRG. NO. 12/12438
7	1	RIG SUPPORT	DRG. NO. 12/12486
8	1	SUCTION PIPE	DRG. NO. 12/12432
9	1	DN800 PN16 FLANGE ADAPTOR	VIKING JOHNSON
10	4	M36X820 STUD/TIE ROD	
11	16	M36 X 4 HEX NUT	FOR STUDS
12	18	M24 x 3 x 120	HEX BOLT/NUT/2 WASHERS
13	8	M20 x 2.5 x 45	HEX BOLT/NUT/WASHER
14	20	M20 x 2.5 x 50	HEX BOLT
15	1	FISH ENTRY PIPE	DRG. NO. M12/12521
16	1	AIR INLET COVER	DRG. NO. Z12/12528
17	4	M16 x 2 x 30	HEX BOLT
18	12	M16 x 2 x 45	HEX BOLT

Appendix II Approval Animal Experimental Committee

WAGENINGEN UR
For quality of life

VISADVIES B.V.
t.a.v Dr. Ir. I.L.Y. Spierts
Twentehaven 5
3433 PT NIewegein

DATUM
30 mei 2012

ONDERWERP
Beoordeling OZP
VA2011_28

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Lelystad

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Betreft Onderzoeksplan 2011_28

Titel Onderzoek visvriendelijkheid axiaalpomp Bedford Pumps UK

Aantal dieren 300,300,300

Diersoort: aal (Anguilla anguilla), baars (Perca fluviatilis), brasem (Abramis brama)

Risico van ongerief matig (3)

Artikel 9 functionaris: Dr. Ir. I.L.Y. Spierts

Periode advies: 1 juni 2012 tot 1 september 2012

Discussie en aanvullende vragen

De DEC complimenteert de onderzoeker met het duidelijke proefplan.
De DEC spreekt zijn waardering uit voor het gebruik van dummy's en zou voor haar beeldvorming graag meer informatie willen hebben over deze dummy's en het gebruik hiervan in proeven. De DEC heeft begrepen dat dummy's vol electronica zitten en wil graag weten wat er mee gemeten kan worden. Verder wil de DEC weten of men meer aan modelontwikkeling/correlatie-analyse kan doen met gebruik van dummy's zodat in de toekomst alleen het gebruik van dummy's voldoende is.
Figuren over de aantallen kloppen niet met de tekst. Hoe komt de onderzoeker aan het aantal van 50 vissen per testscenario.

Afweging

- Het proefvoorstel is getoetst aan de hand van de eisen die gesteld worden ten aanzien van de 3 V's. en Art 2a van het Dierproevenbesluit
- Het doel van de proef. wordt onderschreven. Het belang van de proef weegt op tegen het ongerief van de betrokken dieren en er zijn geen alternatieven beschikbaar..
- -- De uitvoering is verder niet in strijd met andere ethische overwegingen m.b.t. het gebruik van proefdieren.

Voorwaarden

- De indiener dient iedere wijziging van het proefplan ten opzichte van dit advies alsmede onverwachte gebeurtenissen, onverwijld te melden aan de proefdierdeskundige

- Indien het ongerief tijdens de proef afwijkt van het opgegeven (verwachte) ongerief dient dit een welzijnsevaluatie na afloop van de proef te worden
- gemeld

Opmerkingen:

-

Advies : Positief

Met vriendelijke groet,

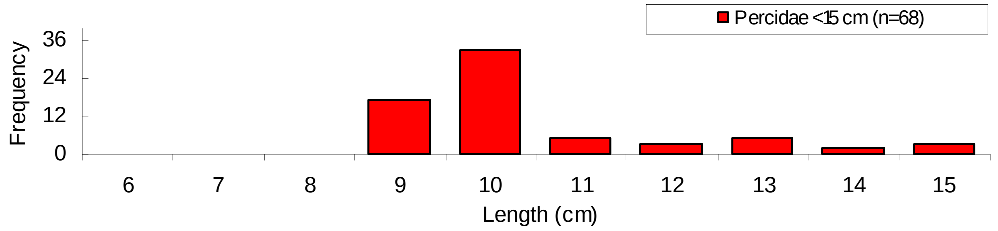
P.S. Kroon
Proefdierdeskundige / Veterinair

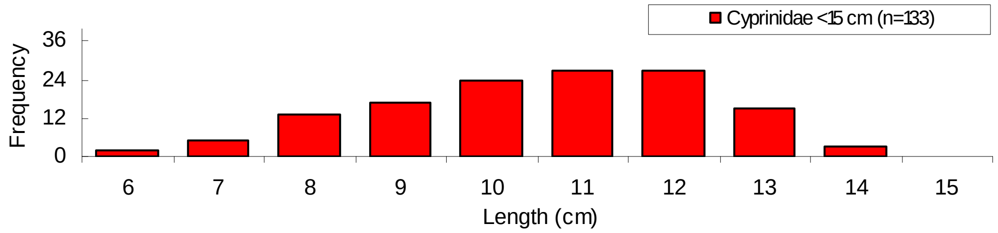
Appendix III Overview death % of already tested pumps

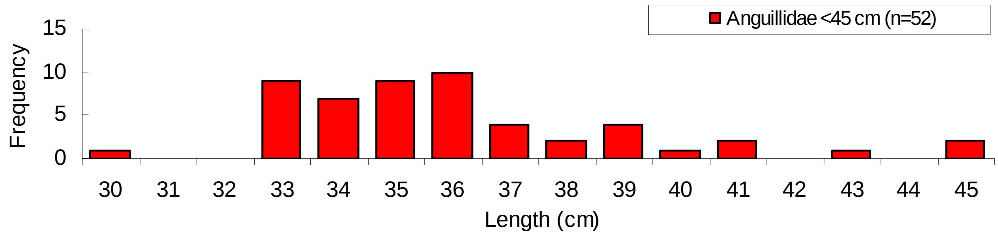
Pomptype	Kenmerken			Visoverleefbaarheid (schadepercentages)				
	Capaciteit (m3/min)	Opvoerhoogte (m)	Toeren	Aal	baarsachtigen < 15cm	baarsachtigen > 15cm	karperachtigen < 15cm	karperachtigen > 15cm
Vijzels				Sterftepercentage (%)				
Buisvijzel	0,6	1	57	0				
Buisvijzel	10	1,05	42		2		0	🟧
Vijzel	23	0,73		🟧	0		2	
De Witvijzel	42	0,7	42		0	0	0	2
Vijzel	120	0,3-1,5	29		0	0	0	13
Vijzel	500	2,2	17	2	0	0	0	1
De WitVijzel	660	0,3	22	0			0	
Vijzel	660	0,3	22				0	
Vijzel	660	0,3	22					1
Centrifugaalpompen								
Centrifugaalpomp	38	3,5	368	🟧	0		1	2
Centrifugaalpomp	400	0,9	205	🟧	0		🟧	
Centrifugaalpomp	1080	1,7[3]	59	0				
Schroefcentrifugaalpompen								
Schroefcentrifugaalpomp	12,5	1,5	480	0			0	0
Schroefcentrifugaalpomp	22	1,15	735	0				
Schroefcentrifugaalpomp	24	1,15			0		1	
Schroefcentrifugaalpomp	25	1,5	400	0			0	0
Schroefcentrifugaalpomp	25	0,15	1000		4		7	🟧
Schroefcentrifugaalpomp	85		416		4		16	43
Schroefcentrifugaalpomp	170	1,52		0	0	0	1	🟧
Schroefcentrifugaalpomp	350	2,8	115	🟧	3	6	4	
Schroefcentrifugaalpomp	505	2,4[1]	143	0			0	
Schroefcentrifugaalpomp	505	2,4[1]	143					🟧
Hidrostal pompen								
Hidrostal	0,6	10	890-1204	0				
Hidrostal	21	3,6	577	🟧	4		🟧	
Hidrostal	42,5	3,5	552		8		8	🟧
Gesl. Schroefp. (compact)	45	2,54	592		3		15	🟧
Gesl. Schroefp. (compact)	90	2,7	364	🟧	35	26	81	90
Gesl. Schroefp. (compact)	105	2,2	291		3		21	
Gesl. Schroefp. (compact)	135	0,5-1	307		1	9	3	
Gesloten schroefpomp								
Gesloten schroefpomp	26	3,08			2		25	
Gesloten schroefpomp	60	0,8	355	32	7	8	20	🟧
Gesloten schroefpomp	81	1	333	0				
Gesloten schroefpomp	1500		50	5				
Open schroefpompen								
Open schroefpomp	24	0,98		🟧	0		45	
Open schroefpomp	40	1,67	580		0		🟧	
Open schroefpomp	76			🟧	0			
Open schroefpomp	120	0,1			5	🟧	18	42
Open schroefpomp	200	0,6	165	8				

Appendix IV Length frequency distribution diagrams

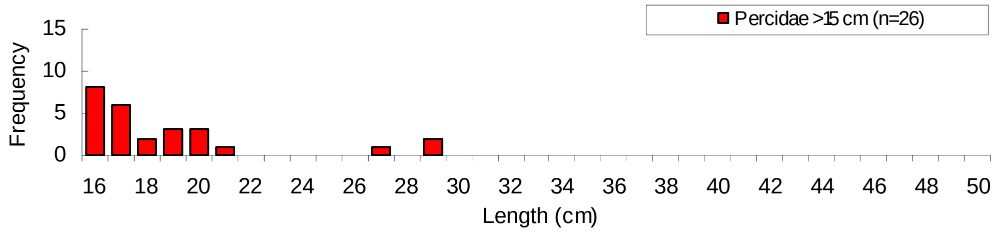
Small fish

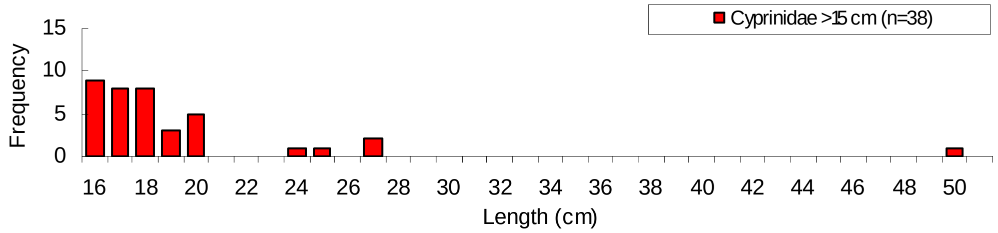


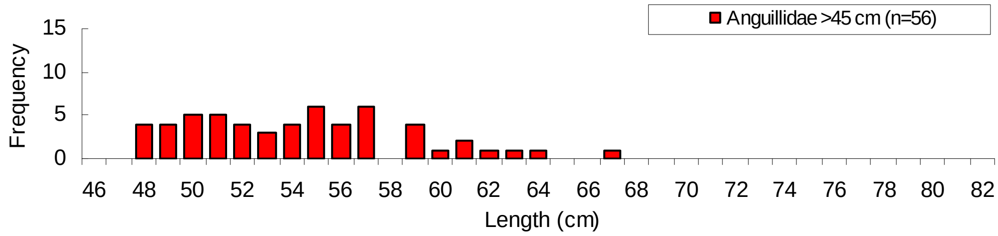




Big fish







Appendix V Percentages fish survival and damages

		N	Survival (no damage)	Survival (+ damage)	Survival (after 48h)
Small fish	Percidae	68	96%	4%	100%*
	Anguillidae	52	92%	8%	100%
	Cyprinidae	133	93%	7%	100%*
Big fish	Percidae	26	92%	8%	100%*
	Anguillidae	56	91%	9%	100%
	Cyprinidae	38	79%	21%	100%*

- Eel: 100 % survival. All eel that survived the 48 h storage period, but showed haemorrhages and irregularities were killed and internally examined for spinal injuries. In case of a broken spine, the eel is considered lost for the posterity and fall in the category *"Survival + damage"*.
- Percids and cyprinids. Although there was little (small cyprinids test 2) or no delayed mortality within 48 h after the experiment, still 10-15% of the cyprinids and percids eventually died after the 48 h period. These death can however not be attributed to the passage of the pump itself (explanation: see § 4.3).

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