POSEIDON WATER

Appendix U
Huntington Beach Desalination Project ISTAP Phase I and II Reports

Renewal of NPDES CA0109223
Carlsbad Desalination Project

Final Report: Technical Feasibility of Subsurface Intake Designs for the Proposed Poseidon Water Desalination Facility at Huntington Beach, California

Authored by the Independent Scientific
Technical Advisory Panel

Under the Auspices of the California Coastal
Commission and Poseidon Resources
(Surfside) LLC

Convened and Facilitated by CONCUR, Inc.

CONCUR
NEGOTIATING EFFECTIVE ENVIRONMENTAL AGREEMENTS

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This report evaluates whether any of several subsurface intake designs would be technically feasible to build and operate as part of the Poseidon Resources (Surfside) LLC (Poseidon) seawater desalination facility proposed for the City of Huntington Beach, California. This report is the product of coastal development permit (CDP) review, the California Coastal Commission (CCC or the Commission) recommendations, and a scientific and technical review conducted by an independent expert panel (the Independent Scientific Technical Advisory Panel, or ISTAP) convened jointly by staff of the Commission and Poseidon.

Background

In 2002, Poseidon submitted a CDP application to the City of Huntington Beach for a proposed seawater desalination facility. In 2003, the City declined to certify the associated Final Environmental Impact Report (EIR) for the proposed project. In 2005, Poseidon re-applied to the City with a modified proposal. Later that year, the City certified the project EIR and in early 2006, approved a CDP for the portions of the project within the City's permit jurisdiction. That CDP was then appealed to the Commission. In May 2006, Poseidon submitted a CDP application to the Commission for portions of the proposed project in coastal waters offshore of Huntington Beach, which are within the Commission's retained permit jurisdiction.[1]

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[1] The California Coastal Act, established by voter initiative in 1972 and made permanent by the Legislature in 1976, includes specific policies meant to provide public access to the coast, protect coastal resources, and ensure appropriate development within the state's Coastal Zone. The Coastal Zone extends along the length of the state and includes coastal waters to three miles offshore as well as areas ranging from several hundred feet to several miles inland from the shoreline.

Many forms of development proposed within the Coastal Zone are subject to provisions of the California Coastal Act and of Local Coastal Programs (LCPs), which are developed by local governments in association with the Coastal Commission. LCPs generally include more specific policies than those in the Act that reflect and more closely address locally important coastal resource issues.

Once the Coastal Commission certifies an LCP and an associated Land Use Plan (LUP), the local jurisdiction takes on most of the permitting authority provided by the Act. The Commission retains its permitting authority over state tidelands (i.e., offshore areas) and in areas of the Coastal Zone that aren't covered by a certified LCP or LUP. There are also areas or types of projects within local jurisdictions where the local government has permitting authority, but where those permits can be appealed to the Commission. Proposed projects that would be located within both the permit jurisdiction of a local government and the Commission may require a CDP from each. This is the case for the proposed Poseidon Water desalination facility in Huntington Beach. Additionally, the proposed project is within the Commission's appeal jurisdiction.

By the end of 2010 the Commission had approved and issued a number of CDPs for desalination facilities that used surface, subsurface, or screened intakes, including one issued to Poseidon for its Carlsbad Desalination Project, the first large-scale project approved in the State of California. In addition, the State Water Resources Control Board (State Board) had approved the Once Through Cooling Policy. These events provided information that was useful for permit review for the Huntington Beach Project. While the Commission was reviewing the CDP application and the appeal, Poseidon modified some components of its proposed facility and submitted a proposed project re-configuration for the long-term stand-alone operation of the desalination facility to the City, which required the City to conduct additional California Environmental Quality Act (CEQA) review and consider a new CDP for the project. In 2010, the City certified a Supplemental EIR and approved a new CDP, which was also appealed to the Commission.

California Coastal Commission Action

In November 2013, the Commission held a public hearing to determine whether to issue a CDP to Poseidon for the offshore portions of its proposed project and to determine how to resolve the appeal of the City's CDP. At that hearing, Commission staff recommended that the Commission conditionally approve both CDPs with a requirement that Poseidon construct a subsurface intake unless Poseidon presented additional information showing that intake method to be infeasible.

The hearing included several hours of public testimony and Commission deliberation, with one of the key issues being whether (a) subsurface intake(s) is feasible at or near the proposed site. Near the end of the hearing, several Commissioners recommended to Poseidon that it work with Commission staff to develop independent verification of whether any of several subsurface intake designs would be feasible for this project. Poseidon then withdrew its CDP application and the Commission voted to continue the appeal of the local CDP.

Shortly after that hearing, and in anticipation of Poseidon's submission of a new CDP application, Commission staff and Poseidon began discussing how to produce an independent scientific and technical review as recommended by the Commissioners. In January 2014, the two parties (known here as the

"Conveners") agreed to undertake an independent review, to be conducted in at least two phases. As part of this process, Poseidon agreed to contract with CONCUR, Inc., a firm specializing in analysis and resolution of complex environmental issues and in structuring independent review processes. While the Commission is not contracting with CONCUR, the agency staff agreed on the choice of CONCUR as the facilitator and convener of this independent review. CONCUR convened a panel of scientific experts – the Independent Scientific and Technical Advisory Panel (ISTAP) – to review the issues at hand and make recommendations to bolster the scientific underpinning of the permit application and review process. For this first phase, the two parties and CONCUR identified the expertise needed on the Panel and jointly agreed on the Panel members selected. The Panel's specific and limited purpose during this Phase I of the independent review was to investigate whether currently available alternative subsurface intake technology can provide a technically feasible method of supplying source water to Poseidon's proposed desalination facility. Working with CONCUR, Commission staff and Poseidon agreed on the Panel's initial scope of work and on its structure and operating procedures. These are described in Appendix B of this report, the Terms of Reference (TOR).

As noted above, the Conveners anticipate that multiple phases of work will be necessary for the Panel to complete it's charge, and that the composition of the Panel may be revised at each phase to provide the necessary expertise. The Panel's first phase of work was limited to evaluating the only the *technical* feasibility of subsurface intake methods rather than the all aspects of feasibility. In other words, the Panel was charged with investigating whether, given hydrogeologic and oceanographic site conditions, any of several currently available subsurface intake methods can be built and operated at the proposed Huntington Beach site. After agreeing upon the Panel composition, the Conveners also jointly developed a bibliography and jointly provided data sources for the Panel to use in its deliberations.

Panel Deliberation Process

The Panel started its work in June 2014. The Panel's initial organizational meeting, convened via conference call, was focused on introducing the Panel members, the parties, and CONCUR, describing and answering questions about the Terms of Reference, and establishing the expected schedule, review process, and other considerations. The parties posted relevant data, reports, and information for the Panel on the Commission's FTP site, with most being available to the interested public.

The Panel's first public meeting was held on June 2014 in Huntington Beach. It included presentations by Poseidon and technical advisors[2], discussions among the Panel members, and opportunities for public comment.

At this public meeting, the Panelists identified and requested additional information to support the analysis of technical feasibility[3]. Several weeks later, at a work session in San Francisco, the Panel evaluated the information made available through the FTP site, at the public meeting, and the additional information they had requested, along with published literature known to the Panelists, and worked to assess the technical feasibility of various subsurface intake designs.

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[2] Information provided to the Panel at that public meeting included:

- Slant Well Intake Investigation - Doheny Ocean Desalination Project - slant well technology at the proposed Doheny Beach desalination facility (presented by Richard Bell, a staff member from the Municipal Water District of Orange County.
- Groundwater Basin and Talbert Gap Overview - detailed information on the Talbert aquifer, local seawater barriers, local sediments, and the use of injection wells serving as water recharge points as well as seawater intrusion buffers (presented by Roy Herndon, a staff member of the Orange County Water District.
- Huntington Beach Project Site Characteristics - characteristics of the proposed Huntington Beach site, including site acreage, surrounding land use and existing infrastructure, and vegetation.
- Review of the Proposed Huntington Beach Project - the scope, goals, and status of the various phases of the Huntington Beach Project, the determination of "feasibility," characteristics of the site, proximity to water delivery systems, and other project components.
- Oceanographic Considerations of Alternative Intakes for the Huntington Beach Desalination Facility - tidal currents in relation to sea floor shelves, interaction with mobile sediments, and other oceanographic considerations.
- Oceanographic Siting - detailed evaluation of the seabed infiltration gallery (SIG) oceanographic siting.
- Conceptual design of a SIG.
- Constructability assumptions and options for the conceptual SIG.
- Alternate Intakes - the process undertaken in other desalination projects (particularly in California) to examine alternate intakes systems.
- Alternate Intake Technologies - evaluation at the Huntington Beach site.

[3] The parties jointly provided the identified information including:

- CCC Nov 2013 Report and Background documents used to evaluate alternatives,
- San Diego County Water Authority (SDCWA) – Feasibility Study for Intake Options,
- Commission's Draft Sea Level Rise Policy Guidance document,
- Sediment management (disposal/reuse) policy excerpts from the Commission,
- Poseidon's proposed Vibracore sampling methodology,
- Studies comparing intake alternatives and key factors in determining feasibility,
- Poseidon's site specific Vibracore data re: determination of range of hydraulic conductivity/K-values,
- Poseidon's documents used to determine the configuration of proposed intake structures, and
- Documents used to assess hydraulic challenges of the current SIG design/technology.

The Panel's work continued in subsequent weeks through conference calls, drafting of writing assignments, and exchange of several iterations of its draft reports. To maintain the Panel's independence, the report preparations and Panel deliberations occurred without input from the Conveners. Only when the Panel had completed a final draft of its report were the parties asked to review and propose edits, though the suggested edits were limited to concluding whether the report was consistent with the agreed-upon scope of work as defined in the Terms of Reference and recommending correction of factual points, as needed. The Conveners were not provided the opportunity to modify the Panel's conclusions or question its technical review. On September 22, 2014, the Commission posted the Panel's Phase I Draft report on its website for public review.

As a final step of this first phase of this independent review process, the Panel invited public comments at a meeting convened in Huntington Beach on September 29, 2014 to address relevant comments on the report. After that meeting, the Panel prepared this final Phase 1 report, which will be used by a new Panel in the Phase 2[4] work and which will become part of the Commission's record for Poseidon's upcoming CDP application. Pursuant to the Terms of Reference, all Panel members are joint authors of the final Phase 1 report, as documented on the signature page of this Report.

Note: During much of this same period, the State was developing a policy meant to help guide development of seawater desalination and clarify the regulatory requirements for proposed intake and discharge facilities. Starting in 2007, the State Water Resources Control Board (State Board) convened its own expert panels and held public workshops and hearings, and in August 2014, released a draft policy that identifies the proposed performance standards, study methods, mitigation measures, and other requirements desalination facilities will be required to meet. The State Board anticipates adopting a final policy later in 2014. Commission staff and Poseidon participated in the policy development, and both parties believe the Panel's work is consistent with the approaches anticipated in the draft policy.

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[4] According to the TOR, Phase 2 of the panel is described as: "Still focused on the Huntington Beach site, the Panel would characterize the technically feasible subsurface intakes identified in Phase 1 relative to a broader range of evaluation criteria, as recommended by the parties and determined by the Panel, such as size, scale, cost, energy use, and characteristics related to site requirements and environmental concerns consistent with the California Coastal Act's definition of feasible, and as compared to the proposed open intake (Appendix B)."

iii. Signature Page

WE, THE UNDERSIGNED MEMBERS OF THE CCC-POSEIDON PROPOSED HUNTINGTON BEACH DESALINATION FACILITY INDEPENDENT SCIENTIFIC TECHNICAL ADVISORY PANEL, AUTHORED AND HEREBY CONFIRM OUR CONCURRENCE WITH THE FULL TEXT OF THIS PHASE 1 REPORT:

Robert Bittner

ROBERT BITTNER

Michael Kavanaugh

MICHAEL KAVANAUGH

MARTIN FEENEY

ROBERT MALIVA

Thomas M. Missimer

THOMAS MISSIMER

iv. Panelists' Executive Summary

a. Introduction

The Independent Scientific and Technical Advisory Panel (ISTAP or "Panel") was established by an agreement between the California Coastal Commission (CCC or Commission), and Poseidon Resources (Surfside) LLC (Poseidon) to undertake an independent assessment of the technical feasibility of using one or more potential subsurface intake technologies to supply the feed water to a seawater desalination facility using the Sea Water Reverse Osmosis (SWRO) technology. The facility would be located in Huntington Beach with a presumed hydraulic capacity to meet a goal of producing 50 Million Gallons per Day (MGD) of potable water. Background on the rationale for establishing the ISTAP process is provided in the convener's preface to this report.

The process of establishing the ISTAP and coordinating ISTAP deliberations and preparation of a Phase 1 consensus technical report is being managed by CONCUR, Inc. (CONCUR), a California firm specializing in facilitation and mediation processes to resolve complex technical disputes. Under the direction of CONCUR, the CCC and Poseidon, designated as "Conveners" in this process, jointly selected five experts on various technical aspects of subsurface intake options. Qualifications for the ISTAP members are provided in Appendix A. CONCUR established a contract with each Panel member that defines the scope of work for the feasibility assessment. The structure and operating procedures of the scientific and technical review and specific charge to the Panelists are defined in the Terms of Reference (TOR) document jointly developed by Poseidon and the CCC with CONCUR's assistance prior to Panelist recruitment (see Appendix B). Additional background on the process is provided in the convener's preface.

The full ISTAP assessment of feasibility will be carried out over the course of two or more phases. The objective of Phase 1 is bounded to examine only the "Technical Feasibility" of subsurface intakes at or near the proposed site at Huntington Beach, California. For the Phase 1 Report, the working definition of "Technical Feasibility" was specified in the expert contract documents as: "Able to be built and operated using currently available methods". The specific question posed to the ISTAP in Phase 1 then is: ***Will any of the currently available subsurface intake designs be technically feasible at the proposed site at Huntington Beach?***

The ISTAP also determined that "Technical Feasibility" should be further defined by generally recognized factors as documented in the California Coastal Act of 1976. This Act provides the following definition:

> *"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. (Section 30108 of the California Public Resources Code)*

Of these four factors, the Phase 1 Assessment focuses primarily on technological factors. The ISTAP also concluded that the definition of "technical feasibility" should be informed by the recent State Water Resources Control Board Draft Desalination Policy published July 3, 2014. The Draft Policy specifies 14 factors, identified in the introduction to this report that should be considered to determine subsurface intake feasibility. The ISTAP has determined that the following six factors are technological in nature, namely, (1) geotechnical data for the site, (2) hydrogeology, (3) benthic topography, (4) oceanographic conditions, (5) impact on freshwater aquifers, and (6) other site and project-specific factors. These six factors thus comprise the "Technical Factors" considered in this Phase 1 assessment, consistent with interpretation of the California Coastal Act definition of "Feasible". Consideration of the other eight factors identified in the Draft Policy may be incorporated into Phase 2 of the overall Panel process to assess feasibility of those technologies deemed "Technically Feasible" in the Phase 1 assessment.

b. Approach

The ISTAP has relied upon both technical information provided by the Conveners as well as an extensive body of published data on all technical considerations for subsurface intake structures associated with desalination facilities worldwide using the SWRO technology. In addition, the ISTAP participated in a public meeting held in Huntington Beach, CA on 9-10 June, 2014, which included presentations by representatives of the conveners and comments from other interested parties. Materials presented at this public meeting are available on the CCC website. Subsequently, the ISTAP met in San Francisco on 28 and 29 July, 2014 to deliberate on the large amount of technical information. On September 22, the Coastal Commission released the Panel's Phase 1 Draft Report, and opened the opportunity for the public to provide comments. On 29 September, 2014, CONCUR convened a public meeting at the Huntington Beach Main Library. The purpose of the information-sharing meeting was for the Panel to present its findings and conclusions, offer clarifications where requested, and receive and consider public comments. Public comments received in writing and verbally as of 3 October, 2014 have been considered by the ISTAP. After consideration of these comments, the ISTAP has incorporated appropriate edits in this Final Report.

In preparing this Report, the first step undertaken by the ISTAP was to identify all possible subsurface intake options that have at least one application of the technology worldwide for the purposes of delivering water from a surface source regardless of economic considerations, or the other factors identified in the California Coastal Act definition of feasibility. These purposes could include not just intakes for desalination plants, but also any subsurface intake technology used to obtain fresh, brackish or saline water from a surface water body. The ISTAP considered that these technical options would be considered as "currently available methods".

The ISTAP then established a list of criteria and subfactors that address all of the technical factors noted above. Information was then developed, based on technical information available to the ISTAP or using professional judgment, to address all technical factors for each of the selected subsurface intake options. The matrix developed through this process then served as the foundation of the ISTAP's determination as to whether or not any of the options were feasible based on technological factors solely. In simple terms, this means that cost and other factors normally considered under the California Coastal Act definition of feasible were not addressed in Phase 1 of the assessment.

c. Site and Project Description

The proposed location of the desalination facility is a 12-acre site inshore of the Pacific Coast Highway, five to ten feet above mean sea level (MSL), adjacent to AES Huntington Beach generating station, approximately two miles south of the Huntington Beach (HB) Municipal Pier, and one mile north of the mouth of the Santa Anna River. The site has an existing 1,800-ft long seawater surface intake that is being used to bring cooling water into the power plant and a 1,500-ft outfall used to discharge the water back to the sea. The beach area that fronts the proposed site is designated for “Public” or “Semi-Public” use. The HB State and City Beaches see more than eight million beach goers annually. The proposed site is adjacent to the Huntington Beach Wetlands Conservancy. The closest ocean Marine Protected Areas (MPAs) to the proposed site are the inlet to the Bolsa Chica estuarine/wetlands complex about three miles north and Crystal Cove, eight miles south of the proposed desalination facility site.

The proposed project site is located on the southwest (SW) edge of the Orange County Water District, which pumps 70% of the water demand for 2.4-million people from 200 wells in Orange County. The proposed site overlies the western portion of the Talbert aquifer, which is a significant groundwater source for Orange County’s water needs. The Talbert aquifer is a confined aquifer that extends and outcrops on the seafloor. As the result of a reversed seaward gradient, seawater intrusion has occurred at the coast and threatens inland portions of the aquifer system. Orange County injects 30 MGD of treated wastewater into the aquifer system to replenish the basin and control seawater intrusion.

The proposed facility is in close proximity, about five miles, from the regional water delivery system, and Poseidon’s intent is to construct a pipeline to use this existing distribution system for acceptance of product water from the desalination facility. Several active faults run parallel to the shoreline, underlie the proposed site, and intersect the Talbert aquifer. These faults pose an earthquake risk that could cause liquefaction and settlement at the facility. The shore near the site is a high-energy zone, characterized by large swells and ocean currents. The nearshore seabed in front of the proposed site is subject to seasonal changes due to wave erosion and seasonal equilibrium changes. As a result, the inshore sediment cover is subject to large-scale seasonal bottom profile changes.

Although Poseidon has withdrawn their permit application at this time, the ISTAP has assumed that the initial permit application and subsequent response by the Coastal Commission staff (Staff Report on Poseidon Application, 10 October, 2013, E-06-007) defines the likely attributes of a future permit application pending the outcome of this assessment process. Thus, the ISTAP considered that each subsurface intake technology would need to be capable of withdrawing 100 to 127 million gallons per day (MGD), the hydraulic capacity needed to meet a production goal of 50 MGD using the SWRO desalination technology. The maximum capacity of 127 MGD was determined by Poseidon to meet concentrate water quality discharge standards in the receiving waters, using 27 MGD to dilute the concentrate from the desalination process with discharge of the diluted concentrate through a conventional outfall design. The lower hydraulic capacity of 100 MGD would still be sufficient to meet the production goal of 50 MGD of potable water. Under this scenario, concentrate disposal would be conducted through appropriately designed diffuser outfalls to meet the water quality discharge standards.

d. Findings

The ISTAP evaluated nine types of subsurface intakes for technical feasibility at the Huntington Beach site. These subsurface intake options included: (1) vertical wells completed in the shallow aquifer above the Talbert aquifer, (2) vertical deep wells completed within the Talbert aquifer, (3) vertical wells open to both the shallow and Talbert aquifers, (4) radial collector wells tapping the shallow aquifer, (5) slant wells tapping the Talbert aquifer, (6) seabed infiltration gallery (SIG), (7) beach gallery (surf zone infiltration gallery)[5], (8) horizontal directional drilled wells, and (9) a water tunnel. The evaluation of the technical feasibility of each of these options, based on analysis of numerous technical factors is presented in Table 5.1. A condensed version of this matrix is shown below in Table ES-1. This evaluation by the ISTAP was based on the hydrogeologic and oceanographic conditions specific to the proposed Huntington Beach AES site and proximate areas. The technical infeasibility of a particular intake technology at this location should not be generalized to feasibility considerations of any intake type in different settings or locations.

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[5] The ISTAP uses the terms “surf zone gallery” and “beach gallery” interchangeably in this Report.

Table ES-1- Subsurface Intake Summary Matrix

	Subfactor	Vertical wells completed above confining unit	Vertical wells completed below confining unit	Vertical wells completed above and below confining unit	Radial collector in shallow aquifer	Slant Wells completed in Talbert aquifer	Engineered seafloor infiltration gallery	Surf zone infiltration gallery	HDD wells in shallow aquifer	Water tunnel
Hydrogeology										
	Impact on fresh water aquifers	Yes	Yes	Yes	No	Yes	No	No	No	No
Design Constraints										
	Performance risk - degree of uncertainty of outcome	Low	Low	Low	Medium	Medium	Medium	Medium	High	Unknown
Oceanographic										
	Sensitivity to sea level rise	High	High	High	High	Medium	Low	Low	Low	Low
Geochemistry										
	Risk of adverse fluid mixing	Low	High	High	Low	High	Low	Low	Unknown	Low
Precedent on large scale in similar geological conditions		Jeddah, Saudi Arabia; 5 MGD from 10 wells	No precedent	No precedent	Pemex system in Mexico, 3 collectors with total capacity of 12 Mgd	No precedent	Fukuoka, Japan. 27 MGD intake capacity	No precedent	Alicante, Spain; designed for 34 MGD, operating at 17 MGD	Alicante, Spain, 17 MGD
Key considerations / fatal flaw(s)		Performance risk: inadequate aquifer capacity and great drawdowns. Low yields would require extremely high number of wells, major water quality risk	Complications with seawater intrusion management and production from Orange Groundwater Basin	Complications with seawater intrusion management and production from Orange Groundwater Basin	High performance risk due to inappropriate geologic conditions	Complications with seawater intrusion management and production from Orange Groundwater Basin; geochemical impacts	Construction complexity	Construction complexity in high energy environment, potential restrictions on allowable construction times/beach closure, impacts of beach renourishment	Performance risk concerns over granular materials and maintenance of well performance	Complex construction involving ground freezing. High performance risk - no precedence for project scale. Cost likely prohibitive
Technically Feasible? Y or N		**N**	**N**	**N**	**N**	**N**	**Y**	**Y**	**N**	**N**

The ISTAP carefully evaluated fatal flaws of each subsurface intake type considered for application at Huntington Beach. Only the seabed infiltration gallery and the surf zone (beach) gallery survived the fatal flaw analysis, and both are deemed technically feasible. Both gallery types would face constructability challenges related to subsea construction. The surf zone gallery was judged to have particularly challenging construction issues (and thus a lesser degree of technical feasibility) related to construction in a high-energy environment. The ISTAP does not consider the existing scale of use of any particular subsurface intake compared to the capacity requirement at Huntington Beach to be a fatal flaw for technical feasibility (e.g., the only existing seabed infiltration gallery has a capacity of 27 MGD compared to the lower hydraulic capacity of 100 MGD required for the proposed Huntington Beach project, and no large scale implementation of a beach gallery has been constructed and operated as of September 2014).

The Panel interpreted its charge relative to the Terms of Reference to be the evaluation of the technical feasibility of subsurface intake technologies linked to the scale of a likely project proposal. Consistent with that approach, the Phase 1 Panel considered nine technologies keyed to a potential project with hydraulic capacity in the range 100 to 127 MGD. The Panel did address the broad issue of downward scalability where it saw relevance, but did not consider a full or parsed range of scale options for any of the nine technologies, as doing so would have exceeded the agreed-upon scope of work defined in the TOR. Scalability issues could be addressed in subsequent assessments of other feasibility factors at the discretion of the Conveners.

It is the collective opinion of the ISTAP that each of the other seven subsurface intake options for the target hydraulic capacity range (100-127 MGD) had at least one technical fatal flaw that eliminated it from further technical consideration. The shallow vertical wells would create unacceptable water level drawdowns landward of the shoreline and could impact wetlands and cause movement of potential contaminants seaward. The deep vertical wells would have a significant impact on the Talbert aquifer that would interfere with the management of the salinity barrier and the management of the interior freshwater basin. The combined shallow and deep-water wells would adversely impact both the shallow aquifer and Talbert aquifer, and in addition, would produce waters with differing inorganic chemistry, which would adversely affect SWRO plant operation. Radial collector wells constructed into the shallow aquifer would have to be located very close to the surf zone which would make them susceptible to damage during storms and would be impacted by the projected sea level rise. Slant wells tapping the Talbert aquifer would interfere with the management of the salinity barrier and the management of the freshwater basin, and further, would likely have geochemical issues with the water produced from the aquifer (e.g., oxidation states of mixing waters). A water tunnel constructed in the unlithified sediment at Huntington Beach would have overwhelming constructability issues.

e. Recommendations

The ISTAP recommends that consideration be given solely to seabed infiltration galleries (SIG) and beach gallery intake systems in the Phase 2 assessment. As noted, the ISTAP was not asked to evaluate the economic considerations of using a subsurface intake versus a conventional open-ocean intake during Phase 1 of the assessment. The ISTAP recommends that in the next phase, the Panel should focus primarily on the constructability of the seabed infiltration and beach gallery intake systems, because this greatly affects the economic viability of their potential use. Other factors should be considered consistent with the definition of "feasibility" in the California Coastal Act.

However, the ISTAP recommends that in the Phase 2 evaluation of the subsurface intake options, a detailed lifecycle cost analysis should be provided to the succeeding committee. This lifecycle cost analysis should contain at least four scenarios, including:

1) the lifecycle cost over an appropriate operating period obtaining the feed water from a conventional open-ocean intake without considering the cost of potential environmental impact of impingement and entrainment,

2) the lifecycle cost over an appropriate operating period obtaining feed water from a conventional open-ocean intake considering the cost of potential environmental impact of impingement and entrainment,
3) the lifecycle cost over an appropriate operating period obtaining the feed water from a seabed gallery intake system (or beach gallery intake system) using the same pretreatment design as used in treating open-ocean seawater, and
4) the lifecycle cost over an appropriate operating period obtaining the feed water from a seabed gallery intake system (or beach gallery intake system) using a reduced degree of pretreatment, such as mixed media filtration and entry into the cartridge filters.

In each of these scenarios, the ISTAP recommends that the selected design hydraulic capacity match both the minimum and maximum flow rates consistent with the desired production rate of a 50 MGD desalination facility using the SWRO technology. The definition of an "appropriate" operating period should follow accepted industry standards for such lifecycle cost analyses. Typically, a period of 30 years is used, but given concerns on the potential for sea level rise impacts, analysis over a longer operating period (e.g. 50 years) may be desirable. In addition, the ISTAP questions the need for the use of seawater to dilute the concentrate discharge given the well-known use of diffuser outfalls to meet ocean discharge requirements.

The ISTAP also recommends that the Phase 2 Panel continue to rely on the definition of "Technical Feasibility" as defined by generally recognized factors as documented in the California Coastal Act of 1976 *(Section 30108 of the California Public Resources Code)*

Chapter I. INTRODUCTION

Poseidon Resources (Surfside) LLC (Poseidon) has proposed construction of a seawater desalination facility using the Sea Water Reverse Osmosis (SWRO) technology in Huntington Beach, California. The California Coastal Commission (CCC or the Commission) acting under the California Coastal Act is responsible for review and approval of the permit application for such facilities. Poseidon's permit application proposed the use of an existing open ocean intake for supply of feed seawater to the facility. However, it has been reported that open ocean intakes can cause unacceptable levels of impingement and entrainment of marine life and have the potential for degrading the local or regional marine ecosystem(s). Because of these concerns, the CCC recommended that Poseidon work with CCC staff to conduct an independent assessment of the feasibility of using subsurface intake technology, with the intention of reducing ecological impacts while still providing a sufficient volume of feed water to the proposed facility.

As a result of this request, Poseidon has temporarily withdrawn the permit application and, with the assistance of CONCUR, has worked with the CCC to form the ISTAP for the express purpose of preparing a concise summary of the technical feasibility of using one or more potential subsurface intake systems for supplying feed water to the proposed Huntington Beach seawater desalination facility (See the convener's preface for the background in establishing the ISTAP process). The specific question to be answered by the ISTAP is: ***Will any of the several potential subsurface intake designs be technically feasible at the proposed site at Huntington Beach?***

CONCUR, CCC, and Poseidon have provided the ISTAP with a wide range of technical information regarding the proposed desalination facility, including specific information on the characterization of the geophysical, hydrological, and geochemical features of the proposed site. However, the aim of CCC and Poseidon has been to conduct an independent scientific fact - finding and review process where the findings and conclusions of the assessment are completed without intervention from CONCUR, CCC or Poseidon. In addition, the ISTAP has not relied solely on the information provided by CONCUR, CCC or Poseidon but has conducted its own search for published literature, relevant case study reports, and available on-site studies of similar or comparable SWRO desalination facilities around the world. For a listing of the documents reviewed by the ISTAP please see Chapter VII of this report – Reports on Subsurface Intakes.

The following brief summary of the proposed project and a site description was developed from information provided to the Panel.

1.1 General

The selected location of the proposed desalination facility is a 12-acre site inshore of the Pacific Coast Highway, five to ten feet above MSL, adjacent to AES Huntington Beach generating station, approximately two miles south of the Huntington Beach Municipal Pier, and one mile north of the mouth of the Santa Anna River. The site has an existing 1,800-ft long seawater intake previously used to bring cooling water into the power plant and 1,500-ft outfall used to return the water. The beach area that fronts the proposed site is designated for "Public" or "Semi-Public" use. The Huntington Beach State and City Beaches see more than eight million beach goers annually.

1.2 Environmental

The proposed site is adjacent to Huntington Beach Wetlands Conservancy. The closest ocean Marine Protected Areas (MPAs) to the proposed site are the inlet to the Bolsa Chica estuarine/wetlands complex about three miles north and Crystal Cove, eight miles south of the proposed desalination facility site.

1.3 Economical

The proposed facility is about five miles from the regional potable water delivery system operated by the Municipal Water District of Orange County and other water utilities, and the intent is for Poseidon to construct a pipeline to this existing distribution system for distribution of the output of the facility.

1.4 Hydrological

The proposed project site is located on the SW edge of the Municipal Water District of Orange County, which pumps 70% of the water demand for 2.4-million people from 200 wells in Orange County. The proposed site overlies the western portion of the Talbert aquifer, which is a significant water supply source for Orange County's water needs. The Talbert aquifer is a confined aquifer that extends and outcrops on the seafloor. As the result of a reversed seaward gradient, seawater intrusion has occurred at the coast and threatens inland portions of the aquifer system. Orange County injects 30 MGD of highly treated reclaimed wastewater into the aquifer system to replenish the basin and control seawater intrusion.

1.5 Seismic activity

Several active faults run parallel to the shoreline, underlie the proposed site, and intersect the Talbert aquifer. These faults pose a risk of liquefaction and settlement at the facility.

1.6 Oceanographic setting

The nearshore area of the site is a high-energy zone, characterized by large swells and ocean currents. In the neighborhood of the Huntington Beach, average incident wave heights of between 0.9 m and 1.2 m prevail 87% of the time during a typical year in an El Niño-dominated climate period. This wave height range occurs primarily during the spring, summer and fall seasonal periods. During the remaining 13% of the time (primarily during winter months), average incident wave heights near the Huntington Beach increase to 2.4 m to 2.7 m, with some waves reaching significant heights as large as 4 m to 6 m.

The nearshore seabed in front of the proposed site is subject to seasonal changes due to wave erosion and seasonal equilibrium changes. As a result, the inshore sediment cover is subject to large-scale seasonal bottom profile changes.

1.7 Constructability

The high-energy surf zone environment off Huntington Beach prevents the use of conventional floating construction equipment and necessitates the use of access trestles or elevated bridging structures built out from shore to allow construction cranes and personnel to safely travel and work above the waves. This method of construction is extremely slow and expensive.

To provide clarity of purpose in preparing this concise short report, the definition of "feasible" has been taken from **California Coastal Act of 1976 Definitions § 30108.**

FEASIBLE

> "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.

The State Water Resources Control Board Draft Desalination Policy published July 3rd 2014 states the following factors should be considered to determine subsurface intake feasibility:

1. Geotechnical data
2. Hydrogeology
3. Benthic topography
4. Oceanographic conditions
5. Presence of sensitive habitats
6. Energy use
7. Impact on freshwater aquifers
8. Local water supply and existing users
9. Desalinated water conveyance
10. Existing infrastructure
11. Co-location with sources of dilution water
12. Design constraints (engineering, constructability)
13. Project lifecycle costs
14. Other site- and factory-specific factors

This independent review is structured in two Phases. The objective in Phase 1 is to examine the "Technical Feasibility" of subsurface intakes at or near the proposed Huntington Beach site. For the Phase 1 report, the TOR's working definition of "Technical Feasibility" is:

“Able to be built and operated using currently available methods”. For this Phase 1 report, ISTAP has considered six of the above listed criteria: 1, 2, 3, 4, 7, and 12 as relevant to technical considerations for a feasibility assessment. The Phase 2 ISTAP Report may consider, among other issues, the remaining criteria: 5, 6, 8, 9, 10, 11, 13 and 14.

Chapter II. APPROACH

2.1 Introduction

The ISTAP conducted this analysis of the technical feasibility of subsurface intake options under the guidance of the Coastal Commission staff and the Project Advocate, Poseidon, who established the Terms of Reference (TOR) for Panel members that describes in general terms the procedures to be followed by the ISTAP members. The main deliverable from the ISTAP is this Phase 1 Report (Report) detailing the deliberations, findings and conclusions of the ISTAP. A public meeting was held in Huntington Beach on 9-10 June 2014, and documentation on the meeting agenda and presentations are available online (http://ftp.coastal.ca.gov[6]). Subsequently, the ISTAP met in San Francisco on 28-29 July, 2014 to deliberate on the large amount of technical information provided both at the public meeting as well as information made available via the Coastal Commission website. On September 22, the Coastal Commission released the Panel's Phase 1 Draft Report, and opened the opportunity for the public to provide comments. On 29 September 29, 2014, the CONCUR convened a public meeting at the Huntington Beach Main Library. The purpose of the information-sharing meeting was for the Panel to present its findings and conclusions, offer clarifications where requested, and receive and consider public comments. Public comments received in writing and verbally as of 3 October, 2014 have been considered by the ISTAP. After consideration of these comments, the ISTAP has incorporated appropriate edits in this Final Report.

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[6] To access the ISTAP meeting information, go to http://ftp.coastal.ca.gov, then go to General Public folder, enter user name: public, password: ocean03. Then select the Expert Panel Public Review folder.

This section of the report provides a brief summary of the approach used by the ISTAP to address the principal question addressed to the ISTAP, namely, is there a "technically feasible" subsurface intake option that "is able to be built and operated using currently available methods?"

The ISTAP relied upon the definition of "technically feasible" established under the California Coastal Act in 1976 in considering the feasibility of subsurface intake options. This definition defines four factors to be considered in determining the feasibility of a project. The ISTAP agreed that in Phase 1 of the study, the exclusive focus would be on the "technological" factors, with a possible Phase 2 study to address issues associated with the other three factors. Thus, the ISTAP considered all possible subsurface intake options that have at least one application of the technology worldwide for the purposes of delivering water from a surface source regardless of economic considerations, or the other factors identified under the California Coastal Act definition. These purposes could include not just intakes for desalination plants, but also any subsurface intake technology used to obtain fresh, brackish or saline water from a surface water body. The ISTAP considered that these technical options would be considered as "currently available methods".

With this definition agreed to by all ISTAP members, a wide range of technologies were considered as potentially technically feasible options for the Huntington Beach Desalination Project (Project). One initial challenge in this approach was the specification of the Project design attributes, particularly the desired maximum hydraulic capacity of the proposed Project needed to meet the proposed goal of producing 50 MGD of potable water.

Although Poseidon has withdrawn their permit application at this time, the ISTAP has assumed that the initial permit application and subsequent response by the Coastal Commission staff (Staff Report on Poseidon Application, 10 October, 2013, E-06-007) defines the likely attributes of a future permit application pending the outcome of this Panel Process. The ISTAP considered subsurface intake technologies that would be capable of producing 100 to 127 million gallons per day (MGD), the hydraulic capacity needed to meet a production goal of 50 MGD using the SWRO desalination technology. The maximum capacity of 127 MGD was determined by Poseidon to meet water quality discharge standards, using 27 MGD to dilute the concentrate from the SWRO desalination process. The lower capacity of 100 MGD would be sufficient to meet the desired hydraulic performance of the proposed Project.

2.2 Potential technologies that meet hydraulic capacity goals

During the San Francisco meeting, the ISTAP conducted a screening analysis to determine the technical feasibility of a wide range of subsurface intake technologies. In addition to the technologies discussed during the Public Meeting in June, the ISTAP also considered other options known to the Panel members based on experience and knowledge of the literature on subsurface intake structures, some of which was written by Panel members. The nine options considered by the ISTAP in the screening analysis are listed below:

1) Vertical wells completed in the shallow aquifer above the Talbert aquifer upper confining unit
2) Vertical wells completed in the Talbert aquifer (below confining unit)
3) Vertical wells completed above and below confining unit
4) Radial (Ranney) collector wells in the shallow aquifer
5) Slant wells completed in the Talbert aquifer
6) Engineered seafloor infiltration gallery
7) Surf zone (beach) infiltration galleries
8) Horizontal directional-drilled (HDD) wells underneath the sea floor.
9) Water tunnels.

The ISTAP then established the factors to be used in the screening analysis. As discussed, the primary technical factors, derived in part from the State Water Resources Control Board Draft 2014 Desalination policy included the following:

- Hydrogeology

- Design constraints
- Oceanographic conditions (including benthic features)
- Geochemistry.

In addition, the ISTAP considered two precedence questions, namely, (a) has the technology been successfully implemented in geologic conditions similar to those expected to be encountered at the Huntington Beach site and (b) has the technology been successfully implemented at a large scale in similar geologic conditions? The ISTAP considers "large scale" to be greater than 10 MGD.

For each of these general factors, the ISTAP considered a series of qualitative and quantitative subfactors that characterize the technical features of each of the screened technologies, including whether or not a technology suffered from a "fatal" flaw that would eliminate that option from further consideration. Details of these subfactors, their relevance to the decision on technical feasibility, and what constitutes a "fatal" flaw are presented later in this Report. Following a thorough screening-level consideration of all the subfactors, as applied to each of the nine technologies considered, the ISTAP then deliberated as to whether or not a technology was: (a) technically feasible or (b) not technically feasible. It should be stressed again that cost was not a factor in screening the nine technologies. Furthermore, the evaluation performed was based on the hydrogeologic and oceanographic conditions specific to the Huntington Beach AES site and proximate areas. The infeasibility of a particular intake type at this location should not be construed as indicating the ISTAP's conclusion that this intake type is not feasible in a different setting or location.

Chapter III. Subsurface Intake Options Considered

3.1 Introduction

Subsurface intake systems have been successfully used at numerous global locations to provide feed water to SWRO water treatment facilities (Missimer, 2009; Missimer et al., 2013). The predominant type of subsurface intake used is vertical wells, but they are most commonly used to supply small (<10,000 m3/d; <2.6 MGD) to medium (10,000-50,000 m3/d; 2.6-13.2 MGD) capacity SWRO plants. Gallery systems are a relatively new class of subsurface intake systems. Beach galleries (referred to herein as either "beach galleries" or "surf zone galleries") were introduced by Missimer and Horvath (1991), Missimer (2009), and Maliva and Missimer (2010). These intakes use a gallery system underlying the intertidal surf zone (Maliva and Missimer, 2010). Seabed galleries are constructed offshore in the seabed and act similar to a slow sand filter (Crittenden et al, 2005; Missimer, 2009).

Additional innovations in SWRO systems are being developed in different parts of the world. A tunnel intake system was designed and constructed at Alicante, Spain (Rachman et al., 2014). This system produces water from a horizontal tunnel that contains lateral screens, similar in concept to a Ranney well. Other systems, such as landward excavations filled with rock and artificial marine filter structures, are also being developed.

There are several reasons why subsurface intake systems are used instead of open-ocean intake types. The primary benefits of subsurface intakes are reductions of possible environmental impacts associated with impingement and entrainment, chemical usage required for pretreatment prior to the RO system, the complexity of in-plant pretreatment processes, and overall SWRO costs, particularly operational costs (Wright and Missimer, 1997; Missimer et al., 2010; Missimer et al., 2013). Additionally, several provisions of California state policies require that entrainment effects be minimized to the extent feasible, which generally requires that subsurface intake methods be assessed as part of environmental and permit review of proposed desalination projects.

The key challenge in the design of subsurface intakes for SWRO facilities is that the technical feasibility of using a given type is site-specific, based on local hydrogeologic and oceanographic conditions. There are limits on the yield of various modular units, such as a single well or a single gallery cell.

3.2 Hydrogeology of the Huntington Beach area

The project area lies on the coastal edge of the Orange County Groundwater Basin. The hydrogeologic setting has been discussed in detail in several of the references cited (Herndon and Bonsangue, 2006, and others) and will not be repeated in this document. Briefly, the nearshore area of Huntington Beach is underlain by a sequence of Holocene and Pleistocene sediments to a depth of approximately 200 feet. These materials mostly constitute the coastal extension of the Talbert aquifer. The thickness of the aquifer decreases seawards as a result of uplift along the Newport-Inglewood Fault. Non-water-bearing consolidated materials have been uplifted on the south side of the fault, reducing the aquifer thickness. In addition to reducing overall aquifer thickness at the coast, movement along the fault has elevated non-water-bearing materials[7] above current sea level, creating natural barriers to groundwater flow. The so-called “Talbert Gap”, located just inland from Huntington Beach, is a subsurface erosional feature in this uplifted block that connects the coastal portion of the basin with the inland portion. A diagrammatical explanation of the Basin is presented below.

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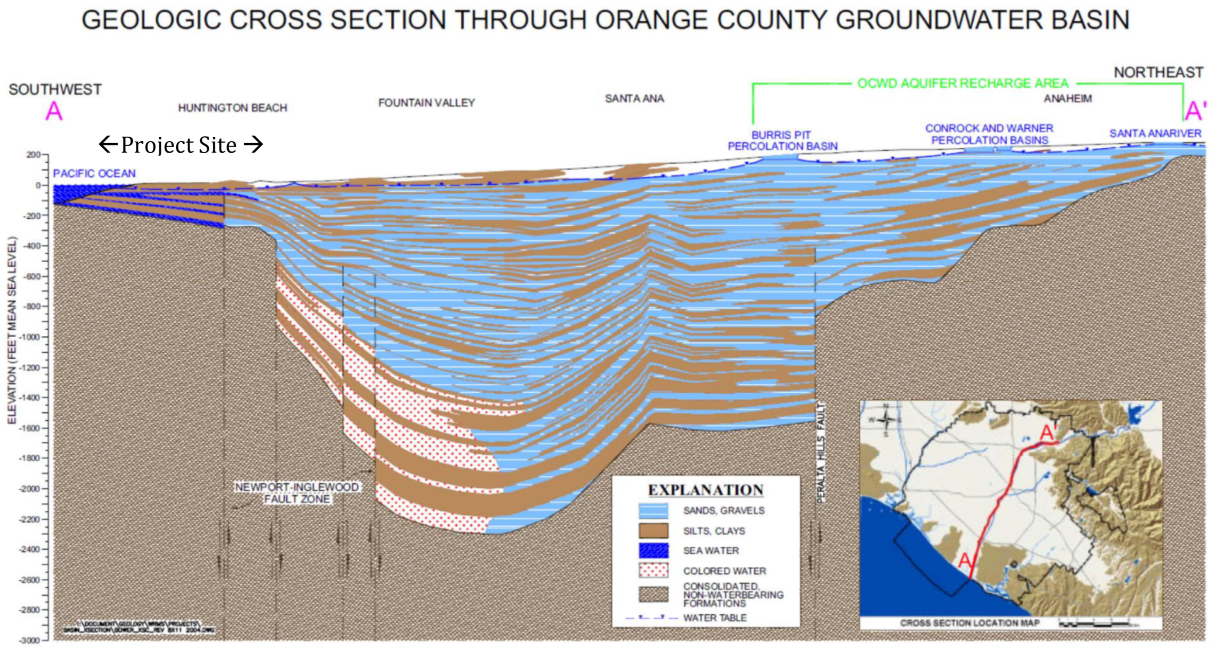
[7] Non-water-bearing materials are typically fine-grained sediments or consolidated rocks that do not transmit water easily.



From the Orange County Water District Groundwater Master Plan (OCWD, 2004) and Edwards et al., (2009)

Figure 3.1. Hydrogeologic section from the Pacific Ocean through the Talbert Gap into the basin (from the Orange County Water Groundwater Master Plan and Edwards et al., 2009)

The Talbert aquifer has been impacted by seawater intrusion. Inland extractions have lowered water levels significantly below sea level and reversed the seaward gradient such that seawater now moves inland toward and through the Talbert Gap and threatens the water quality in the thicker portion of the groundwater basin north of the Newport-Inglewood Fault. Local water management agencies have instituted management efforts to control seawater intrusion into the inland portion of the basin by raising groundwater levels within the Talbert Gap with injection wells.

Based on exploratory work performed by Psomas (2011), GeoSyntec (2013) and others, the localized generalized sequence of sediments in the project area consists of shallow silty-sand deposits to a depth of approximately 70 feet where a 10- to 20-foot thick finer-grained layer is encountered. This finer-grained layer constitutes the aquitard that overlies the sand, gravel and clay deposits that comprise the Talbert aquifer. The base of the Talbert aquifer is at a depth of approximately 200 feet. Groundwater occurs under unconfined conditions in the geologic materials above the aquitard, and confined conditions in materials below the aquitard.

3.3 Well intake systems

3.3.1 Introduction

Globally, the highest capacity subsurface intakes using wells for a SWRO facility are located at Sur, Oman (42.2 MDG), Tordera at Blanes, Spain (33.8 MGD), Pembroke, Malta (31.7 MGD), and Bajo Almanzora, Mallorca, Spain (31.7 MGD) (David et al., 2009; Missimer et al., 2013). Very large capacity Ranney well systems are used in the United States as intakes of freshwater along rivers (Missimer, 2009). All of these seawater facilities use conventional vertical wells that are constructed in high permeability limestone aquifers. These geologic settings in consolidated strata contrast with the unconsolidated materials at the proposed project site in Huntington Beach. The largest capacity vertical well intake systems that produce from unlithified, siliciclastic aquifers are located in Saudi Arabia along the coast of the Red Sea (Al-Mashharawi et al., 2014). A large number of smaller capacity systems have been documented globally (Schwartz, 2000, 2003; Voutchkov, 2005; Bartek et al., 2012). These facilities have a maximum capacity of up to about 15 MGD (Al-Mashharawi et al., 2014; Dehwah et al., 2014).

3.3.2 Vertical wells completed above upper confining unit

Although not specifically presented as a potential source for this project, this possibility is included because this source has precedent in California. The wells would be less than 100 feet in depth and would be designed to produce from shallow sediments above the aquitard and in direct hydraulic continuity with the ocean.

Shallow wells producing from beach deposits have been used to supply feedwater for small desalination facilities worldwide. Wells producing from beach deposits typically provide high-quality water with SDI[8] values less than 2. In California, Marina Coast Water District operated a beach well to supply their desalination facility in the 1990's. This well was approximately 60 feet deep, produced from medium-grained sand, and had a production rate of approximately 400 gpm (Fugro 1995). The currently operating desalination facility in Sand City, California uses shallow (approximately 60 feet in depth) beach wells to provide feed water for the small (~ 0.3 MGD) facility. The beach sands at Sand City are finer grained than Marina.

The ultimate yield of any well source would be dependent on the number of wells; the number of wells is a function of the location of the wells, the spacing of the wells and the materials from which they produce. In general, water produced from beach wells would be derived from both inland and offshore sources - the ratio between these sources again being a function of the location and the hydrogeologic setting.

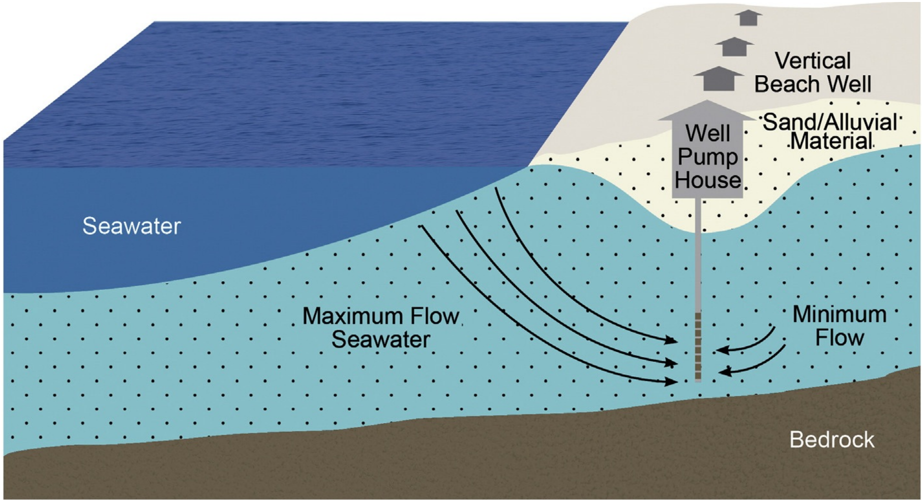


Figure 3.2. Conceptual diagram of the beach well (from Missimer et al., 2013).

3.3.3 Vertical wells completed below confining unit

Deep vertical wells completed in the Talbert aquifer was formally discussed and evaluated by Poseidon (Psomas 2011, Geosyntec, 2013). These wells would be perforated below

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[8] SDI is an abbreviation for Silt Density Index. This is a parameter used by membrane manufacturers and consultants to determine the potential for membrane fouling. It is commonly used in SWRO plant design, especially for pretreatment systems.

the regional aquitard. The source of the produced water would be a blend of native ground water, induced vertical leakage from the ocean, and horizontal flow from the outcrop of the sediments that comprise the Talbert aquifer on the seafloor. The blend would be a function of the distance to the subsea outcrop and the vertical leakage through the aquitard.

The yield per well would be a function of aquifer transmissivity and well spacing (which controls interference between wells). The per-well yield advanced by Poseidon is 1.2 MGD per well, an estimate that appears reasonable for the materials. The per-well yield is less sensitive to setback from the ocean than shallow wells – however, water quality in the blend would have some sensitivity to the distance from the ocean. Extractions from the confined Talbert aquifer would have on-land drawdown impacts. These drawdown impacts would complicate seawater intrusion management efforts and could have undesirable impacts on coastal wetlands (Geosyntec, 2013).

3.3.4 Vertical wells completed above and below confining unit

Another subsurface option would be a supply developed utilizing vertical wells that produce from both the shallow and the Talbert aquifers. No data was provided by Poseidon on this option. This could be in the form of individual wells that are perforated in, and produce from, both aquifer systems or co-located well couplets of two wells, one producing from the shallow the other from the deeper aquifer. This later concept would avoid the complications of interconnection of the aquifer systems and would allow capitalization on the infrastructural investment (power, access road, piping, etc.) in each well location.

Individual dual-perforated well or well couplet yields, depending on the actual materials, could be approximately that of the summation of the two estimated yields, or approximately 2 MGD per installation. However, whereas the multi-aquifer wells or well couplets could increase per-installation yields, the on-land drawdown impacts associated with extractions from the Talbert aquifer would be unmitigated.

3.3.5 Radial collector in shallow aquifer

A collector well consists of a large diameter (typically 18 feet) caisson from which lateral perforated spokes are advanced out from the caisson toward or under a proximate water body (Figure 3.3). Collector wells have been used for the development of drinking water sources from rivers in the United States for over 80 years. Typical installation involves advancement of 200- to 300-foot-long laterals into the coarse gravels underlying riverbeds. In these geologic settings, discharge rates of 10 to 15 MGD per collector well can be achieved. Collector wells have also been used for production of seawater. However, the experience using them is more limited, and because materials are finer-grained, per-well yields are significantly lower.

The construction of a collector well has an advantage over conventional vertical wells in that the location of the structure that contains pumping equipment is offset from the location of the source of water by the length of the lateral. The yields are significantly higher than conventional wells because the effective radius of the well can be measured in tens of feet rather than in inches.

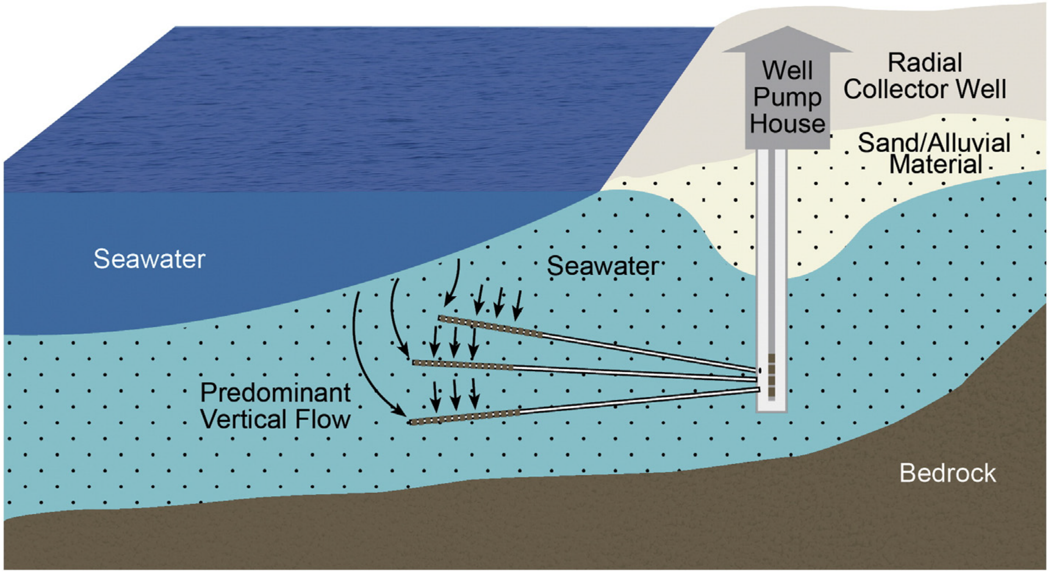

Figure 3.3. Conceptual diagram of the collector well (from Missimer et al., 2013).

For the subject project, collector well yields of 5 MGD have been suggested by Poseidon. Given the materials described and the hydrogeologic setting, this estimate appears reasonable.

Based on the information provided by Poseidon, it appears that this estimate was based on collector wells that would produce from the Talbert aquifer. A more appropriate target aquifer for this technology might be the shallow aquifer - that is, the materials above the confining layer. However, given the finer-grained materials and reduced available drawdown in the shallow aquifer, yields from collector wells would likely be lower**.**

The largest capacity SWRO intake system is located at the PEMEX Salina Cruz Refinery, Mexico with three wells of 4 MGD each, yielding a total capacity of about 12 MGD (Voutchkov, 2005). This is consistent with the assessment and design work performed by Staal, Gardner and Dunne/Ranney Corporation (Staal, Gardner and Dunne, 1992) in Marina, California that suggested a per-well yield of 4 MGD for collectors producing from the shallow beach sands.

3.3.6 Slant wells completed in shallow aquifer

Advancing drilling technology has allowed the construction of conventional wells at an angle (Figure 3.4). Although it is believed that angles as small as 10 degrees from horizontal can be achieved, the sole successful well was drilled at an angle of 22 degrees in Dana Point, California (USBR, 2009, GeoScience, 2012). The ability to construct wells at an angle allows the perforated portion of the well to be placed closer or under an adjacent water body to more effectively induce vertical flow through the overlying beach sands from this water body into the well. The amount of flow derived directly from the overlying water body is a function of the depth of cover and the vertical hydraulic conductivity of the overlying materials.

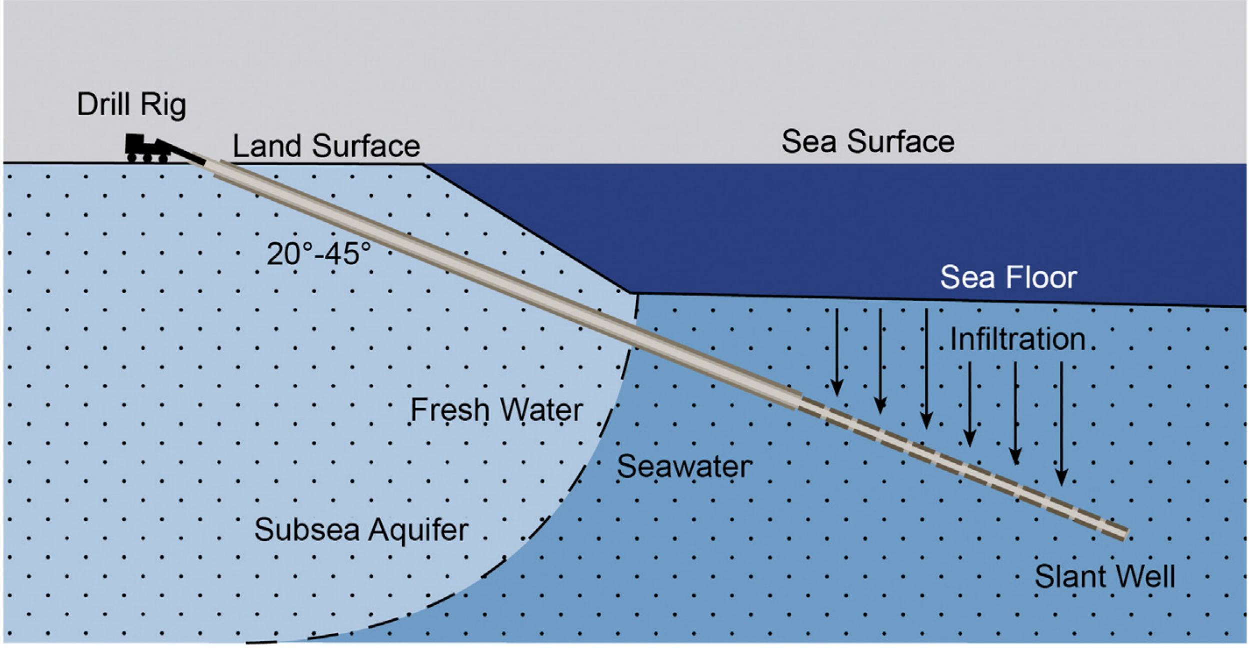

Figure 3.4. Conceptual diagram of the slant well (from Missimer et al., 2013).

Analysis presented by Poseidon suggested that to produce the required 127 MGD, as many as twelve three-well pods producing 12.9 MGD each would be required at a spacing of 600 feet. A separate analysis of the feasibility of the slant wells was performed by Geosyntec (2013). This analysis estimated that each well could produce 2200 gpm, 40 wells would be needed, and three miles of beachfront would be required to produce the required 127 MGD.

Only one slant well has been successfully constructed to date, although a major installation to provide 20 MGD of feedwater capacity is under consideration in the Monterey Bay area. The successfully completed well is at Dana Point. When it was built and tested in 2006, it was test pumped at 2000 gpm and displayed a well efficiency of 95%. Recent longer term testing of the completed test well in 2012 documents the reduction in well efficiency from the original value of 95% in 2006 to 52% in 2012 (GeoScience 2012). Given this observed reduction in efficiency over a short period, the long-term performance of the technology has yet to be confirmed.

Assuming the slant wells would be constructed at a 22-degree angle, and are located 100 feet inland from the shoreline, the end of the perforated portion of the slant well will be at least 150 feet below the seafloor. As considered, extractions will be from the Talbert aquifer system with previously noted inland drawdown impacts.

3.3.7 Horizontal directionally drilled (HDD) wells underneath the sea floor

HDD wells are directionally drilled borings that would be drilled from a common location on the shoreline (Figure 3.5). The boreholes would fan out at a shallow distance under the seafloor and then exit the seafloor at a distance offshore where a permeable flexible casing would be pulled back from the ocean location into the borehole. Feedwater would be derived from the ocean through vertical infiltration through the seafloor. The productivity of the wells is the function of the permeability of the overlying sediments comprising the seafloor. This approach has been used with some success in the desalination facility in Alicante, Spain. This HDD array was originally sized for 45 MGD. However, actual performance has been lower and water quality problems have occurred (Rachman et al., 2014).

Figure 3.5. Conceptual diagram of the HDD wells at Huntington Beach (from Neodren, 2014).

Preliminary analysis by of the project in Alicante, Spain for Poseidon suggests that the required 127 MGD of feedwater could be provided by 60 wells in two fans of 30 wells. However, after receipt of the recent hydraulic conductivity values from the vibracore samples, this estimate (provided by Poseidon) was reported to range between 84 and 231 wells contained in three to eight fans.

3.4 Gallery intake systems

3.4.1 Introduction

Gallery intake systems are designed based on the concept of slow sand filtration. However, there are differences in how the gallery intake systems function within the seawater environment. In freshwater sources, such as a river, a surface film forms on slow sand filters, called the "schmutzdecke" (i.e., dirty layer in German), which is biologically active and is a key part of the treatment process (Huisman and Wood, 1974; Crittenden et al., 2005; Hendricks, 2001, 2011). Slow sand filters have a long history of successful operation for treatment of water for potable purposes worldwide, beginning in the early 1900s. As a result of the bio-active layer formation, most of the reduction of water constituents that require removal prior to RO treatment occurs within the upper few inches of the filter surface. In seawater gallery systems, this upper layer does not form, and therefore, the treatment occurs throughout the uppermost two to six feet of the gallery (unpublished research conducted at the King Abdullah University of Science and Technology, Saudi Arabia [2014]).

3.4.2 Surf zone infiltration galleries

Beach (surf zone) gallery intake systems are a type of slow sand filter constructed beneath the intertidal zone of the beach (Figure 3.6). The gallery is constructed with a series of sand layers, fine at the top with a progressive increase in grain size with depth. The top layer is constructed with the native sand on the beach so that it is compatible with it. The lowest layer is gravel and is used as a support and water collection layer. Seawater is pumped from the bottom layer using a header pipe and a series of screens, similar in concept to a seabed infiltration gallery system (SIG). While slow sand filters rely upon gravity to operate, a beach gallery is pumped to create suction head and pull the water through the filter. This pumping allows (a) adjustments to be made to the infiltration rate, or (b) increases or decreases in suction pressure to be made, to make the inflow rate constant.

A key aspect of a beach gallery system is that it underlies the surf zone of the beach, fully or in part. This means that the active infiltration face of the filter is continuously cleaned by the mechanical energy of the breaking waves and is therefore self-cleaning (Maliva and Missimer, 2010). Also, the location within the intertidal zone allows the gallery to be continuously recharged with no impact on the inland shallow aquifer system.

The vertical flow of water from the sea assures that the inorganic chemistry is not significantly altered over time. The water quality should remain relatively constant based on the hydrology of the Huntington Beach area. The gallery system is unaffected by variations in the deeper groundwater, which could be fresh or brackish in nature at the shoreline. The uppermost natural sand layer is the primary treatment zone within the filter and will likely allow the removal of all algae and a high percentage of bacteria and naturally occurring organic compounds (e.g., natural organic matter). The long-term data collected at the seabed gallery in Japan shows that the SDI was reduced below two, which is at the approximate level produced by conventional SWRO pretreatment systems (Shimokawa, 2012).

The beach gallery would reduce or eliminate the impingement and entrainment of marine fauna. Also, upon completion of construction, the gallery would be located below the surface and could not be observed by beach users.

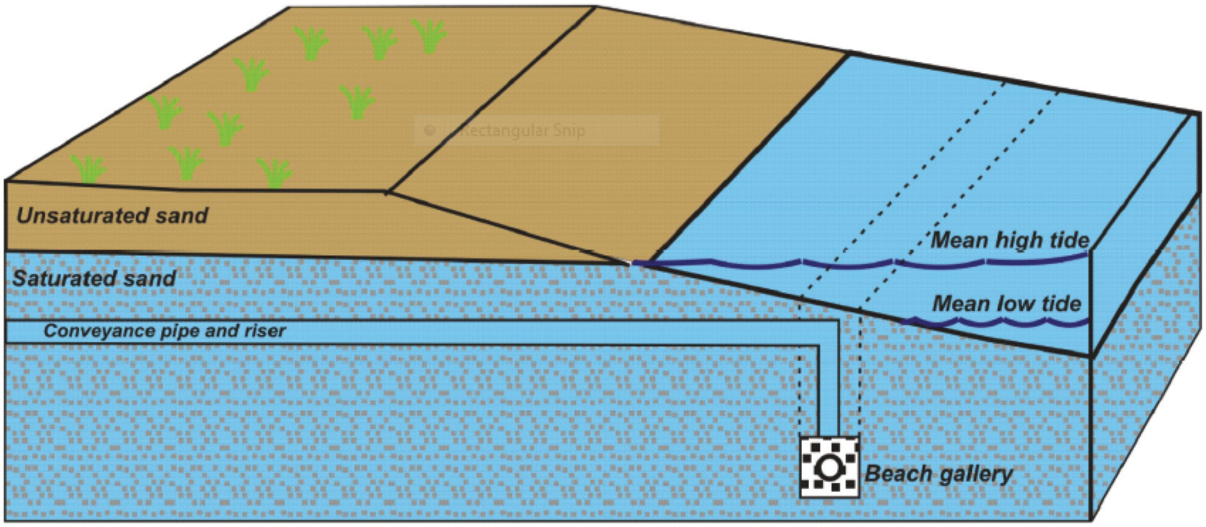

Figure 3.6. Conceptual diagram of the beach gallery (from Maliva and Missimer, 2010).

3.4.3 Engineered seafloor infiltration galleries (SIGs)

A seabed (or seafloor) gallery or seabed infiltration gallery (SIG) is constructed offshore in a stable location. It is another engineered and constructed filter. It uses the concept of slow sand filtration, and the uppermost layer is the part of the filter that contributes most to treatment of the infiltrating water.

The largest SIG system in operation worldwide is the Fukuoka in Japan with a capacity of about 27.2 MGD (Figure 3.7; Hamano et al., 2006; Shimokawa, 2012). A significant SIG test facility has been constructed at the City of Long Beach, California (Wang et al., 2007; Wang et al., 2009).

There are a number of different configurations that can be used in the design of a SIG with implications for system reliability. The Fukuoka SIG has one collection pipe leading from the pumping station on the coast to the offshore SIG. It is a single cell design with no backup pump or means of conducting maintenance during operation. The operation of the Fukuoka SIG has been very successful over the last eight years with no maintenance of the gallery surface and production of seawater with a very low silt-density index (Shimokawa, 2012; Sesler and Missimer, 2012), resulting in very infrequent cleaning of the membranes. The site is located in sheltered water with lower wave heights and currents compared to the open-coast of Huntington Beach. The plant site is subject to intense storm activity.

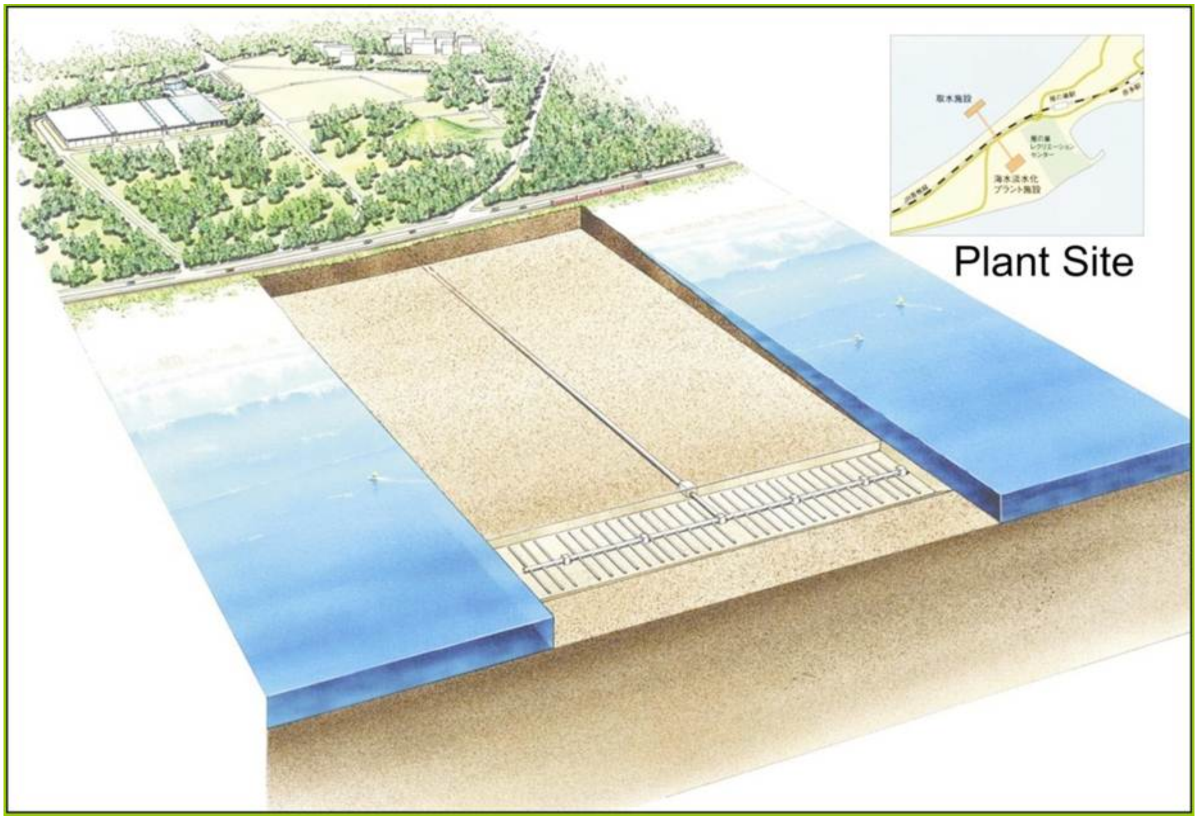

Figure 3.7. Fukuoka, Japan SIG conceptual diagram (from Pankratz, 2006).

An important issue in the siting, design, and construction of a SIG is the bottom stability and the robustness of the design to withstand any extreme natural events, such as earthquakes and harmful algal blooms. The Fukuoka SIG operated without interruption through a 6.5 earthquake on the Richter scale in 2005. The SIG showed only a short-duration increase in the silt density index, but continued to provide high quality seawater to the SWRO plant.

To further increase reliability, SIGs can be constructed as modular systems using a series of gallery cells, each equipped with a pump. This allows shorter distance collection systems to be used to improve flow balance within the gallery and allows a high percentage of the SWRO facility to operate in the event of a pump failure or some clogging of a cell. An example of a SIG design with multiple cells is shown in Figure 3.8. Note that this preliminary design was for a very large capacity SWRO facility (140 MGD) in Saudi Arabia.

The engineered filter used in a SIG contains multiple layers with an upper active layer and several layers used that gradually reduce the grain size to transition into a basal, high permeability collection layer (Figure 3.8). Similar to a beach gallery system, most of the water treatment occurs in the upper layer.

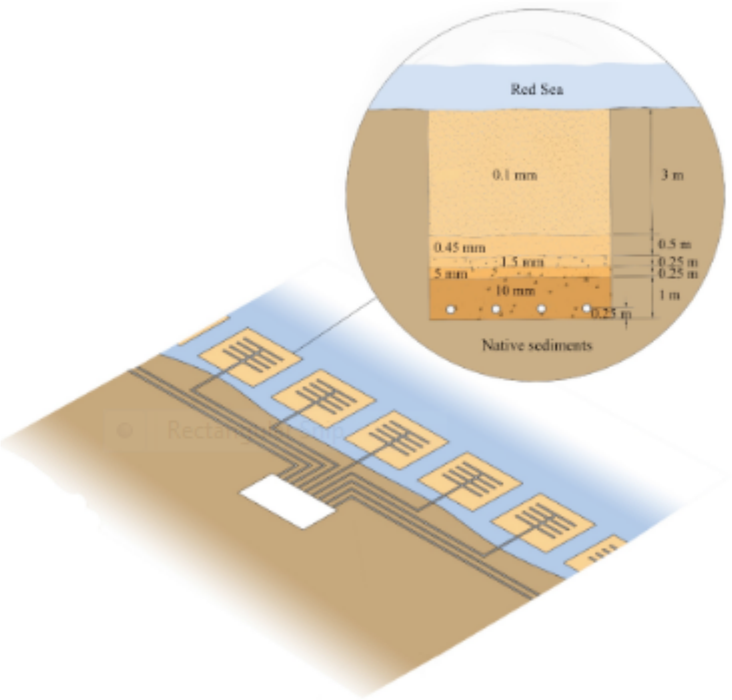

Figure 3.8. Conceptual design of a SIG for the Shuqaiq SWRO plant, Red Sea, Saudi Arabia (from Mantilla and Missimer, 2014).

3.5 Water tunnels

A tunnel intake was recently constructed to provide some or all of the 34.3 MGD of feedwater required to operate the Alicante II SWRO plant in Spain (Rachman et al., 2014). This system contains a tunnel underlying the beach area. The tunnel contains a series of collectors, commonly drilled upward into the overlying aquifer (Figure 3.9). The laterals contain screens that are open to the aquifer and yield water to the tunnel as it is pumped. It operates in a manner similar to a vertical Ranney collector system.

The tunnel system lies fully beneath the surface and would have no significant environmental impact during operations. The induced vertical flow of seawater would produce water with a quality essentially identical to seawater and without inducing impacts to the shallow aquifer landward of the beach. No information was provided by Poseidon on this option.

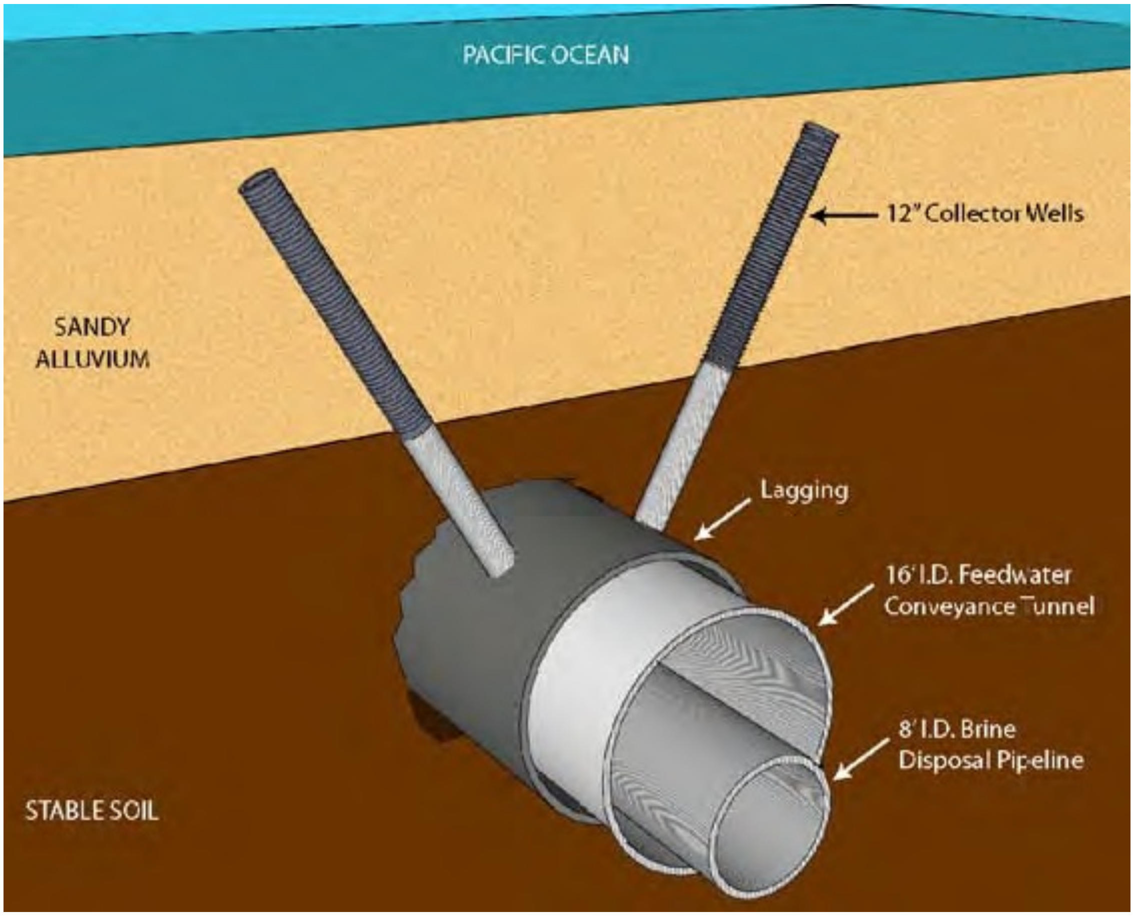

Figure 3.9. Conceptual diagram of a tunnel intake system proposed for another southern California SWRO plant.

3.6 Discussion

The ISTAP considered various subsurface intake systems for use at the proposed 50 MGD capacity SWRO system at the City of Huntington Beach, California. Most subsurface intake systems used at various global locations were reviewed. A common theme throughout the world supporting the use of subsurface intake systems include: (1) reduced environmental impacts, (2) production of feedwater of a higher quality compared to a conventional open-ocean intake, (3) reduced potential for membrane biofouling, and (4) reduced operating costs.

At a very high infiltration rate (10 m/d) the water entrance velocity at the seawater/sea bottom interface would be 0.0045 in/s. Therefore, no significant entrainment of marine organisms would occur. No operational environmental impacts would, therefore, occur.

Subsurface intake systems tend to greatly improve feed water quality by reduction of SDI and removal within the aquifer system or constructed filter of virtually all of the algae, up to 98% of the bacteria, up to 50% of the natural organic matter with a higher percentage of organic polymers removed, and a reduction of significant quantities of transparent exopolymer particles (TEP) (Schwartz, 2003; Choules et al., 2007; Laparc et al., 2007; Rachman et al., 2014; Dehwah et al., 2014). TEP is created by self-assembly of acidic polysaccharides secreted by algae and bacteria (Passow, 2000). Organic biopolymers and TEP in the raw seawater conditions the SWRO membranes and leads to membrane biofouling (Passou and Alldredge, 1994; Berman, 2012; Berman et al., 2011). Significant reduction in concentrations of biopolymers and TEP in the feed water decreases the risk of membrane biofouling and tends to increase the time between required membrane cleanings and allows longer operating life for the membranes (Vesa et al., 2008). Thus, a subsurface intake may eliminate or significantly reduce the need for a pretreatment system that would be needed to produce an equivalent RO feed water quality if a surface intake were used with a standard water pretreatment system.

Use of higher feed water quality in a SWRO reduces the complexity of in-plant pretreatment systems, thereby decreasing the usage of chemical, such as chlorine and coagulants, reduces capital costs of constructing these systems, and reduces electric power consumption. These factors tend to decrease the operating cost of SWRO water treatment (Wright et al., 1997; Missimer et al., 2010) for subsurface intake systems.

Chapter IV. DISCUSSION OF FEASIBILITY CRITERIA

4.1 Introduction

The technical feasibility of a subsurface intake type depends on a variety of hydrogeological, design, oceanographic, and geochemical constraints. In addition, consideration needs to be given to the historical experiences of the various intake types, and particularly whether precedent exists for the investigated subsurface intake type, meaning that this type has been constructed and successfully operated at a comparable scale and in a similar setting as the studied Huntington Beach site. In order for a subsurface intake type to be considered technically feasible at the Huntington Beach site, there must not be any fatal flaws, which are defined as conditions that would either not allow a full-scale system to be successfully constructed and operated or would result in a high risk of failure or unacceptable performance of Poseidon's full-scale target minimum hydraulic capacity of 100 MGD.

Following is a discussion of the feasibility criteria developed by the ISTAP to evaluate the subsurface intake options described above at the Huntington Beach site. The application of these criteria to the Huntington Beach site is presented in Section VII. Some criteria might not lead to a fatal flaw from a purely technical perspective, but could impact feasibility from an economic, regulatory, or environment perspective, whose consideration is not part of Phase 1 of the ISTAP assessment. For example, low vertical well yields could require an uneconomically large number of wells to obtain 100 or 127 MGD of seawater, and thus be economically infeasible, whereas the option might still be technically possible.

Evaluation of the technical feasibility of the considered subsurface intake options involved the collective professional judgment of the Panel as to whether or not the option could be built and reliably operated using currently available methods. The application of professional judgment involved consideration of the available data on the hydrogeology, oceanography, and water quality of the Huntington Beach area and construction and operational experiences at other sites.

4.2 Hydrogeological Feasibility Factor

4.2.1 Impacts on freshwater aquifers

Groundwater pumping on the seaward site of the Talbert Gap could induce seaward flow of water from the Orange County Groundwater Basin. The pumping of saline water could have beneficial impacts as adding an extractive component to the Talbert Gap Salinity Barrier. The pumping would tend to draw the saline-water interface seawards. However, large-scale groundwater pumping seaward of the Talbert Gap may also result in abstraction of freshwater from the basin, adversely impacting its water budget and causing additional drawdowns. Subsurface intake options that would be expected to produce large volumes of water from the Orange County Groundwater Basin would be considered fatally flawed.

4.2.2 Potential yields per installation

Potential yields per installation are best estimates of unit yield per well, acre of gallery subsurface area, and per foot of HDD well or water tunnel. In the absence of site-specific data, these values were estimated based on local hydrogeology and the performance of similar systems constructed elsewhere.

4.3 Design Constraints

4.3.1 Units required for 127 MGD

The number of units (e.g., wells, gallery acres, feet of HDD wells) was obtained by dividing the maximum hydraulic capacity of 127 MGD by the potential yield per installation. A 20% back-up (redundancy) factor was applied, which allows for system capacity to be maintained during operation and maintenance activities and unexpected breakdowns of system components, and some decline in performance over time.

4.3.2 Linear beachfront required

Linear beachfront requirement gives an indication of how spread out a system will be and is an important cost and logistical factor. The requirements were determined by multiplying the number of units by anticipated minimum spacing. For example, a spacing of 100 feet was used for vertical wells completed above the confining unit. Actual spacing requirements would be determined through groundwater modeling to evaluate well interference. A 10-foot separation of surf zone gallery cells is assumed.

4.3.3 Onshore footprint

Onshore footprint is the area permanently required for the number of units. For vertical wells, a 50-ft by 50-ft easement at the wellhead with a 10-ft by 200-ft pipeline easement are assumed to be required. The estimated onshore footprints do not include temporary construction easements. The offshore footprint of seafloor and surf zone infiltration galleries is determined by the number of units required (Section 7.3.1).

4.3.4 Scalability

Scalability refers to the ability to increase the capacity of the system. Subsurface intakes inherently have a modular design, and capacity can be adjusted by changing the number of units. Wells have estimated per well yields, and a specified project demand can be matched to the required number of wells. Likewise, infiltration galleries have yields per unit area. Again, the required demand for a project can be matched to the area required to supply that demand. Not addressed are economies of scale, which is not in the TOR for Phase 1. In general, galleries, and perhaps also water tunnels, tend to have relatively high economies of scale (i.e., there are unit cost savings associated with constructing larger systems), whereas wells have a relatively low economy of scale.

4.3.5 Complexity of construction

Complexity of construction refers to the potential for difficulties to occur during construction. It also ties into the local availability of contractors who are qualified to perform the work and that have the specialty equipment and experience with this specific type of work. Options that have a complex construction would be expected to be relatively expensive, of long duration, and risky in terms of difficulties encountered during construction. Complexity of construction, as considered herein, also includes consideration of factors that may impede or delay construction including: uncertainties and extended duration for obtaining construction permits, seasonal restrictions on beach construction due to public use, seasonal restrictions of offshore operations due to sea conditions, and environmental impacts from construction.

4.3.6 Performance risk

Performance risk is essentially the potential for the intake system to not meet project performance expectations in terms of water yield and quality. It is one of the most important factors in evaluating the technical feasibility of an intake option, as there must be confidence that a constructed intake can satisfactorily perform over the 30-year planned minimum life of the desalination plant. A high degree of uncertainty with regard to the likelihood of successful implementation (i.e., a high potential for system failure or underperformance) is considered a fatal flaw. Performance risk also relates to the opportunities to pilot test an intake option or accurately estimate system performance using other means or data, including the operational history of comparable systems constructed in similar geologies to Huntington Beach. For example, vertical well intakes have a low performance risk because they can be readily pilot-tested.

4.3.7 Reliability of intake system

The reliability of an intake system considers whether or not, or the degree to which, an intake option is expected to maintain acceptable performance over the planned lifespan of the desalination plant. Typically, that lifespan for planning purposes is defined as 30 years, but longer lifespan can be considered. The reliability of intake system factor allows for normal operation and maintenance activities, provided that they can be readily performed and would restore system performance. For example, vertical wells are expected to require periodic rehabilitation using standard methods and replacement of pumps. Evaluation of the reliability of some intake options is complicated by the absence of long-term operation data from precedent systems. The absence of a precedent is of particular concern for system types that do not have precedence for use in freshwater supply. For example, data are not available on the long-term performance of HDD and slant wells, and whether or not they can be rehabilitated to close to original conditions.

4.3.8 Frequency of maintenance

Frequency of maintenance is the relatively frequency at which an intake option is expected to require operation and maintenance activities to either address breakdowns (e.g., pump failure) or restore system performance (e.g., well rehabilitation).

4.3.9 Complexity of maintenance

Subsurface intake systems are generally expected to require some maintenance over their operational lives. Complexity of maintenance addresses both technical difficulties associated with potential maintenance activities and logistical issues that may make maintenance more complex. For example, rehabilitation of slant and HDD wells is much more complex than that of vertical wells. Although potential maintenance of seafloor infiltration galleries is technically simple (e.g., raking the surface), it has a relatively high complexity because it is performed offshore.

4.3.10 Material constraints

Material constraints address construction materials requirements for intake types. In general, seawater intakes should be constructed of corrosion resistant materials.

4.4 Oceanographic constraints

Oceanographic constraints address coastal sedimentological and environmental constraints. Sea level change (rise) is of importance because it effects the position of the beach.

4.4.1 Sensitivity of sea level rise

Sensitivity to sea level rise relates to the effects of changes in water depth and landwards beach migration on constructed intakes. The location of intake structures needs to consider the projected rise of seawater and beach migration over their operational lives. Intakes using wells are designed and located with the intent of producing infiltrated seawater, with their optimal location being as close to the shoreline (subtidal zone) as safely possible. Locating them further inland to avoid the impacts of future sea level rise would place them now in a sub-optimal setting. Intakes that require inundation (e.g., galleries and off-shore water tunnels) would not be sensitive to a rise in sea level.

4.4.2 Sensitivity to Huntington Beach sedimentation rate

Under normal conditions, Huntington Beach would be retreating due to erosion. However, the beach is being maintained through artificial renourishment by the U.S. Army Corps of Engineers. Sedimentation rate, whether natural or anthropogenically influenced, may impact subsurface intakes by either burying or exhuming them. It is assumed that a SIG would be installed in a sedimentologically stable area. The sensitivity of intake design option was evaluated based on the projected Huntington Beach sedimentation rates and likely intake locations and designs. Sedimentation rate is not applicable to vertical, slant, and radial collector wells.

4.4.3 Sensitivity to Huntington Beach bathymetry

Sensitivity to Huntington Beach bathymetry addresses both current and potential post-sea level rise future conditions. This factor is not applicable to vertical, slant, and radial collector wells.

4.4.4 Suitability of bottom environment conditions

Suitability of bottom environmental conditions is applicable to only seabed and surf zone infiltration galleries. Unsuitable conditions would be a rocky bottom or the presence of sensitive environments (e.g., kelp beds). The latter would constitute a fatal flaw.

4.5 Geochemical constraints

Seawater desalination facilities using reverse osmosis technology require feed water with a low suspended solids concentration, low concentrations of clogging organic compounds, and stable water chemistry. Chemical conditions within the subsurface intake should also not be conducive for biogeochemical clogging and associated loss of performance. The most stable systems are those that produce only seawater from vertical infiltration. Mixing of waters with different chemistries can result in a variety of adverse inorganic chemical reactions, such as elemental sulfur and iron oxyhydroxide precipitation.

4.5.1 Risk of adverse fluid mixing

The risks of adverse fluid mixing are greatest where waters from different directions within an aquifer (landwards vs. seawards), aquifers, or aquifer depths enter an intake (or enter different intakes and later mixing within piping system). Systems with the lowest risk of adverse fluid mixing are constructed subsea and produce water largely by vertical infiltration.

4.5.2 Risk of clogging

Loss of intake capacity by clogging (also referred to as plugging) can be caused by a variety of chemical, biological, and physical processes. The greatest risk of clogging occurs where there is mixing of dissimilar waters or a change in water chemistry (e.g., introduction of dissolved oxygen). Clogging is of greatest concern where rehabilitation is complex and expensive (Section 7.3.9).

4.5.3 Risk of changes on inorganic water chemistry

Seawater desalination facilities are designed to treat water with a specific envelope of chemical conditions. Long-term changes in water chemistry caused, for example, by different fractions of landward derived freshwater could interfere with the reverse-osmosis process. The risk is lowest where intakes produce water predominantly by vertical infiltration of seawater (e.g., subsea galleries).

4.6 Precedents

Confidence in the feasibility of an intake option type is greatest where there is a track record of successful implementation of the type at other sites with geological conditions similar to Huntington Beach and ideally also of a comparable hydraulic capacity. Inasmuch as subsurface intakes have a high scalability, the absence of precedents for the proposed 127 MGD system is not considered to be a fatal flaw. However, problems (under-performance) at precedent systems is an important consideration for evaluation of the technical feasibility of the intake option at Huntington Beach, especially if there is no documentation of the cause and resolution of the problem.

Chapter V. Evaluation of Subsurface Intake Types

5.1 Evaluation matrix

An evaluation of the considered subsurface intake types with respect to the feasibility criteria is provided as a coarse screening matrix in Table 5-1. Table 5-1 is based on the collective professional judgment of the Independent Scientific and Technical Advisory Panel. The values of the parameters used are best, ballpark estimates based on available local or general intake-type information in the absence of site-specific actual data. It is important to stress that feasibility issues did not closely depend upon the specific values used. For example, an increase or decrease of well or gallery yields by a factor of two would not impact technical feasibility. However, well or gallery yields are an important economic issue. The technical feasibility of each design option is further discussed in Section 5.2. As noted elsewhere in this Report, the ISTAP stresses that the evaluation was based on the hydrogeologic and oceanographic conditions specific to the Huntington Beach AES site and proximate areas. The infeasibility of a particular intake type at this location should not be generalized to feasibility assessments of any specific intake type in a different setting or location.

5.2 Subsurface intake type feasibility at Huntington Beach

5.2.1 Vertical wells completed above upper confining unit

Vertical wells have the lowest performance risk because their performance can be readily determined through a test well program. The available information on the geology of the Huntington Beach area indicates that the shallow aquifer is moderately transmissive (permeable), which would limit well yields and increase the number of wells required to produce 127 MGD. Assuming a well yield of 0.72 MGD/well, 212 wells would be required. A subsurface intake system that requires such a large number of wells is technically challenging but not infeasible (not taking cost into consideration), provided that well sites can be obtained. The 0.72 MGD (500 gpm) yield may be optimistic in terms of long-term pumping rates, and a lower well yield would result in an even greater number of wells required. A more fundamental limitation is that a production rate of 127 MGD is well beyond what is likely sustainable from the shallow aquifer. As was noted by Mr. Roy Herndon of the OCWD during the public meeting, the proposed groundwater pumping would be about 45% of the total Orange County Groundwater Basin pumping. Pumping would result in very large drawdowns, which would pull freshwater from the landward direction resulting in a high water quality risk. Vertical wells completed in the shallow aquifer above the confining unit above the Talbert aquifer are thus considered to be infeasible.

5.2.2 Vertical wells completed below confining unit

Large-scale water production from the Talbert aquifer would draw large volumes of water from the landward direction, from the Orange County Groundwater Basin, which is considered a fatal flaw rendering the option infeasible. Additional considerations are impacts to the Talbert Gap salinity barrier, which could be net beneficial, and a geochemical risk from the mixing of waters.

5.2.3 Vertical wells completed above and below confining unit

Dual-zone aquifer would have the benefit of greater well yields, but would still have the fatal flaw of a large component of the flow being derived from the Orange County Groundwater Basin. Geochemical incompatibility would also be a major concern due to the mixing of waters from two aquifers within the wells or piping system if paired wells were used.

5.2.4 Radial collector in shallow aquifer

Radial (Ranney) collector wells have the advantage that large volumes of water (equivalent to multiple vertical wells) may be produced from a single well site. Radial collector wells are typically installed in hydrogeological settings where (a) high transmissivity interval(s) is(are) present (e.g., gravel bed) in which laterals can be installed, rather than in sandy strata such as present at the project site. Radial collectors are considered to have a medium performance risk due to the very high cost of testing the option. A full-scale system would have to be constructed. There are also practical limitations on the lengths of laterals. The driller does not recommend/warranty laterals greater than 250 ft., which would mean the laterals would be installed largely above the shoreline (rather than subsea), as caissons would have to be constructed back from current high-tide line. Radial collector wells are considered technically infeasible at the Huntington Beach site due to an inappropriate geology and because the excessively high production rates from the shallow aquifer would not be viable.

5.2.5 Slant wells completed in Talbert aquifer

Slant wells completed in the Talbert aquifer would draw large volumes of water from the Orange County Groundwater Basin, which in itself is considered a fatal flaw. Recent public comments have suggested that pumping seawards of the Talbert Salinity Barrier could have beneficial impacts in managing seawater intrusion. In the Panel's opinion, however, this benefit is too uncertain to overcome the ISTAP conclusion about the fatal flaw of this technology as applied to the proposed Huntington Beach site. The advantage of having a subsea completion is largely lost in confined aquifers. The performance risk is considered medium, as the dual-rotary drilling method used to construct the wells is a long-established technology, but there is very little data on the long-term reliability of the wells. Maintainability is also a critical unknown issue.

5.2.6 Engineered seafloor infiltration galleries (SIGs)

The results of the investigations by Scott Jenkins (as presented to the Panel) and others indicate that an area with a stable seafloor is present off the Huntington Beach site that has a relatively low environmental sensitivity. Inasmuch as the overlying sand materials can be engineered to provide the target infiltration rate, and desired filtration performance and hydraulic retention time, construction of an engineered seafloor infiltration gallery is considered to be technically feasible. The limited precedence for this type of system (Fukuoka, Japan system) is favorable as far as systems maintaining their capacity over time. However, the experiences at

Fukuoka are not necessarily transferable to Huntington Beach. The key consideration for a seafloor infiltration gallery is construction complexity due to its construction offshore at depth. Maintenance would also be complex, but not a fatal flaw. An engineered seafloor infiltration gallery is thus considered to be technically feasible.

5.2.7 Surf zone infiltration galleries

A surf zone infiltration gallery has the dual advantages of (a) construction near shore and potential greater yields (per unit area) than a seafloor system due to a coarser grain size (and greater hydraulic conductivity) and (b) the self-cleaning nature of the beach. However, the construction complexity is high due to the high-energy breaking wave conditions in the surf zone. In order to provide a safe work environment above the waves for equipment and crews constructing the surf-zone infiltration gallery, all construction of the gallery would have to performed from the top of a pile supported steel access trestle (temporary bridge) that would be built over-the-top and elevated above the breaking waves.

The installation and advancement of such a trestle system is time-consuming and expensive in that all work must be performed in a series of activities rather than concurrently as performed in most normal marine construction operations. Work from the top of the trestle would include construction of the trestle, installation of steel sheetpiles, dredging, installation of the intake piping system, backfilling, extraction of sheetpiles, and finally removal of the trestle. These operations could involve local beach closure of approximately 1500 feet of beach at a time over a time period of approximately four to five years. In addition, the trestle and sheetpiles could not be easily removed to allow timely public use of beach areas during summer seasons. Such disruption to the environment and public use of extensive beach areas would create a very difficult condition for obtaining construction permits from state and Federal regulatory agencies within a reasonable and predictable time. Potential restrictions on the time of year in which construction would be allowed would extend the construction period beyond that feasible for the project. The combination of the above factors is considered to make a surf zone infiltration gallery construction very challenging at the Huntington Beach site.

The length of construction along the beach would also impact littoral sand movement, causing temporary local deposition and erosion as the gallery construction advances. However, this impact on construction could be minimized by advancing construction of the gallery in a down-coast or southward direction. A surf zone infiltration gallery would also be impacted by periodic beach renourishment activities. Construction of a surf zone infiltration gallery is considered to be technically feasible in that it is technically possible to construct such a system. However, great constructability challenges would be expected, which would impact the ability to meet project schedules and costs.

5.2.8 Horizontal directionally drilled (HDD) wells underneath the sea floor

Horizontal directionally drilled (HDD) wells can technically be installed at the Huntington Beach site, as the underlying technology is well established. The performance of the HDD systems will be suboptimal in granular materials (sands) as opposed to lithified strata (limestone) and thus a greater (undetermined) number of drains would be required. There is inadequate data on the long-term reliability and maintainability of the HDD wells/drains at this time. This subsurface intake design option is considered technically infeasible at the Huntington Beach site because of a high performance risk. There is too great uncertainty that a system could be constructed that would reliably provide the required water volume over the operational life of the desalination facility.

5.2.9 Water tunnel

A water tunnel constructed subsea would have the advantages of high water quality stability and minimal impacts to the beach area. Water tunnels have severe construction complexity as ground freezing may be required. Water tunnels are considered to be infeasible due to a high performance risk. There is an unacceptable degree of uncertainty in the performance of these systems, which cannot be practicably pilot-tested.

Table 5-1 Subsurface Intake Summary Matrix

	Subfactor	**Vertical wells completed above confining unit**	**Vertical wells completed below confining unit**	**Vertical wells completed above and below confining unit**	**Radial collector in shallow aquifer**	**Slant Wells completed in Talbert aquifer**	**Engineered seafloor infiltration gallery**	**Surf zone infiltration gallery**	**HDD wells in shallow aquifer**	**Water tunnel**
Hydrogeology										
	Impact on fresh water aquifers	Yes	Yes	Yes	No	Yes	No	No	No	No
	Potential Yield per installation (MGD)	0.72	2.2	3	5	12.9 MGD per 3-well cluster[3]	5 MGD/acre	10 MGD / acre	0.67 to 2.2 MGD/drain[1]	2,600 GD/ft[2]
Design Constraints										
	Units required for 127 MGD with 20% safety factor	212	70	51	31	12 (3-well clusters)	30.48 acres	15.24 acres	227 to 69 drains	9 miles
	Linear beachfront	4 miles	2 miles	1.4 miles	2 miles	1.3 miles		1.0 miles[4]	1.8 to 2.8 miles	
	Area	2.2 acres[5]	0.7 acres	0.5 acres	0.3 acres	1.4 acres[6]	30.48 acres	15.24 acres	2.4 acres[7]	0.5 acres
	Scalability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Complexity of construction	Low	Low	Low	Medium	Medium	High	High	Medium	Very High
	Performance risk - degree of uncertainty of outcome	Low	Low	Low	Medium	Medium	Medium	Medium	High	Unknown
	Reliability of intake system	High	High	High	Medium	Medium/unknown	Medium	Medium/ unknown	Unknown	High
	Frequency of maintenance	High	High	High	Medium	High	Medium/Unknown	Medium/ unknown	High	Low
	Complexity of maintenance	Low	Low	Low	Medium	Medium	High	Medium	High	High
	Material constraints	Non-metallic, sea water resistant. Duplex stainless steel pumps	Non-metallic, sea water resistant. Duplex stainless steel pumps	Non-metallic, sea water resistant. Duplex stainless steel pumps	Non-metallic, sea water resistant. Duplex stainless steel pumps	Non-metallic, sea water resistant. Duplex stainless steel pumps	HDPE/PVC	HDPE/PVC	Non-metallic, sea water resistant. Duplex stainless steel pumps	Pre-cast concrete/ss reinforcing. Laterals non-metallic
Oceanographic										
	Sensitivity to sea level rise	High	High	High	High	Medium	Low	Low	Low	Low
	Sensitivity to HB sedimentation rate	N/A	N/A	N/A	N/A	N/A	Low	Low	Low	Low
	Suitability of HB Bathymetry	N/A	N/A	N/A	N/A	High	High	High	High	High
	Suitability of bottom environmental conditions	N/A	N/A	N/A	N/A	N/A	High	High	N/A	N/A

Table 5-1 Subsurface Intake Summary Matrix (Continued)

	Subfactor	**Vertical wells completed above confining unit**	**Vertical wells completed below confining unit**	**Vertical wells completed above and below confining unit**	**Radial collector in shallow aquifer**	**Slant Wells completed in Talbert aquifer**	**Engineered seafloor infiltration gallery**	**Surf zone infiltration gallery**	**HDD wells in shallow aquifer**	**Water tunnel**
Geochemistry										
	Risk of adverse fluid mixing	Low	High	High	Low	High	Low	Low	Unknown	Low
	Risk of clogging	Low	Medium	High	Low	Medium	Low	Low	Medium	Low
	Risk of significant change in inorganic chemistry of water quality over the long term?	High	High	High	High	High	Low	Low	Medium	Low
Precedent in use		Worldwide. Largest systems use (e.g., Sur, Oman) use carbonate aquifers. Sand City - 0.3 MGD is largest in sand.	Numerous brackish RO well fields	No precedent	Ocean Beach, SF (Aquarium)	One test well (Dana Point). None in operation	Monterey Aquarium (small). Long Beach (small test).	Small scale systems	Eight systems installed mostly in Spain	Alicante, Spain
Precedent on large scale in similar geological conditions		Jeddah, Saudi Arabia; 5 MGD from 10 wells	No precedent	No precedent	Pemex system in Mexico, 3 collectors with total capacity of 12 Mgd	No precedent	Fukuoka, Japan. 27 MGD intake capacity	No precedent	Alicante, Spain; designed for 34 MGD, operating at 17 MGD	Alicante, Spain, 17 MGD
Key considerations / fatal flaw(s)		Performance risk: inadequate aquifer capacity and great drawdowns. Low yields would require extremely high number of wells, major water quality risk	Complications with seawater intrusion management and production from Orange Groundwater Basin	Complications with seawater intrusion management and production from Orange Groundwater Basin	High performance risk due to inappropriate geologic conditions	Complications with seawater intrusion management and production from Orange Groundwater Basin; geochemical impacts	Construction complexity	Construction complexity in high energy environment, potential restrictions on allowable construction times/beach closure, impacts of beach renourishment	Performance risk concerns over granular materials and maintenance of well performance	Complex construction involving ground freezing. High performance risk - no precedence for project scale. Cost likely prohibitive
Technically Feasible? Y or N		**N**	**N**	**N**	**N**	**N**	**Y**	**Y**	**N**	**N**

Table 5-1 Notes:

[1] 2.7 MGD average rage per drain for Alicante, Spain system, corrected for lower hydraulic conductivity at Huntington Beach
[2] Average rate for Alicante, Spain system
[3] Based on Dana Point test slant well
[4] Based on 150 ft. width by 300 ft. length cells and 30 ft. separation
[5] Assumed 250 ft. 2 per well; does not include construction easement
[6] Assumed 100 ft. by 50 ft. easement plus pipe line easement; does not include construction easement
[7] Assumed 300 ft. by 50 ft. easement plus pipe line easement; does not include construction easement, and seven clusters

The judgments included in this Table are in response to the hydrogeologic and oceanographic conditions specific to the proposed HB AES site and proximate areas. The technical infeasibility of a particular intake technology at this location should not be generalized to feasibility considerations of any intake type in different settings or locations.

Chapter VI. Summary, Conclusions, and Recommendations for Phase 2

The ISTAP evaluated nine types of subsurface intakes for technical feasibility at the Huntington Beach site. The subsurface feasibility options included: (1) vertical wells completed in the shallow aquifer above the Talbert aquifer, (2) vertical deep wells completed within the Talbert aquifer, (3) vertical wells open to both the shallow and Talbert aquifer, (4) radial collector wells tapping the shallow aquifer, (5) slant wells tapping the Talbert aquifer, (6) seabed infiltration gallery (SIG), (7) beach gallery (surf zone infiltration gallery), (8) horizontal directional drilled wells, and (9) a water tunnel.

The hydraulic design capacity for these subsurface intake types ranged from 127 MGD for the combined requirement of the proposed SWRO plant and RO concentrate discharge dilution, and 100 MGD, if the concentrate discharge dilution was unneeded (diffuser system used to reduce environmental impacts from the concentrate discharge).

The ISTAP used a standard definition of technical feasibility as defined in the California Coastal Act and carefully evaluated fatal flaws of each subsurface intake type considered for application at the proposed Huntington Beach site. Only the seabed infiltration gallery and the beach gallery survived the fatal flaw analysis and both are deemed to be technically feasible at this site. The design of both types of galleries is well understood, but construction challenges would be expected for both due to their subsea/subtidal construction. The surf zone (beach) gallery, in particular, was judged to have some potentially difficult constructability challenges (and thus a lesser degree of technical feasibility) related to construction in the high-energy surf zone. The ISTAP does not consider the existing scale of use of any particular subsurface intake compared to the capacity requirement at Huntington Beach to be a fatal flaw for technical feasibility (e.g. the only existing seabed infiltration gallery has an hydraulic capacity of 27 MGD versus the 100 MGD proposed at the Huntington Beach site, and no large scale implementation of the beach gallery has been constructed and operated to date).

It is the collective opinion of the ISTAP that each of the other seven subsurface intake options for the desired hydraulic capacity range (100-127 MGD) had at least one technical fatal flaw that eliminated it from further technical consideration. The shallow vertical wells would create unacceptable water level drawdowns landward of the shoreline and could impact wetlands and cause movement of potential contaminants seaward. The deep vertical wells would have a significant impact on the Talbert aquifer that would interfere with the management of the salinity barrier and the management of the interior freshwater basin. The combined shallow and deep-water wells would adversely impact both the shallow aquifer and Talbert aquifer, and in addition, would produce waters with differing inorganic chemistry, which would adversely affect SWRO plant operation. Radial collector wells constructed into the shallow aquifer would have to be located very close to the surf zone which would make them susceptible to damage during storms and would be impacted by the projected sea level rise. Slant wells tapping the Talbert aquifer would interfere with the management of the salinity barrier and the management of the freshwater basin, and further, would likely have geochemical issues with the water produced from the aquifer (e.g., oxidation states of mixing waters). The recently-collected offshore hydraulic conductively data shows that the use of HDD wells is technically questionable and the largest capacity system in Spain is currently not operating at its original design capacity. The water tunnel constructed in the unlithified sediment at Huntington Beach would have overwhelming constructability issues.

The ISTAP recommends in Phase 2, further consideration be given solely to seabed infiltration galleries (SIG) and beach gallery intake systems. For clarification, the ISTAP believes that the remaining subsurface intake system deemed to be technically feasible could meet the seawater extraction goals of either 100 or 127 MGD.

It is important to stress that the ISTAP interpreted its Phase 1 charge relative to the Terms of Reference to be the evaluation of the technical feasibility of subsurface intake technology linked to a proposal. Consistent with that approach, the Phase 1 Panel considered nine technologies keyed to a potential project in the range 100 to 127 mgd. The Panel did address the broad issue of downward scalability where they saw relevance, but did not consider a full or parsed range of scale options for any of the nine technologies as this task exceeded the agreed upon scope defined in the TOR. Scalability issues could be addressed in subsequent assessments of other feasibility factors at the mutual agreement of the conveners.

Further, it was not the charge of the Phase 1 ISTAP to evaluate the economic considerations of using a subsurface intake versus a conventional open-ocean intake in this phase. The ISTAP recommends that the Phase 2 Panel give considerable analysis to the constructability of the seabed infiltration and beach gallery intake systems, because this greatly affects the economic viability of their potential use. However, the ISTAP recommends that in the Phase 2 evaluation of the subsurface intake options that a detailed lifecycle cost analysis should be provided to the succeeding committee. This lifecycle cost analysis should contain at least four scenarios, including: (1) the lifecycle cost using the appropriate operating period duration obtaining the 127 MGD of feed water from a conventional open-ocean intake without considering the cost of potential environmental impacts of impingement and entrainment, (2) the lifecycle cost using the appropriate duration of an operating period obtaining the 127 MGD of feed water from a conventional open-ocean intake and considering the cost of potential environmental impacts of impingement and entrainment, (3) the lifecycle cost using the appropriate duration of an operating period obtaining the 127 MGD of feed water from a seabed gallery intake system (or beach gallery intake system) using the same pretreatment design as used in treating open-ocean seawater, and (4) the lifecycle cost using the appropriate duration of an operating period obtaining the 127 MGD of feed water from a seabed gallery intake system (or beach gallery intake system) using a reduced degree of pretreatment, such as mixed media filtration followed by cartridge filters.

In each of these scenarios, the ISTAP recommends that the selected design hydraulic capacity match both the minimum and maximum flow rates consistent with the desired production rate of a 50 MGD desalination facility using the SWRO technology. The definition of an “appropriate” operating period should follow accepted industry standards for such lifecycle cost analyses. Typically, a period of 30 years is used, but given concerns on the potential for sea level rise impacts, analysis over a longer operating period (e.g. 50 years) may be desirable. In addition, the ISTAP questions the need for the use of seawater to dilute the concentrate discharge given the well-known use of diffuser outfalls to meet ocean discharge requirements.

The ISTAP also recommends that "Technical Feasibility" should continue to be defined by generally recognized factors as documented in the California Coastal Act of 1976. *(Section 30108 of the California Public Resources Code)*

Chapter VII. Bibliography – Reports on Subsurface Intakes

7.1 Peer-reviewed publications, selected peer-reviewed conference papers, and books

Allen, J. B., Tseng, T. J., Cheng, R. C., Wattier, K. I. (2008). Pilot and demonstration-scale research evaluation of under-ocean floor seawater intake and discharge. Proceedings of the American Water Works Association Water Quality Technology Conference, Nov. 16-20, 2008, Cincinnati, Ohio.

Al-Mashharawi, S., Dehwah, A. H. A., Bandar, K. B., Missimer, T. M. (2014) Feasibility of using a subsurface intake for SWRO facility south of Jeddah, Saudi Arabia. *Desalination and Water Treatment*, Doi: 1080/19443994.2014.939870.

Amy, G., Carlson, K., Collins, M. R., Drewes, J., Gruenheid, M., and Jekel, M. (2006). Integrated comparison of biofiltration in engineered versus natural systems. In: R. Gimbel, N. J. D. Graham, and M. R. Collins (eds.), *Recent progress in slow sand filtration and alternative biofiltration processes.* London, IWA Publishing, p. 3-11.

Barrett, J. M., Bryck, J., Collins, M. R., Jamois, B. A., Logsdon, G. S. (1991). *Manual of design for slow sand filtration*. American Water Works Association Research Foundation and American Water Works Association, Denver, Colorado.

Bartak, R., Grischek, T., Ghodeif, K., Ray, C. (2012). *Beach sand filtration as pre-treatment for RO desalination*. *International Journal of Water Science* 1(2), 1-10.

Berman, T. (2010). Biofouling: TEP-a major challenge for water separation. *Filtration & Separation* 47(2), 20-22.

Berman, T., Mizrahi, R., Dosoretz, C. G. (2011). Transparent exopolymer particles (TEP): A critical factor in aquatic biofilm initiation and fouling on filtration membranes. *Desalination* 276, 184-190.

Choules, P., Schotter, J.-C., Leparc, J., Gai, K., Lafon, D. (2007). Operation experience from seawater reverse osmosis plants. Proceedings, American Membrane Technology Conference and Exposition, Las Vegas, Nevada, 2007.

Crittenden, J. C., Trussell, R. R., Hand, D. W., Howe, K. J., G. Tchobanoglous, G. (2005) *Water Treatment: Principles and Design*. Hoboken, NJ, John Wiley & Sons.

David, B., Pinot, J.-P., Morrillon, M. (2009).Beach wells for large scale reverse osmosis plants: The Sur case study. Proceedings of the International Desalination Association World Congress on Desalination and Water Reuse, Atlantis, The Palm, Dubai, UAE, November 7-12, 2009, IDAW/DB09-106.

Dehwah, A. H. A., Li, S., Al-Mashharawi, S., Winters, H., Missimer, T. M. (2014). Influence of beach well and deep ocean intakes on TEP and organic carbon reduction in SWRO systems, Jeddah, Saudi Arabia. Journal of the American Water Works Association (in press).

Dehwah, A. H. A., Missimer, T. M. (2013) Technical feasibility of using gallery intakes for seawater RO facilities, northern Red Sea coast of Saudi Arabia: The king Abdullah Economic City site. *Desalination and Water Treatment* 51 (34-36), 6472-6481, Doi: 10.1080/19443994.2013.770949.

Hamano, T., Tsuge, H., Goto, T. (2006). Innovations perform well in first year of operation. *Desalination and Water Treatment* 16(1), 31-37.

Hendricks, D.W. (ed.) (1991). *Manual of design for slow sand filtration*. AWWA Research Foundation and American Water Works Association, Denver, 247 pp.

Hendricks, D.W. (2011). *Fundamentals of water treatment unit processes: Physical, chemical, and biological.* Boca Raton, CRC Press, 883 pp.

Huisman, L., and Wood, W.E. (1974) *Slow sand filtration*. World Health Organization, Geneva, 122 p.

Laparc, J., Schotter, J.-C., Rapenne, S., Croue, J. P., Lebaron, P., Lafon, D., Gaid, K. (2007). Use of advanced analytical tools for monitoring performance of seawater pretreatment processes. Proceedings of the International Desalination Association World Congress on Desalination and Water Reuse, Maspalomas, Gran Canaria, Spain, October 21-26, 2007, IDAWC/MP07-124.

Lujan, L. R., Missimer, T. M. (2014) Technical feasibility of a seabed gallery system for SWRO facilities at Shoaiba, Saudi Arabia and regions with similar geology. *Desalination and Water Treatment*, Doi: 10.1080/19443994.2014.909630.

Maliva, R. G., Missimer, T. M. (2010). Self-cleaning beach gallery design for seawater desalination plants. *Desalination and Water Treatment* 13(1-3), 88-95.

Mantilla, D., Missimer, T. M. (2014). Seabed gallery intake technical feasibility for SWRO facilities at Shuqaiq, Saudi Arabia and other global locations with similar coastal characteristics. *Journal of Applied Water Engineering and Research*, http://dx.doi.org/10.1080/2349676.2014.895686.

Missimer, T. M. (1994). *Water supply development for membrane water treatment facilities*, 1st edition. Lewis Publishers, Boca Raton, Florida.

Missimer, T. M. (2009). *Water supply development, aquifer storage, and concentrate disposal for membrane water treatment facilities*, 2nd edition. Methods in Water Resources Evaluation Series No. 1. Schlumberger Water Services, Sugar Land, Texas.

Missimer, T. M., Ghaffour, N., Dehwah, A. H. A., Rachman, R., Maliva, R. G., Amy, G. (2013) Subsurface intakes for seawater reverse osmosis facilities: Capacity limitation, water quality improvement, and economics. *Desalination* 322, 37-51, Doi: 10.1016/j.desal.2013.04.021.

Missimer, T. M., Horvath, L. E. (1991). Alternative designs to replace conventional water-water intakes for membrane treatment facilities. Proceedings of the International Desalination Association World Congress on Desalination and Water Reuse, 131-140.

Missimer, T. M., Maliva, R. G., Thompson, M., Manahan, W. S., Goodboy, K. P. (2010). Reduction of seawater reverse osmosis treatment costs by improvement of raw water quality, Innovative intake design. Desalination & Water Reuse 20(3), 12-22.

Missimer, T. M., Winters, H. (2003). Reduction of biofouling at a seawater RO plant in the Cayman Islands. Proceedings of the International Desalination Association World Congress on Desalination and Water Reuse, Paper BAH03-190.

Niizato, H., Inui, M., Kira, N., Inoue, T., Oiwa, T., Cai, H., Yanagimoto, Y., Nishimura, T. (2013). Innovative SWRO desalination technology introducing high-speed seabed infiltration system (HiSIS). Proceedings of the International Desalination Association World Congress on Desalination and Water Reuse, October 20-25, Tianjin, China, Paper IDAWC/TIAN13-033.

Pankratz, T. (2006). Seawater desalination technology overview. Presentation to the Georgia Joint Comprehensive Desalination Study Committee, August 22-23, 2006, St. Simons Island, Georgia.

Passow, U. (2000). Formation of transparent exopolymer particles, TEP, from dissolved precursor material. *Marine Ecology Progress Series* 192, 1-11.

Passow, U., Alldredge, A. L. (1994). Distribution, size and bacterial-colonization of transparent exopolymer particles (TEP) in the ocean. *Marine Ecology Progress Series* 113(1-2), 185-198.

Rachman, R. M., Li, S., Missimer, T. M. (2014) SWRO feed water quality improvement using subsurface intakes in Oman, Spain, Turks and Caicos Islands, and Saudi Arabia. Desalination, http://dx.doi.org/10.1016/j.desal.2014.07.032.

Schwartz, J. (2000). Beach well intakes for small seawater reverse osmosis plants. Middle East Desalination Research Center Project 97-BS-015, August.

Schwartz, J. (2003). Beach well intakes improve feed-water quality. *Water & Wastewater International* 18(8).

Sesler, K., and Missimer, T. M. (2012) Technical feasibility of using seabed galleries for seawater RO intakes and pretreatment: Om Al Misk Island, Red Sea, Saudi Arabia. IDA Journal: *Desalination and Water Reuse* 4(4), 42-48.

Shimokawa, A. (2012). Fukuoka District desalination system with some unique methods. Proceedings of the International Desalination Workshop on Intakes and Outfalls. National Centre of Excellence in Desalination, May 16-17, 2012, Adelaide, Australia.

Vesa, M. J., Ortiz, M., Sadhwani, J. J., Gonzalez, J. E., Sanatana, F. J. (2008). Measurement of biofouling in seawater: some practical tests. *Desalination* 220, 326-334.

Voutchkov, N. (2005). SWRO desalination process: on the beach-seawater intakes, Filtration & Separation 42(8), 24-27.

Voutchkov, N., 2005, Thorough study is key to large beach-well intakes: Desalination & Water Research, v. 14, no. 1, p. 16-20.

Wang, S., Leung, E., Cheng, R., Tseng, T., Vuong, D., Carlson, D., Henson, J., Veerapaneni, S. (2007). Under sea floor intake and discharge systems. Proceedings of the International Desalination Association World Congress on Desalination and Water Reuse, Maspalomas, Gran Canaria, Spain, October 21-26, 2007, Paper IDAWC/MP07-104.

Wang, S., Allen, J., Tseng, T., Cheng, R., Carlson, D., Henson, J. (2009). Design and performance update of LBWD's under ocean floor intake and discharge system. Proceedings of the Alden Desalination Intake/Outfall Workshop, October 16, 2009, Holden, Massachusetts.

Williams, D. E. (2008). Research and development for horizontal/angle well technology, U.S Department of the Interior, Bureau of Reclamation, Desalination and Water Purification Research and Development Program Report No. 151.

Williams, D. E. (2012). Multiple advantages of slant wells for ocean desalination feedwater supply, Abstracts and Program of the National Ground Water Association Summit.

Williams, D. E. (2014). Subsurface intakes-latest developments in slant well technology. Proceedings of the AWWA/AMTA Membrane Technology Conference, Las Vegas, Nevada, March 10-13, 2014.

Williams, D. E., and Kyle, R. J., 2011, Utilization of subsurface slant and vertical intake systems for desalination feed water supplies: Proceedings of the American Membrane Technology Association Conference on Desalination and Exposition, Miami Beach, FL, 10 p.

Wright, R. R. Missimer, T. M. (1997). Alternative intakes for seawater membrane water treatment plants. Proceedings of the International Desalination Association World Congress on Desalination and Water Reuse, Madrid, Spain.

7.2 Conference papers, reports and support documents

Feeney, M.B., 2009, Sand City Desalination Facility - Feedwater Wells Construction – Summary of Operations Report. Consultant's report prepared for City of Sand City.

Fugro West, Inc., 1996. Summary of Operations Construction and testing of Seawater Intake Well and Brine Injection Well prepared for marina Coast Water District.

Geoscience, Inc. 2012, Aquifer Pumping Test Analysis and Evaluation of Specific Capacity and Well Efficiency Relationships SL-1 Test Slant Well Doheny Beach, Dana Point, California Prepared for: Municipal Water District of Orange County September 7, 2012.

Geosyntec Consultants, 2013. Feasibility assessment of shoreline subsurface collectors: Huntington Beach seawater desalination project, Huntington Beach, California. Consultant's report prepared for Poseidon Resources.

Malfeito, J., and Jimenez, A., 2007, Horizontal drains intakes for seawater desalination-Experience of Cartagena: Proceedings of the American Membrane Technology Association Conference on Desalination and Exposition, Las Vegas, Nevada, 4 p.

MBC Applied Environmental Sciences, 2009, Huntington Beach Generating Station Environmental study (exact report title unknown), Chapter 3 – Sediment characteristics: Consultants report to the Huntington Beach Generating Station, 40 p.

Missimer, T. M., 1997, Technical evaluation of Ranney collectors for raw water supply to seawater reverse osmosis treatment facilities: Proceedings, International Desalination Association World Conference on Desalination and Water Reuse, Madrid, Spain, v. 1, p. 439-454.

Missimer, T. M., Manahan, W. S., and Maliva, R. G., 2010, Technical and economic analysis of intake options for the proposed 70 L/s Tia Maria seawater RP treatment facility in southern Peru: Proceedings of the American Membrane Technology Association Conference and Exposition, San Diego, CA, 10 p.

PSOMAS, 2011, Technical memorandum on feasibility of vertical extraction wells for Poseidon desalination plant feed water supply: Consultants report to Poseidon Resources Corporation, 29 p., and appendices.

San Diego Regional Water Quality Board, 2007, Environmental evaluation of the Carlsbad desalination facility, Chapter 4. Technology, 27 p.

Staal, Gardner, and Dunne, 1992. Feasibility Study Saline Ground Water Intake System, Monterey Sand Company Site, Marina, California, California prepared for the Monterey Peninsula Water Management District.

Taylor, J. M. C., and Headland, 2005, Analysis and design of infiltration seawater intakes: Proceedings, American Society of Civil Engineers World Water Congress, Impacts of Global Climate Change. World Water and Environmental Resources, May 15-19, Anchorage, Alaska, 12 p.

Tenera Environmental, 2006, Offshore survey at Huntington Beach generating station intake and discharge structures: Consultants report prepared for the AES Huntington Beach Generating Station, 16 p.

U.S. Department of the Interior Bureau of Reclamation, 2009, Desalination and Water Purification Research and Development Program Report No. 152, Results of Drilling, Construction, Development, and Testing of Dana Point Ocean Desalination Project Test Slant Well, January 2009 , Prepared by Geoscience, Inc.

7.3 Posted literature

California Coastal Commission (2004). Seawater Desalination and the California Coastal Act (2004) – in particular, Chapter 2.2.1 (on feasibility) and Chapter 5.5.1 (on intakes): http:www.coastal.ca.gov/energy/14a-3-2004-desalination.pdf.

Edwards, B.D., Ehman, K. D., Ponti, D. J., Reichard, E. G., Tinsley, J. C., Rosenbauer, R. J., Land, R. (2009). Stratigraphic controls on saltwater intrusion in the Dominguez Gap area of coastal Los

Angeles. In: Lee, H.J., W.R. Normark (eds.), Earth Science in the Urban Ocean: The Southern California Continental Borderland. Geological Society of America Special Paper 454, p. 375-395.

Herndon, R. 1992. Hydrogeology of Orange County Ground Water Basin – An Overview. In: Heath, E.G., Lewis, W. L. (eds.) (1992). The Regressive Pleistocene Shoreline – Southern California. South Coast Geological Society, Inc. Annual Field Trip Guide Book No. 20.

Missimer, T. M., Ghaffour, N., Dehwah, A. H. A., Rachman, R., Maliva, R. G., Amy, G. (2013) Subsurface intakes for seawater reverse osmosis facilities: Capacity limitation, water quality improvement, and economics. *Desalination* 322, 37-51, Doi: 10.1016/j.desal.2013.04.021.

Orange County Water District (OCWD) (2009). Groundwater Management Plan 2009 Update GWMP. July 2009.

Sommerfield, C.K., Lee, H. J., Normark, W. R. (2009). Postglacial sedimentary record of the Southern California continental shelf and slope, Point Conception to Dana Point. In: Lee, H.J., Normark, W. R. (eds.), Earth Science in the Urban Ocean: The Southern California Continental Borderland, Geological Society of America Special Paper 454, p. 89-115.

Water ReUse Association (2011). Assessing seawater intake systems for desalination plants, 2011.

Wong, F.I., Dartnell, P., Edwards, B. D., Phillips, E. L. (2012). Seafloor geology and benthic habitats, San Pedro Shelf, southern California. U.S. Geological Survey Data Series 552. http://pubs.usgs.gov/ds/552/

Chapter VIII. APPENDICES

8.1 APPENDIX A: Biographies of Panelists

Robert Bittner, P.E.

Mr. Robert Bittner is a professional engineer and President of Bittner-Shen Consulting Engineers, Inc., a firm specializing in the design of innovative marine structures including bridge foundations, marine terminals, offshore GBS structures, locks and dams. He has 40 years experience in construction engineering and project management on major marine structures worldwide, including the Itaipu Dam in Brazil and the Oresund Tunnel connecting Denmark and Sweden. One focus of his work has been minimizing construction cost of major marine structures through the design and development of innovative construction methods and equipment.

Prior to starting his own firm in 2009, Mr. Bittner was President of Ben C. Gerwick, Inc. While at Gerwick, he provided construction-consulting services worldwide and managed the design of several marine structures, including an innovative float-in dam on the Monongahela River in Pennsylvania for the US Army Corps of Engineers. Additionally, he led the Gerwick team that developed a new float-in cofferdam system that has been successfully used on the foundations for the New Carquinez Straits Bridge in the San Francisco Bay Area, the New Bath-Woolwich Bridge in Maine, the new Port Mann Bridge in Canada, and three major bridges in Asia. Mr. Bittner was Chairman of the Marine Foundations Committee for the Deep Foundations Institute (DFI) for 6 years from 2003 to 2008, and is currently President of DFI.

Mr. Bittner holds a B.S. in Civil Engineering and an M.S. in Construction Management, both from Stanford University.

Martin Feeney, PG CEG CHg

Martin Feeney is an independent consultant providing hydrogeologic support services to municipalities, water agencies and water utility companies. Mr. Feeney is a California Professional Geologist with specialty certifications in engineering geology (CEG) and hydrogeology (CHg) and has more than 30 years experience in groundwater consulting. Mr. Feeney was a founding Principal of Staal, Gardner and Dunne, Inc. (later becoming Fugro West, Inc.) and managed this firm's Monterey County office for nine years. He was later was a member of the firm, Balance Hydrologics, Inc. Mr. Feeney's experience in groundwater supply issues includes basin analysis, well siting and design, groundwater modeling (both flow and solute-transport), perennial yield analysis, water quality assessments, and regulatory compliance.

During his career, Mr. Feeney has designed and managed the construction of over 120 municipal wells with depths to 2,500 feet, diameters to 24-inches and discharge rates of up to 6,000 gpm. He has significant experience in drilling and well construction technology as well of the assessment and rehabilitation of existing wells. Mr. Feeney also has significant experience in groundwater issues associated with desalination facilities. He has worked in the Caribbean on numerous subsurface feedwater supply systems and was instrumental in the development of the feedwater and reject disposal systems utilized in the desalination facilities in Marina and Sand City, CA. Mr. Feeney has been involved in the evaluation of subsurface feedwater supply feasibility on beaches of Ventura, Monterey and San Diego Counties. These evaluations include alternative subsurface feedwater supply approaches including vertical wells, Ranney Collectors, horizontal wells and slant wells.

Mr. Feeney has participated in several peer review advisory panels. Currently, he is a member of the so-called "Hydrogeologic Working Group" evaluating the feasibility and potential water rights impacts of the installation of a 24 MGD capacity slant well array on the edge of Monterey Bay to support a regional desalination facility. Mr. Feeney is also currently is a member of the DPH-mandated Independent Advisory Panel for the Monterey Regional Water Quality Control Agency's Groundwater Replenishment project utilizing highly treated wastewater for groundwater recharge. He has previously served on advisory panels focusing on the overdraft issues in the Salinas and Pajaro Valleys, the sewer system in Los Osos and groundwater management plan development in the Carpenteria Basin. He has a BS in geology (UCSC) and a MA in Environmental Planning -Groundwater Emphasis (UCD, CSUN).

Michael C. Kavanaugh PhD, P.E., BCEE

Dr. Michael Kavanaugh is a professional engineer and Senior Principal with Geosyntec Consultants, Inc. He is a registered professional engineer in California, a Board Certified Environmental Engineer (BCEE), and an elected Fellow of the Water Environment Federation. Dr. Kavanaugh has over 40 years of consulting experience advising private and public sector clients on water quality, water and wastewater treatment, and groundwater restoration issues.

In addition to his consulting practice, Dr. Kavanaugh has broad experience in science advising for policy. He completed several assignments with the National Research Council including chair of the Water Science and Technology Board and the Board on Radioactive Waste Management. He also chaired the NRC committee on alternatives for ground water cleanup (1994) and recently chaired a NRC study on the future of subsurface remediation efforts in the U.S. with a report released 2013. For the past ten years, he has been a regular contributor to the Princeton Groundwater professional courses offered in the U.S. and Brazil. Dr. Kavanaugh was elected into the National Academy of Engineering (NAE) in 1998.

He has a B.S. and M.S. degrees in Chemical Engineering from Stanford and the University of California, Berkeley, respectively and a PhD in Civil/Environmental Engineering from UC Berkeley.

Robert G. Maliva, Ph.D.

Dr. Robert Maliva is a hydrogeologist and is currently a Principal Hydrogeologist with Schlumberger Water Services USA, Inc. based in Fort Myers, Florida. Dr. Maliva specializes in alternative water supply projects including managed aquifer recharge, alternative intakes for desalination systems, and injection well systems used for the disposal of desalination concentrate and other liquid wastes. He has been a consulting hydrogeologist since 1992.

Dr. Maliva has managed or taken the technical lead on numerous water resources and hydrologic investigations including water supply investigations, wellfield designs, aquifer storage and recovery (ASR) projects, contamination assessments, and environmental site assessments. He has designed raw water supply wellfields for brackish water desalination systems, alternative intakes for seawater desalination systems, and injection well systems for concentrate disposal.

He is the senior author of two books, "*Aquifer Storage and Recovery and Managed Aquifer Recharge Using Wells: Planning, Hydrogeology, Design, and Operation"* (2010) and *"Arid Lands Water Evaluation and Management"* (2012), and has numerous peer-reviewed publications. Dr. Maliva has a Ph.D. from Harvard University and has held research positions in the Department of Earth Sciences at the University of Cambridge, England, and the Rosenstiel School of Marine and Atmospheric Science of the University of Miami, Florida. He also has an A.M. in Geology from Indiana University at Bloomington, Indiana and a B.S. in Geology from State University of New York at Binghamton, New York, USA.

Thomas M. Missimer, Ph.D.

Dr. Thomas Missimer is a hydrogeologist and president of Missimer Hydrological Services, Inc., a Florida-based consulting firm. He is licensed as a professional geologist in four states. Dr. Missimer is also a visiting professor of environmental science and engineering (specialty in hydrogeology) at the King Abdullah University of Science and Technology in Saudi Arabia and is currently a visiting professor at the U. A. Whitaker College of Engineering, Florida Gulf Coast University.

He has 41 years of experience as a hydrogeologist and has completed projects in groundwater development, water resources management, and the design and construction of various water projects. He has worked on a large number of artificial aquifer recharge projects used for storage and treatment of impaired waters (domestic wastewater and stormwater) and for seasonal and strategic storage of potable water (aquifer storage and recovery projects). He is the author of nine books and more than 350 technical papers of which about 80 are published in peer-reviewed journals.

Dr. Missimer has specialized in the design, permitting, and construction of intake systems for brackish-water and seawater reverse osmosis desalination systems. His book entitled "Water supply development, aquifer storage, and concentrate disposal for membrane water treatment systems" (Schlumberger, 2009) is a widely used reference in this field and has won two publishers awards in technical communication. His first wellfield project used to supply feed water for an RO system was completed in 1977, and he has worked on over 80 other systems worldwide. He and his students have completed and published 6 technical feasibility investigations over the last three years along the shorelines of the Red Sea and Arabian Gulf to assess the use of seabed gallery intake systems. In 1991, he won the best paper presentation award from the International Desalination Association for his paper on use of subsurface intake systems to supply large-capacity seawater desalination systems.

He has a BA in geology from Franklin & Marshall College, an MS in geology from Florida State University, and a PhD in marine geology and geophysics from the University of Miami.

Terms of Reference
for an Independent Scientific and Technical Advisory Panel (ISTAP) to Examine the Feasibility of Subsurface Intakes and Advise the California Coastal Commission on Poseidon Water's Proposed Huntington Beach Desalination Project
April 18, 2014

Headings Included Here
A. Background
B. Mission Statement and Purpose
C. Criteria to Guide the Panel's Assessment of Feasibility
D. Initial Work Program
E. Qualifications and Recruitment Criteria for Panel Members
F. Method of Panel Recruitment
G. Administrative Arrangements/Operating Procedures
H. Meeting Formats
I. Authorship Attribution, Distribution and Dissemination of the Panel's Report
J. Final Report as Part of Public Record
K. Statement of Concurrence

A. Background
As part of its review of a permit application from Poseidon Resources to construct and operate a desalination facility in Huntington Beach, the California Coastal Commission directed the applicant to undertake a more complete independent analysis of intake alternatives. Due to concerns over impacts on the coastal environment and marine ecosystems [Coastal Act Sections 30230 and 30231 in particular], the Commission recommended that Poseidon examine in more detail the feasibility of subsurface intakes.

In order to establish a review process that is responsive to the Commission's guidance and appropriately engages Poseidon, both parties have agreed to undertake an independent scientific review. To help implement this guidance, Poseidon has agreed to contract with CONCUR, Inc., a firm specializing in analysis and resolution of complex environmental issues and in structuring independent review processes. While the Commission is not contracting with CONCUR, the agency staff agrees on the choice of CONCUR as the facilitator and convener of this independent review.

This Terms of Reference document (TOR) sets the structure and operating procedures of the scientific review and sets the specific charge to the Panelists. The intention of this Terms of Reference is that, while Poseidon and the agency staff may have some divergent interests, they will collaborate and strive to reach agreement on these elements of the review process.[1]

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[1] In this TOR, Poseidon Resources (Surfside) LLC will be referred to simply as "Poseidon", the term "Commission" refers to the agency and its governing board, and the staff of the Coastal Commission will be referred to as "agency staff". The term "both parties" means Poseidon and agency staff.

CONCUR will convene a panel of scientific experts—the Independent Scientific and Technical Advisory Panel—to review the issues at hand and make recommendations to bolster the scientific underpinning of the permit application and review process.

Both parties agree that this "joint fact-finding process" is a credible and effective way to respond to the guidance provided by the Commission. The Panel will consider a defined set of questions, deliberate, and prepare reports that will be delivered to both parties. These reports will provide evidence for the Commission and agency staff to consider when staff prepares its recommendation to the Commission regarding the proposed project. The Panel's final reports will be part of the Commission's record for Poseidon's permit application.

B. Mission Statement and Purpose

The broad goal of the Independent Scientific and Technical Review Panel is to provide credible, legitimate and independent scientific advice and guidance to support permit review.

The Panel's specific and limited purpose is to investigate whether alternative intakes would be a feasible method to provide source water to Poseidon's proposed desalination facility. It will focus on the extant site at Huntington Beach, but may investigate alternate sites on the Orange County coast. If subsequent phases of work are initiated, the expectations are that the Panel will compare the relative degree of feasibility of alternative intakes as described below.

Poseidon will fund the Panel and CONCUR. To ensure the Panel's independence, it will be guided by CONCUR and will report directly to agency staff with input from but without alteration by Poseidon. To provide transparency, the public will be invited to participate in some Panel meetings (but not Panel work sessions) and to comment at intervals on the Panel's interim and final work products for each phase of work as may be undertaken.

C. Criteria to Guide the Panel's Assessment of Feasibility

Both parties will set forth criteria they find important to the consideration of "feasibility" as defined in the Coastal Act, which will be reviewed and considered by the Panel in determining the feasibility criteria to be used for each phase that is undertaken.

D. Initial Work Program

The scope of work may include one or more phases as set forth below.

After each phase, both parties will consider the results of the phase and advise on next steps.

Both parties agree that the intent of the review is to work through to a final product for each phase that is undertaken. Both parties commit to at least the first phase of work outlined. Both parties would need to concur to go beyond Phase 1 and involve the Panel in later phases. Both parties anticipate that the disciplines composing the Panel would need to be rethought between Phase 1 and Phase 2. The disciplinary composition of the Panel may be revised at each phase to provide the necessary expertise.

Both parties agree that multiple phases will be necessary to generate the information the Commission needs to proceed to a final decision.

The Phase 1 scope of work is as follows:

Phase 1: Technical Feasibility at Huntington Beach.[2] Investigate whether alternative subsurface intake designs would be technically feasible at the proposed site at Huntington Beach. This assessment of technical feasibility will include a characterization of the geophysical, hydrogeological and geochemical features of the site and will identify the expected size and hydrogeological effects of the range of subsurface intakes that could be accommodated on the site, including those that could provide source water for the proposed 50 mgd facility. For Phase 1, both parties agree that the working definition of technically feasible is: able to be built and operated using currently available methods. This phase will include gaining command of the project and context, clarification of the goals and scope of this phase, review of published literature, case reports, and on-site studies. The Panel would prepare a report at the end of this phase that describes technically feasible alternative intake designs at or near the site and may also be asked to prepare interim informal reports.

At the end of Phase 1, both parties would consider the Panel report and the makeup of the Panel needed for the next Phase. Based upon the discussions to develop the Phase 1 scope of work, both parties have developed the following scope of work for Phase 2, if both parties decide to initiate a second phase.

Phase 2: Additional Review of Components of Feasibility at Huntington Beach. Still focused on the Huntington Beach site, the Panel would characterize the technically feasible subsurface intakes identified in Phase 1 relative to a broader range of evaluation criteria, as recommended by the parties and determined by the Panel, such as size, scale, cost, energy use, and characteristics related to site requirements and environmental concerns consistent with the Coastal Act's definition of feasible, and as compared to the proposed open intake. The Panel would prepare a report at the end of this Phase and may also be asked to prepare interim informal reports.

Both parties will decide after Phase 2 whether to conclude the ISTAP or whether to conduct additional studies and review. For instance, if initial review indicates that constructing a subsurface intake at the Huntington Beach site may not be feasible, a potential third phase could consider other locations on the Orange County Coast that might offer superior conditions for construction of subsurface intakes. The Panel could perform a reconnaissance-level review to identify alternative sites that should be the subject of a more in-depth analysis by the Panel or others and studied concurrently or at a later date. This reconnaissance level review should be considered a coarse screening. A fourth phase may entail a more in-depth analysis of alternate sites and if the ISTAP is involved may require additional expertise.

E. Qualifications and Recruitment Criteria for Panel Members

In Phase 1, the Panel is expected to include disciplines that as a whole should provide coverage of all of the following areas:

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[2] The parties are aware that State Water Board staff is developing an amendment to the Ocean Plan that would address issues associated with desalinization facilities. The parties intend that the ISTAP process would be able to receive briefings on the progress and outputs of the SWRCB process (perhaps with State Board staff as technical advisors to this process).

- Subsurface intake design, construction, and/or operation
- Geophysical and/or hydrogeological study design and modeling
- Coastal processes and/or physical oceanography – hydrodynamics, sediment transport, sediment characterization, etc.
- Coastal engineering/construction methods/cost analysis
- Geophysical and/or hydrogeological characteristics of Orange County coastal areas
- Groundwater geochemistry

At each later phase both parties will work to define needed qualifications and disciplinary recruitment criteria. Other later phases of the Panel may include such disciplines as marine ecology or cost-benefit analysis.

Additional Recruitment Criteria

Panel members should possess demonstrated aptitude and capability in the following areas:

- Able to operate as an independent expert representing their professional discipline and experience in their participation in this ISTAP
- Experience providing scientific advice for developing public policy
- Ability to integrate multiple disciplinary perspectives
- Experience with highly contentious issues and high stakeholder interest
- Experience preparing reports for policy audiences
- Availability to work in a team setting
- Willingness to work with the expectation that the Panelists will author the report, accept attribution to the entire report, and sign the final report (Note: CONCUR will support the drafting and production of the report in all stages of work.)

Method of Panel Selection

Both parties, working with CONCUR, will jointly select the Panel. The credentials of potential members will be considered on their merits relative to the selection criteria listed above.

F. Technical Advisors

Individuals may also be considered for a potential Technical Advisor role. It is expected that a small number of Technical Advisors may be asked to make short presentations to contribute to the deliberations of the Panel and provide additional detail and context to support the Panel's work. It is understood that Technical Advisors are not expected to meet the Panelists' rigorous criteria for independence. Technical Advisors are not expected to participate in the entire duration of the Panel's work, but may be called in for specific topics. Technical Advisors will not participate in the internal Panel deliberations, nor will they be asked to co-author or co-sign the final Panel report.

G. Method of Panel Recruitment

Both parties will consider criteria for the recruitment of Panelists and will use their professional networks to identify and suggest potential candidates. CONCUR will also use its professional network and make suggestions for potential candidates. Together, all parties will form a pool of candidates, which the agency staff, Poseidon, and CONCUR will jointly review with the aim of reaching agreement on the full Panel.

H. Administrative Arrangements and Operating Procedures

Both parties agree to the following provisions to ensure proper administration of the independent Panel:

1. Poseidon will provide funds to CONCUR, Inc. in advance of convening the Panel in an amount outlined by the Scope of Work developed by the facilitator.

2. Panel members will be remunerated by CONCUR, with the panelist's client understood to be the ISTAP.

3. Poseidon and agency staff will work with the facilitator to draft and proceed jointly to agree to the Terms of Reference (TOR). By mutual agreement of all parties, supplemental Terms of Reference may be incorporated at a later time.

4. The Panel, once constituted, will be asked to verbally communicate with Poseidon or agency staff only with representatives of both parties participating via the facilitator *(or with cc's to CONCUR).* Questions or comments (including requests for additional information, data, or documents) should be stated in writing, with copies to both parties.

5. The Panel's work products are to reflect its independent scientific and technical judgment. Both agency staff and Poseidon will contribute information and review, but neither agency staff nor Poseidon will alter the work products, and there will be clear identification as to their independent status. Both parties will not alter work products, but will have opportunities to comment on draft work products, as will members of the public.

6. Questions will be posed to the Panel via a written program of work and supplementary memoranda. The Panel will respond with written statements, which may be supplemented with briefings.

7. CONCUR shall designate Principal Scott McCreary as the facilitator for directing the activities of the Panel and as the point of administrative contact. The Poseidon point of contact is Stan Williams. The Coastal Commission point of contact is Tom Luster.

8. The Panel's formal contacts with agencies, stakeholders and the public will be via procedures established through the Terms of Reference in consultation with Poseidon, agency staff, and CONCUR to strike a balance between the Panel's independence and ensuring fair and open access to the Panel and its work products.

I. Meeting Formats

Meetings of the Panel will be of three types:

- **Panel meetings** with structured opportunities for observers, representatives of agencies, and Technical Advisors (as described in F. above) to hear and make presentations and public comments.
- **Work sessions**, where the Panel may interact with invited Technical Advisors
- **In person or by-telephone work sessions** of the Panel.

CONCUR will prepare summaries of deliberations of all meetings. Summaries will be made available to the public. CONCUR will be the primary point of contact for handling press inquiries. Agency staff and Poseidon may consider the use of short, joint statements at intervals.

Panel members will need to review critical Commission and other documents so that their comments and recommendations are based on:

- The best possible understanding of the physical requirements of desalination, local land use conditions and limitations, marine ecosystems in the region of the proposed project;
- An understanding of the policy and administrative context of Commission deliberations;
- The timelines and targets for Commission permit review and related actions;
- The timelines and targets for Poseidon's corporate planning.

J. Authorship, Attribution, Distribution and Dissemination of the Panel's Report

The expectation is that Panel members will author, accept attribution, and sign the final report in its entirety. The Panel will submit the results of its review to Poseidon and agency staff simultaneously. If requested, the Panel may present the findings of its report in a Workshop format or briefing to the Commission.

K. Final Report Becomes Part of the Public Record

Upon its presentation, this Report becomes part of the public record.

L. Statement of Concurrence

We hereby concur and agree to this Terms of Reference document and funding requirements as described in this document.

Coastal Commission:
Chief Deputy Date: 4/30/2014
Tom Luster Date: 4/30/14

Poseidon Resources (Surfside) LLC:
Date: 4/18/2014
Date: 4/18/2014

Phase 2 Report: Feasibility of Subsurface Intake Designs for the Proposed Poseidon Water Desalination Facility at Huntington Beach, California

Authored by the Independent Scientific Technical Advisory Panel

Under the Auspices of the California Coastal Commission and Poseidon Resources (Surfside) LLC

Convened and Facilitated by CONCUR, Inc.

CONCUR
NEGOTIATING EFFECTIVE ENVIRONMENTAL AGREEMENTS

August 17, 2015

i. Table of Contents

The following documents can be found in the ISTAP Phase 2 Report: Supplementary Appendix:

APPENDIX D: Life Cycle Costs Associated with Different Project Scales
APPENDIX E: Data Related to OCWD Willingness to Pay
APPENDIX F: Sensitive Plants and Animals in the Huntington Beach Wetland Area

ii. List of Tables and Figures

iii. Conveners' Preface

This report evaluates whether subsurface intake designs would be a feasible method for Poseidon Water to obtain seawater for its proposed desalination facility in Huntington Beach, California. The report is a product of coastal development permit review, Coastal Commissioner recommendations, and a scientific and technical review conducted by an independent expert panel convened by Coastal Commission staff and Poseidon Water ("Conveners") with assistance and facilitation from CONCUR, Inc. The report will be used as part of the Commission's upcoming review of Poseidon's expected application for a coastal development permit to determine how and whether the proposed project will be consistent with policies of the Coastal Act and of the City of Huntington Beach Local Coastal Program.

The Conveners would first like to thank the Panelists for the diligence and critical thinking they exhibited during this review. We appreciate their willingness to take on this difficult, complex, and in some ways groundbreaking subject matter to produce a report that we hope will be understandable and useful to all the parties interested in this proposed project. We would also like to thank the entire CONCUR contingent for organizing, facilitating, shepherding, cajoling, and otherwise exhorting the Panelists and Conveners to continue moving forward through several tough issue areas during this process. CONCUR's expertise and experience has been an invaluable part of this review.

As described elsewhere in this report, the Conveners determined that the Panel's work would be done in one or more phases. In the first phase, the Panel was to determine whether any of several subsurface intake options were technically feasible at or near the proposed project site – that is, whether they could be built and operated given site conditions. At the end of Phase 1, the Conveners considered the report and agreed to initiate a second phase. The makeup of the Panel was modified to address the scope of work for Phase 2. Appendix C describes the background of the proposed project and the Panel process.

In Phase 2, the Panel would characterize the environmental, economic, and social feasibility of any options deemed technically feasible during Phase 1. The Conveners will decide after Phase 2 whether to conclude the ISTAP or whether to conduct additional studies and review.

For instance, if initial review found that there were no acceptable subsurface intake methods at or near the proposed site, the Conveners could either have the Panel move forward with Phase 3 to evaluate whether subsurface options would work at other sites or Poseidon could choose to submit an application based on the results of the Panel's completed work. We look forward to presenting this Phase 2 report to help determine the next steps in the process.

We expect that different parties, including the Conveners themselves, will have different interpretations of portions of this report and of the Panel's conclusions. We acknowledge that the Panel's work is an important component of the upcoming Coastal Commission review, but that it is just one of many aspects of the proposed project the Commission will be considering. The Panel's work is detailed and extremely useful in many ways, but is not meant to be a substitute for a full environmental or project review. We also emphasize that the Panel's analysis has been focused on this particular proposed project and this particular site, and the Panel's conclusions should not be applied to other projects or locations. That said, we expect that the Panel's work will not only be useful for evaluating Poseidon's proposed project, but that its approach be considered where necessary for other proposed water supply projects along the California coast.

iv. Signature Page

WE, THE UNDERSIGNED MEMBERS OF THE CCC-POSEIDON PROPOSED HUNTINGTON BEACH DESALINATION FACILITY INDEPENDENT SCIENTIFIC TECHNICAL ADVISORY PANEL, AUTHORED AND HEREBY CONFIRM OUR CONCURRENCE WITH THE FULL TEXT OF THIS PHASE 2 REPORT:

ROBERT BITTNER

JANET CLEMENTS

LARRY DALE

SUSAN LEE

THOMAS MISSIMER

MICHAEL KAVANAUGH

v. Executive Summary

a. Introduction

In April, 2014, Poseidon Resources, LLC ("Poseidon") and the California Coastal Commission ("CCC"), designated as the "Conveners", agreed to undertake an independent scientific review of the feasibility of subsurface seawater intake technologies, in the context of a potential permit application to construct and operate a desalination facility in Huntington Beach, California. The Conveners established Terms of Reference (TOR) for an Independent Scientific and Technical Advisory Panel (ISTAP or Panel) (see Appendix B) that defined the objectives and procedures for conduct of the scientific review. The process of coordinating ISTAP deliberations and technical report preparation has been managed by CONCUR, Inc. (CONCUR), a California firm specializing in facilitation and mediation processes to resolve complex technical disputes.

In Phase 1 of the review process, the primary objective of the Panel was to assess the technical feasibility of subsurface intake technologies that could potentially be applicable for the desalination facility proposed by Poseidon for the Huntington Beach site. The Phase 1 ISTAP reviewed the technical feasibility of nine subsurface intake technologies and concluded that two of the technologies, namely, a seafloor infiltration gallery (SIG) and beach infiltration galleries (BIG), met criteria established by the Phase 1Panel to define technical feasibility (See Report of Phase 1 ISTAP, http://www.coastal.ca.gov/pdf/ISTAP_Final_Phase1_Report_10-9-14.pdf).

Consistent with the TOR for the ISTAP, in December of 2014, the Conveners established a second panel (Phase 2 ISTAP) to assess the broader feasibility of the two technically feasible options for subsurface intake technologies, with the directive to consider economic, environmental and social factors consistent with the definition of "feasibility" considered applicable to the proposed project. To address these broader issues associated with a feasibility assessment, the composition of the second panel was expanded to include experts in natural resource economics and environmental and social science to complement experts in engineering, water quality and constructability issues associated with desalination plants and alternative intake systems.

b. Approach

Following selection of the members of the Phase 2 ISTAP, Concur organized a meeting with the Conveners and Panel members to review the Terms of Reference (TOR) for Phase 2, and to establish an approach for data collection needed to satisfy the scope of the feasibility evaluation as defined in the TOR for the two subsurface technologies considered technically feasible by the Phase 1 ISTAP. The Panel considered various definitions of "feasibility" as defined in the Coastal Act, in the California Environmental Quality Act, and in the recent State Water Resource Control Board (SWRCB) amendment to the California Ocean Plan. It was recognized, however, that the details of assessing the economic, environmental and social factors associated with a desalination facility on the California coast must be considered within the context of project and site-specific issues arising from the proposed project. The

Panel also considered the definition of economic feasibility regarding subsurface intakes as adopted in the May 6, 2015 amendment to the Ocean Plan, approved by the State Water Resources Control Board that states, "*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*."

The primary focus of the Phase 2 ISTAP is assessing the feasibility of the SIG. However, for purposes of assessing the economic feasibility of the SIG, it was necessary to assess the overall project cost for both intake options (open ocean or SIG), which includes the cost of all engineered components of a desalination facility. It should be noted that the Phase 2 ISTAP was not asked to assess the feasibility of the other components of the SWRO Plant including the pretreatment systems, the membrane system or the brine disposal system.

In meeting the TOR for the Phase 2 Panel, we conducted the following tasks, using either conference calls, in person meetings with or without the conveners, or electronic communications for information transfer:

- Reviewed the technical feasibility of the two subsurface options selected in Phase I of the ISTAP, and determined that the beach infiltration gallery would not be feasible.
- Determined key technical assumptions for the two construction methods for the seafloor infiltration gallery (SIG).
- Established the baseline hydraulic capacity (scale) for the Huntington Beach proposed desalination facility, and defined the range of scales to be evaluated in the economic assessment of project alternatives, namely, the relative costs of the proposed desalination facility, with and without a SIG at varying scales.
- Completed a technical assessment of the two SIG construction alternatives, and established assumptions needed for the environmental and economic analysis.
- Collected necessary data to assess the economic feasibility of the three intake alternatives (open ocean, SIG-Trestle, SIG-Float In).
- Assessed the environmental and social factors qualitatively and identified those factors that can be quantified with respect to mitigation requirements.
- Compiled and analyzed the capital, operations and maintenance (O&M) costs associated with each alterative, including mitigation costs for environmental impacts that can be quantified.
- Conducted a life cycle analysis for costs of each alternative and a sensitivity analysis to provide a justifiable range of life cycle unit costs (i.e. cost per acre foot of produced water).
- Analyzed the impact of varying the scale of the desalination facility on the life cycle costs
- Completed an assessment of the economic feasibility of each alternative by comparing a range of unit cost estimates (i.e. 2015 dollars/acre foot of produced water) with the range of water costs that a utility may be willing to pay given a reasonable estimate of the costs of alternative sources

and defining a "cost recovery year" in which the willingness to pay matches the likely average unit cost of water production.

- Prepared the final report of the Phase 2 process.

c. Site and Project Description

Poseidon's proposed location for the desalination facility, as described in their 2012 permit proposal to the CCC is approximately 2 miles south of the Huntington Beach Municipal Pier, and 1 mile north of the mouth of the Santa Ana River. The proposed location for the SIG is approximately 3400feet offshore (ISTAP, 2014) considered the optimum location based on studies conducted on behalf of Poseidon (Jenkins and Wasyl, 2014).

At this location, the seafloor is approximately 42 feet below Mean Sea Level (MSL), and the area is subject to almost continuous long-period ocean swells that prevent the efficient use of conventional marine floating equipment. As a result, we considered two construction techniques to address this specific problem. These are:

> ***SIG-Trestle:*** All construction would be performed off of a trestle elevated above the waves, and
>
> ***SIG-Float-In:*** All major SIG components would be prefabricated off-site and floating equipment would be used to transport and install modular units at the designated SIG location.

Poseidon proposed a facility with a product (or production) capacity of 50 million gallons per day (MGD) with water quality that would meet the requirements of a potential purchaser of the produced water. We assumed that the produced water would have a total dissolved solids (TDS) content of approximately 500 mg/L, which requires greater than 99 percent (%) removal of TDS (i.e., assuming seawater with a TDS of 35,000 mg/L) by the reverse osmosis (RO) process. Thus, a 50 MGD facility requires an intake capacity of approximately twice the product capacity. Poseidon proposed an intake capacity of 106 MGD, which is a reduction from the 127 MGD intake capacity in their original permit application to the California Coastal Commission (CCC) due to elimination of the brine dilution option for brine disposal. Under this scenario, we have assumed that brine disposal would be accomplished with a diffuser design that would meet the brine discharge requirements at the site, specified in the recent amendment to the California Ocean Plan, approved in May, 2015 by the SWRCB.

We were also asked to consider a range of product capacities in this feasibility assessment. We selected the following product capacities in addition to the 50 MGD product capacity option for consideration: namely, 12.5, 25, and 100 MGD product capacities. These capacities reflect our judgment as to the practical ranges of product capacity that would be reasonable to consider. As noted, the intake capacities for each of these options would be approximately twice the product capacity.

For the 50 MGD product capacity, equivalent to 106 MGD intake capacity, the areal requirement for construction of the SIG is determined by the design flow rate through the constructed sand layer over the extraction gallery piping. For a 5 MGD per acre flow rate, the SIG will require approximately 26 acres of areal extent with 30 cells, based on the presumed cell geometry. The proposed layout of the SIG and a cross-section illustrating the filtering layer is shown in Figure 3-2.

Other Engineering Assumptions: For each of the three alternatives, we assumed that the desalination process will consist of a seawater reverse osmosis (SWRO) membrane process with appropriate auxiliary equipment in the facility needed for membrane pretreatment, brine disposal, disposal of pretreatment residuals, and for other fluid management requirements. For the open ocean intake, standard pretreatment processes are expected, including coagulation/filtration to remove materials that can foul the RO membranes causing more frequent cleaning and increased costs of membrane replacement. For the SIG alternative, pretreatment requirements would be reduced due to some removal of naturally occurring fouling agents in the SIG filter layer. This eliminates the capital and O&M costs for the coagulation/filtration process. However, to maintain membrane effectiveness and hydraulic capacity, an ultrafiltration (UF) membrane pretreatment process will be required. The fraction of influent requiring operation of the UF process may vary depending on pretreatment effectiveness of the SIG filter layer and the resulting influent water quality. We have assumed a 60% bypass of the UF process for costing purposes.

d. Sources of Information

We utilized numerous information sources in assessing the environmental, social and economic factors determining the feasibility of the SIG. The engineering assumptions for the construction of the SIG using either the trestle or the float-in construction option originated from literature sources for SIG construction, professional judgment, and information provided by Poseidon to the Panel. Information needed to assess the environmental and social impacts of the alternative intake options was provided by Panel members and in discussions with Conveners. Where these factors could be monetized, we accepted mitigation cost estimates from both Conveners based on studies conducted by Poseidon, and CCC staff expertise.

Capital and financing costs for the open ocean and SIG alternatives were initially provided by Poseidon, and adjusted based on Panel experience or judgment. Operation and maintenance (O&M) costs for both the open ocean and SIG intakes were provided by Poseidon, but adjusted based on Panel experience with pretreatment systems for SWRO plants.

The expected accuracy of the capital cost estimates varied depending on the engineered components considered and categorized according to accepted industry standards for construction and life cycle cost estimates (See e.g., ASTM Standard E2516-11, Standard Classification for Cost Estimate Classification System, March 2015). For example, capital and O&M cost estimates for the SWRO plant were considered to be a Category II cost estimate with an accuracy range of +/- 10% to 25% based on the experience of Poseidon in construction of the Carlsbad Plant and on literature sources with cost data on SWRO plants worldwide. On the other hand, construction of the SIG, using either construction method, is considered a Category IV cost estimate with an accuracy range of -30%/+50% given that a SIG of this scale has never been constructed worldwide, nor in similar ocean environments. This range of cost estimates is consistent with industry practice for feasibility level assessments of project alternatives.

Thus, the capital and O&M costs for the two SIG alternatives have a greater range of cost uncertainty compared to the cost estimates for the open ocean intake option, given that the SIG cost estimates are a blend of Category II and Category IV components. The ocean open intake option, on the other hand, primarily incorporates Category II components, with sufficient worldwide and local experience to provide cost estimates with less uncertainty.

e. Environmental and Social Assessment

Among the three additional feasibility factors, other than technical feasibility, considered by the Panel, the environmental and social factors are the most difficult to quantify. Consideration of these two factors to evaluate the feasibility of specific subsurface intake options is driven by the Coastal Commission's concerns about the environmental impacts of the proposed open ocean intake on the coastal environment and marine ecosystems. However, both SIG options have additional environmental impacts, primarily due to construction activities, which must be considered in the feasibility determination. These impacts are not considered or evaluated in detail as they would be in an Environmental Impact Report (EIR), but they are considered here in an effort to determine how they might affect the feasibility of the SIG options with respect to these two factors. The costs associated with mitigation activities required to offset potential environmental and social impacts are included in the economic analysis described in Chapter V. However, these costs do not capture the full extent of potential and likely impacts. Certain environmental effects can be monetized and included in the life cycle cost analysis of the different intake alternatives. The effects are the following:

- Mitigation costs for effects on the marine ecosystem due to entrainment and impingement resulting from open ocean intake, including an initial cost for coastal land acquisition and/or restoration and ongoing annual maintenance costs for restored or acquired habitat; and
- Payments for loss of beach access or recreation opportunities by construction activities.

A range of environmental impacts would be generated, directly or indirectly, as a result of constructing and operating the different SIG construction options. The potential environmental impacts associated with the SIG options are summarized as follows:

<u>Onshore construction in Huntington Beach State Beach parking lot for pipe headers and pumps (Trestle and Float-in Option)</u>

- Construction noise, onshore traffic, air emissions, greenhouse gas emissions, degradation of coastal views, recreational disturbance, disturbance of sensitive biological resources, loss of revenue to State Beach due to loss of parking spaces, and potential loss of income related to beachfront business decline.

Onshore and nearshore construction to install the trestle (Trestle only)

- Air emissions, greenhouse gas emissions, degradation of coastal views, onshore traffic.

Offshore construction of the SIG (Trestle and Float-in Option)

- Air emissions, greenhouse gas emissions, commercial and recreational fishing obstruction, risk of offshore contamination from construction accidents, short-term loss of benthic habitat.

Use of construction yard at Port of LA/LB (Float-in only)

- Land use disruption and onshore traffic.

Disposal of dredged marine sediments at approved offshore site (Trestle and Float-in Option)

- Effects on marine ecology.

Operation and maintenance of SIG (Trestle and Float-in Option)

- Effects on marine ecology (long-term and construction-based), and seafloor obstructions.

Detailed descriptions of each of these impacts for the two SIG alternatives are included in Table 4.1.

The primary marine and coastal impacts that would likely result from construction and operation of the SIG options are summarized in Table 4.2. These impacts are characterized as to their likely severity in a qualitative manner. These impacts would be described and evaluated in detail in an EIR, or a subsequent CEQA or CEQA-equivalent document, if Poseidon proceeds with an application.

f. Economic Assessment

Section 5 provides the details of the economic assessment completed by the panel. Key steps in this process included:

- Characterizing the range of capital, operation and maintenance (O&M), and social and environmental mitigation costs used to characterize the economic and financial feasibility of the three intake options.
- Preparation of two cost estimates for each scenario representing a "high" end of the cost range, and a "low" end of the cost range. Various assumptions are incorporated into each of the high and low end estimates as described in the text.
- Development of a life cycle cost analysis of the design alternatives, and assessment of the impact of different financial assumptions on the life cycle costs for each alternative and both the high and low cost estimate. The lifecycle cost is presented as an annualized cost per acre-foot (AF) of water produced (unit cost), which allows the cost of water to be directly compared across design and financial scenarios.
- Evaluation of the price that Orange County Water District (OCWD) might be willing to pay for water supplied by the proposed desalination facility (the water price), using OCWD's Water

Purchase Agreement Term Sheet with Poseidon (i.e., Term Sheet) as a starting point and assessing the change of that price over time with appropriate escalation factors[1].

- Assessment of the likelihood that project revenues will cover project costs at a given point in time, defined as the cost recovery year[2]. We compared the unit cost (to Poseidon) of water supplied by the project with the amount that OCWD might pay for that water as identified in its current Term Sheet for an estimated cost recovery year.
- Determination of the range of costs that inform whether or not the SIG is likely to be economically viable applying the definition of economic feasibility included in the recent Desalination Amendment to the Ocean Plan, approved on May 6, 2015 by the SWRCB.

In addition, the Panel conducted sensitivity analyses to assess the impact of varying the product capacity (12.5, 25 and 100 MGD compared to the 50 MGD capacity), the lifetime of the project (30 years and 50 years), and different discount rates (3% and 7%) on the life cycle unit costs. The sensitivity analysis encompassed 96 different scenarios thus providing a comprehensive assessment of the relative impact of the various factors on the life cycle costs, which provides the basis for assessing the economic viability and thus, economic feasibility of the SIG.

g. Findings

Finding 1: The capital costs in 2015 dollars for the Ocean Open Intake range from a low of $852 million to a high of $899 million. O&M costs for this option range from $49 to $54 million per year.

We provide a range of capital and O&M costs as summarized in Table ES.1 which includes a high and low estimate for each cost category. This range reflects the modifications to cost data provided by Poseidon and modified as mentioned based on Panel expertise and experience.

Finding 2: The capital costs in 2015 dollars for the SIG range from a low of $1,936 million to a high of $2,347 million. O&M costs are the same for each SIG option and range from $42 to $58 million per year.

Table ES.1 summarizes the capital/financing and O&M costs for the two SIG options. The SIG Float-in option has a lower capital cost at the high end of the cost range compared to the SIG-Trestle option, but capital costs are similar for the low end of the cost range. Annual O&M costs for the SIG options are $4 to $7 million less than O&M costs for the open ocean intake option or a modest reduction of approximately 7 to15%.

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[1] We based the OCWD water price on the amount that OCWD will likely have to pay for water supplied by the Metropolitan Water District (MWD) of Southern California in the future (which OCWD would rely on in absence of the desalination facility). On top of this price, we have factored in a subsidy that MWD provides local communities for developing local water supplies, as well as a premium that OCWD has indicated it is willing to pay for the increased water supply reliability that the desalination plant will provide. Ultimately, the OCWD water price will be based on negotiations between OCWD and Poseidon.

[2] This analysis includes a range of life cycle costs based on two different discount rates.

Table ES.1 Comparison of Capital and Annual O&M Costs (In 2015 $ millions)

	Ocean Open Intake	SIG - Trestle	SIG - Float-in
Estimation Methodology	**Capital**		
ISTAP High Estimate	852	2,347	2,115
ISTAP Low Estimate	899	1,936	2,109
	O&M		
ISTAP High Estimate	54	58	58
ISTAP Low	49	42	42

Finding 3: Based on a life-cycle analysis, the unit costs for produced water for the 50 MGD product capacity option ranges from a minimum of $1,517 to a maximum of $4,995/AF, in 2015 dollars. The variation in unit costs is predominately dependent on the intake technology, rather than the discount rate (3% or 7%) or the project duration (30 or 50 years).

Table ES.2 provides a summary of unit costs for produced water from a 50 MGD product capacity desalination plant at the Huntington Beach site. The minimum and maximum unit costs represent the results of assessing the impact of two discount rates and two project durations on various cost factors. The average unit cost for the Ocean Open Intake is estimated to be $1914/AF, compared to average cost for the two SIG options of approximately $3,461/AF. The selection of a SIG intake technology, regardless of the construction method, increases the estimated unit cost for the 50 MGD product capacity by nearly 80%.

Table ES.2 Unit Cost Summary ($/acre foot)

(All factors combined)			
Range	**Ocean Open Intake**	**SIG - Trestle**	**SIG - Float-in**
Minimum	1,517	2,121	2,279
Maximum	2,259	4,995	4,601
Average	1,914	3,452	3,471
Percent Increase	NA	80	81

Note: Product Capacity of 50 MGD, 3% and 7% Discount Rates, 30 and 50 year project duration

Finding 4: Reducing the product scale of the desalination facility decreases capital and O&M costs, but the unit cost increases as the scale (or product capacity) decreases from 50 MGD to 12.5 MGD. Alternatively, increasing the product capacity to 100 MGD results in a net decrease in unit cost.

Table ES.3 presents the impact of varying the scale of the plant product capacity on the life cycle unit cost ($/AF, produced water) for the three alternatives. As anticipated, consistent with the literature on desalination costs, unit costs decrease as the plant product capacity increases, with a 14 to 20 % reduction in unit costs between the 12.5 MGD product capacity and the 100 MGD product capacity. The constructions costs of the SIG are reduced to some degree but not as a linear scale due to high mobilization costs regardless of scale. The scale effect on the unit cost as the product capacity is reduced has less of an impact on the overall unit cost that the choice of intake technology.

Table ES.3 Scale Impacts on Unit Costs ($/acre foot)

Scale (MGD-product)	**Ocean Open Intake**	**SIG - Trestle**	**SIG - Float-in**
12.5	1,694	2,497	2,646
25	1,650	2,282	2,410
50	1,517	2,121	2,279
100	1,466	2,011	2,156

Note: 50 year life, @ 3% discount rate

Finding 5: Unit costs decrease with increasing project duration (project life) and increase with higher discount rates.

The impacts of project duration and discount rates are summarized in Table ES.4. For all three alternatives, extending the project duration from 30 to 50 years decreases the unit costs for produced water. A higher discount rate increases unit costs due to the increased cost of project financing, a factor that usually represents more than 35 percent of total capital costs for large scale (>25 MGD product capacity projects). (NRC, Report on Desalination, 2008)

Table ES.4 Project Duration and Discount Rate Impacts on Unit Costs ($/acre foot)

Assumptions	**Capital**		
	Ocean Open Intake	**SIG - Trestle**	**SIG - Float-in**
30 yrs @3%	1,716	2,553	2,762
50 yrs @ 3%	1,517	2,121	2,279
30 yrs @ 7%	2,254	3,847	4,314
50 yrs @ 7%	2,115	3,533	3,953

h. Conclusions

Conclusion 1: The beach infiltration gallery is infeasible at the Huntington Beach location

At the initiation of Phase 2, we reconsidered the feasibility of the beach infiltration gallery technology that had been retained as likely feasible by the Phase 1 ISTAP. Several factors lead us to find that this technical option is infeasible at the Huntington Beach location. First, our additional engineering design assessment concluded that a substantially larger gallery would likely be required compared to the considerations in Phase 1. Second, we further considered the periodic beach re-nourishment schedule, which means that the surf zone migrates following nourishment cycles, reducing the effectiveness of the intake filtration through the sand. Third, construction of a larger-than-anticipated gallery would require many years to construct due to construction constraints on a highly used public beach.

Conclusion 2: Two construction methods are feasible for constructing the SIG

In addition to the trestle construction method suggested by Poseidon, the panel suggested consideration of a second, more efficient and less disruptive construction method for the SIG. This "float-in" construction method would not require construction of a trestle and would involve use of pre-fabricated cells brought to the offshore site from industrial port construction sites (Ports of Los Angeles or Long Beach).

Conclusion 3: The environmental impacts of the SIG options would not likely prohibit their implementation

The construction of either SIG option would create highly visible and disruptive activities at the Huntington Beach waterfront and in the nearshore environment. The Panel concludes that, while the environmental impacts of the SIG options, regardless of construction methods, would be potentially severe, they would still be short-term in comparison with the operational life of the desalination facility (30 to 50 years). Therefore, assuming implementation of commonly-used coastal mitigation techniques and serious consideration of methods to protect coastal recreation and tourism income, the environmental effects are not considered likely to result in either SIG option being found to be infeasible.

Conclusion 4: The open ocean intake option for a product capacity of 50 MGD may be economically feasible in the near future, depending on outcome of negotiations with OCWD

Based on our economic analysis, the facility with a product capacity of 50 MGD and an open ocean intake has an average unit cost of $1,639/AF using a 3% discount rate. Under the current term sheet, OCWD might be willing to pay these water costs in 2018 (Figure ES-1). The corresponding unit cost using a 7% discount rate is $2,189/AF. Our analysis indicates that OCWD would be willing to pay this amount for water in 2024. Therefore this option may be economically viable, consistent with the Ocean Amendment definition of economic feasibility.

Conclusion 5: The higher unit costs for the SIG options regardless of construction method significantly extend the period of time before the unit cost could be comparable to costs of other available water supplies

The average unit cost of the SIG-trestle intake option for the 50 MGD product capacity facility is $2661/AF using a 3% discount rate. The corresponding unit cost of a SIG-float intake option is $2665/AF. OCWD might not be willing to pay this water cost until 2042 assuming conditions included in the current term sheet (Figure ES-1). Using a 7% discount rate, the unit costs of the 50 MGD SIG trestle and SIG-float intake options are $4243/AF and $4277/AF, respectively. OCWD might be willing to pay these water costs beginning in 2059.

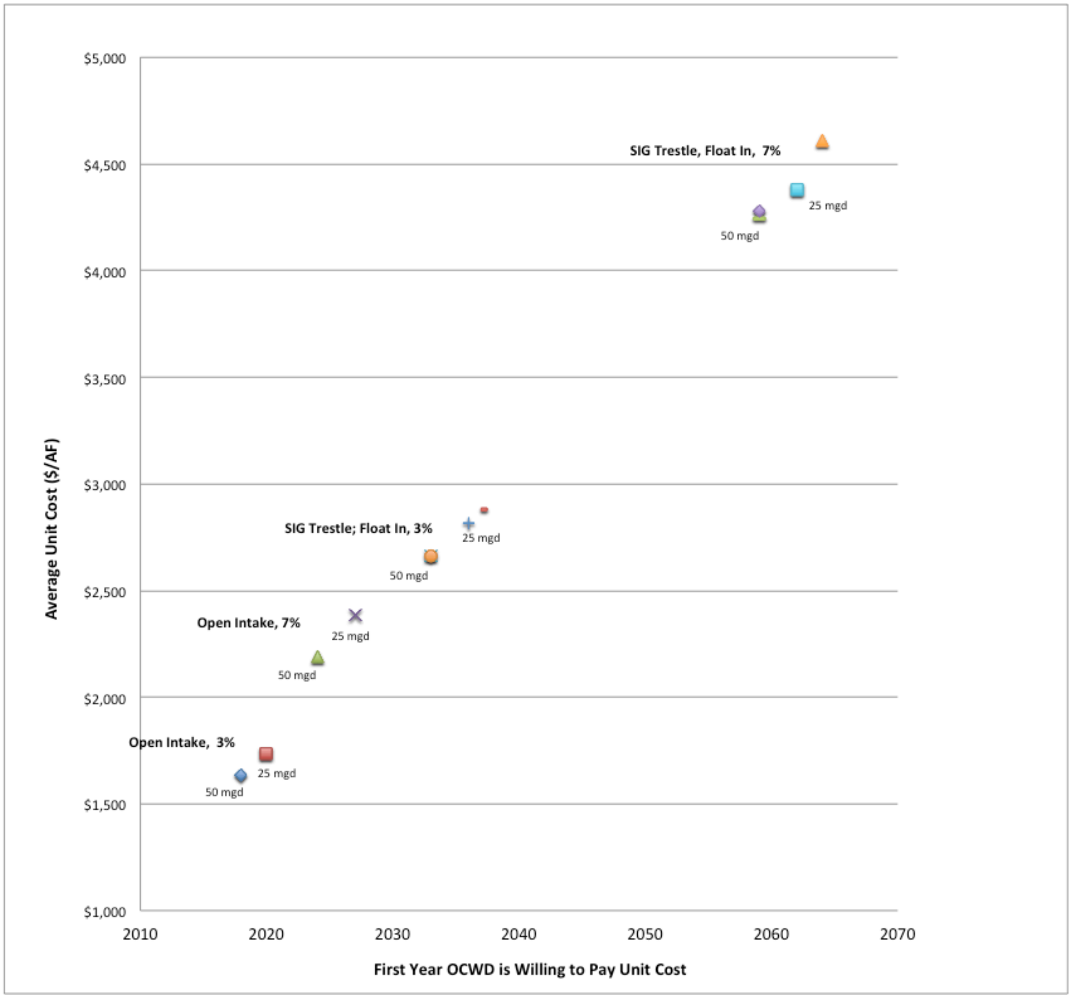

Figure ES.1 The Unit Cost to Produce Water and First Year OCWD is Willing to Pay Unit Cost[3]

Conclusion 6: The SIG option is not economically viable at the Huntington Beach location within a reasonable time frame, due to high capital costs and only modest reduction in annual operating costs

The economic viability of the SIG, regardless of construction technique, and for a product capacity of 50 MGD at this off shore location, is highly uncertain and thus the SIG option faces financing risks that pose significant barriers to implementation. We conclude that it is unlikely that the unit price for produced water from a SWRO plant with the SIG intake technology would find a buyer under current and likely future estimates of alterative waters sources through 2033. The very high capital cost adds operating cost

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[3] Unit costs are averaged over high and low cost estimates and 30 and 50-year life cycle scenarios

in the form of additional interest that overwhelms the savings in pretreatment operating costs provided by the SIG intake.

Chapter I. INTRODUCTION

In April, 2014, Poseidon Resources, LLC ("Poseidon") and the California Coastal Commission ("CCC"), agreed to undertake an independent scientific review of the feasibility of subsurface seawater intake technologies, in the context of a potential permit application to construct and operate a desalination facility in Huntington Beach, California. Subsurface intake technologies, in comparison to an open ocean intake, offer the environmental benefit of reducing impacts on marine ecosystems caused by entrainment and impingement effects from the intake of seawater. These two parties, designated in this context as the "Conveners", established Terms of Reference (TOR) for an Independent Scientific and Technical Advisory Panel (ISTAP) (TOR, April, 2014) that defined the objectives and procedures for conduct of the scientific review, with the process facilitated by the firm CONCUR. The scientific and technical review process was envisioned to occur in two or more phases, with each phase of the process designed to generate reports that can provide evidence for the CCC to consider in the event that Poseidon resubmits a permit application for the proposed facility.

In Phase 1 of the process, the primary objective of the Panel was to assess the technical feasibility of subsurface intake technologies that could potentially be applicable to the Huntington Beach site proposed by Poseidon. The Phase 1 ISTAP consisted of five technical experts on various aspects of subsurface intake technologies. Biographies of the Phase 1 Panel can be found in Appendix A to the Phase 1 Report. The Phase 1 ISTAP reviewed the technical feasibility of nine subsurface intake technologies and concluded that two of the technologies, namely, a seafloor infiltration gallery (SIG) and beach (or surf zone) galleries, met criteria established by the Panel for technical feasibility. The Panel's final report is available on the CCC website (ISTAP Phase I Report, 2014, http://www.coastal.ca.gov/pdf/ISTAP_Final_Phase1_Report_10-9-14.pdf).

Consistent with the TOR for the ISTAP, in December of 2014, the Conveners established a second panel to assess the feasibility of the two technically feasible options, with the directive to the second panel to consider feasibility factors other than technical including economic, environmental and social factors. To address the broader issues associated with a feasibility assessment, the composition of the second panel was expanded to include experts in economics and environmental impacts to compliment experts on engineering, water quality and constructability issues. The members of this second ISTAP, their affiliations and primary areas of expertise are listed in Table 1.1. Biographies of the six members of the second ISTAP can also be found in Appendix A to this report.

Table 1.1 Panel Members Affiliations and Areas of Expertise

Name	**Title**	**Areas of Expertise**
Robert Bittner, M.S., P.E.	President, Bittner-Shen Consulting Engineers Inc.	Engineering, design of innovative marine structures
Janet Clements, M.S.	Managing Economist, Stratus Consulting	Natural resource and environmental economics, Triple Bottom Line analysis
Larry Dale, M.S., Ph.D.	Environmental Economist, Lawrence Berkeley National Laboratory	Environmental economics, energy efficiency and climate change
Michael Kavanaugh, M.S., Ph.D., P.E., BCEE	Senior Principal, Geosyntec Consultants, Inc.	Engineering, science advising for policy
Susan Lee, M.S.	Vice President, Aspen Environmental Group	Environmental impact assessment
Thomas Missimer, M.S., Ph.D.	President, Missimer Hydrological Services Inc.	Hydrogeology, design of desalination intake systems

1.1 Objectives of Phase 2

The primary objective of the Phase 2 ISTAP is to investigate and report on the feasibility of the two subsurface seawater intake methods deemed technically feasible in the Phase 1 ISTAP process (seawater infiltration gallery (SIG) and beach infiltration gallery (BIG)) to provide seawater for a seawater reverse osmosis (SWRO) desalination plant located in Huntington Beach, California. In the Phase 1 investigation only one size plant was considered, namely, a plant producing 50 million gallons per day (MGD) of product water, which requires an intake capacity of approximately 100 MGD. In the Phase 2 process, feasibility has been assessed at varying scales of the plant intake capacity. Specifically, the Phase 2 ISTAP evaluated the feasibility of alternative intake options associated with 25, 50, 100, and 200 MGD intake capacity, which are approximately equivalent to product capacities of 12,5, 25, 50 (proposed project) and 100 MGD. In assessing the impact of scale on the feasibility of the SIG, the Panel relied upon scaling factors used in the industry to assess the impact of capacity on unit costs.

1.2 Overview of the Report

This Phase 2 ISTAP Report ("Report") summarizes the findings and conclusions of the Panel's deliberations on the overall feasibility of the seafloor infiltration gallery (SIG), which is considered to be the only technically feasible alternative seawater subsurface intake technology relative to an open ocean intake for the Huntington Beach site (See Phase 1 report for discussion of other intake technologies considered). Regardless of the intake technology chosen, the overall project will include four main components, namely; 1) an intake structure, 2) pretreatment systems to prepare the seawater for membrane desalination, 3) the reverse osmosis membrane system and 4) a brine disposal system. Generally, for both intake options, the other plant components are assumed to be similar with some modifications as discussed later in the Report.

The primary focus of the Phase 2 ISTAP is assessing the feasibility of the SIG. However, for purposes of assessing the economic feasibility of the SIG, it is necessary to assess the overall project cost for both intake options (open ocean or SIG), which includes estimated costs for the all four of the main components of the project, not just the cost of the SIG. It should be noted that the Phase 2 ISTAP was not asked to assess the feasibility of the other components of the SWRO Plant

Two possible construction methods are evaluated for the SIG, namely a) performing all work off of a trestle elevated above the waves (SIG-Trestle) and b) prefabricating all major SIG components off-site and using floating equipment to transport and install modular units (SIG-Float-in). The Phase 2 ISTAP concluded that the beach infiltration gallery option was no longer considered to be technically feasible due primarily to the cycle of beach sand replenishment and the resulting migration of the surf zone as well as other technical limitations. The rationale for this opinion is provided in Section 3.2.

This report is organized as follows:

- Chapter II defines “feasibility” in the context of this study;
- Chapter III describes the alternative intake technologies considered in this report (SIG and the proposed open ocean intake), including construction methods, schedules, pretreatment options, and scales;
- Chapter IV presents a qualitative discussion of environmental and social considerations related to the intake options;
- Chapter V contains the economic analysis of the intake options and discussion of economic feasibility;
- Chapter VI presents conclusions;
- Chapter VII contains the bibliography; and
- Appendices present additional tables, panelist biographies and the Terms of Reference guiding the panel’s work.

Chapter II. DEFINITION OF FEASIBILITY

2.1 Background

The Conveners instructed the Phase 2 ISTAP to consider feasibility factors as defined in the Coastal Act, as well as other factors that the ISTAP believes should be incorporated into the broader feasibility assessment of subsurface seawater intakes. In addressing this issue, the Phase 2 ISTAP relied on various sources that address the definition of "feasibility" that expands beyond the technical factors evaluated by the Phase 1 Panel. These sources include the California Coast Act, The California Environmental Quality Act (CEQA) and the recent amendment to the Ocean Plan approved by the State Water Resources Control Board adopted on May 6, 2015.

According to the 1976 Coastal Act, Section 30108, *"Feasible" means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, and environmental, social, and technological factors.* However, the Coastal Act is silent on details of the components of these factors, despite the fact that "feasible" is found in many sections of the Act, with numerous examples of phrases such as "where feasible", "to the extent feasible", "economically feasible development", "to the maximum extent feasible" and so on.

In the California Environmental Quality Act (CEQA), "feasible" is defined in Section 21061.1 of the Act (originally adopted in 1969). One important example within CEQA is the application of the concept of feasibility in approval of projects that may have undesirable environmental effects. Section 21002 of CEQA states: *The Legislature finds and declares that it is the policy of the state that public agencies should not approve projects as proposed if there are* ***feasible*** *alternatives or* ***feasible*** *mitigation measures available which would substantially lessen the significant environmental effects of such projects, and that the procedures required by this division are intended to assist public agencies in systematically identifying both the significant effects of proposed projects and the* ***feasible*** *alternatives or* ***feasible*** *mitigation measures which will avoid or substantially lessen such significant effects.* ***The Legislature further finds and declares that in the event specific economic, social, or other conditions make infeasible such project alternatives or such mitigation measures, individual projects may be approved in spite of one or more significant effects thereof*** **(emphasis added).**

Finally, economic feasibility in the context of desalination projects in California has recently been addressed in the Desalination Amendment to the Ocean Plan. This Amendment states, "*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*."

The Phase 2 ISTAP has considered the definition of "feasible" as specified in the Coastal Act, CEQA, and the Desalination Amendment to the California Ocean Plan, recognizing, however, that the details of assessing the economic, environmental and social factors must be considered within the context of project and site-specific issues. In particular, the Phase 2 ISTAP recognizes that the relative importance of each of the three factors continues to be a controversial issue in the application of CEQA to development projects in California and that there exists significant case law related to disputes over CEQA decisions, especially with respect to economic feasibility. Therefore, in addressing the social, environmental and economic factors relevant to reaching conclusions on the overall feasibility of the SIG, the Phase 2 ISTAP provides in this Report an analysis of a number of subfactors within each factor to support the feasibility assessment. A similar process was followed in the Phase 1 Panel deliberations on the technical feasibility assessment, in which numerous relevant subfactors were assessed for each of the nine subsurface intake technologies considered (See Phase 1 Report for details). In addition, the Phase 2 ISTAP considered the time factor in assessing "feasibility", recognizing that completing the project within a "reasonable" time frame must also be given appropriate weight.

Chapter III. ALTERNATIVE INTAKE TECHNOLOGIES CONSIDERED

3.1 Introduction

The ISTAP Phase 1 report concluded that additional technical feasibility analyses should be conducted for two subsurface intake technologies that survived the initial “fatal flaw” analysis. These intakes were the “beach infiltration gallery” or BIG (called “surf zone infiltration gallery” in the Phase 1 report) and the “seafloor infiltration gallery” or SIG. The method of construction for the SIG was deemed to be use of a trestle from the beach to the offshore position of the SIG; the trestle would be used to mobilize equipment through the surfzone and into the harsh and high-energy environment occurring at the site.

Poseidon’s proposed open ocean intake would use the existing power plant intake pipe with a velocity cap structure at its seaward terminus and would use traveling screens located in the power plant forebay with a return flow to allow some of the ichthyoplankton[4] to be returned to the sea.

Based on additional information obtained on the coastal stability and the U. S. Army Corps of Engineers schedule of maintenance, the ISTAP 2 made an additional assessment of the technical feasibility of the beach infiltration gallery as proposed (see Section 3.2). Also, a second construction method was developed for the SIG.

3.2 Reassessment of Beach Infiltration Gallery Technical Feasibility

This discussion summarizes the key factors that stimulated a further assessment of the technical feasibility of the beach infiltration gallery intake. These factors include; 1) additional engineering design assessment and the impact of the beach re-nourishment schedule, 2) construction complexity, and 3) the construction schedule as related to the overall SWRO desalination construction project.

The Phase 1 ISTAP report contained some reservations regarding specific technical issues related to the BIG system with regard to the construction complexity and the fact that no large-scale example of such a system is in current operation worldwide (ISTAP 1, 2014). The positive factors that convinced the Phase 1 ISTAP to consider this subsurface intake type as technically feasible included information provided by the California Coastal Commission staff that this type of project could receive the appropriate permits to be constructed and the required area of the gallery was 15.24 acres which is about one-half of the area required for an offshore seabed gallery. This smaller area was based on the higher hydraulic conductivity of the beach sand.

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[4] Ichthyoplankton are the eggs and larvae of fish. They are usually found in the sunlit zone of the water column, less than 200 meters deep.

New information has been gathered and analyzed to reconsider some of the assumptions used by the Phase 1 ISTAP to reach initial conclusion that the beach infiltration gallery intake system was technically feasible.

3.2.1 Additional Design Issues and Impact of the Beach Re-Nourishment Schedule

Two key design issues with regard to the technical feasibility of the beach infiltration gallery intake relate to the possible use of a higher infiltration rate compared to the offshore gallery. First, a beach intake gallery is essentially self-cleaning because of the turbulence caused by breaking wave action (Maliva and Missimer, 2010). Second, the technology benefits from the high hydraulic conductivity of the beach sands (40-60 ft/day at Huntington Beach (Rosas et al., 2014, supplementary information file)), compared with offshore hydraulic conductivity that is less than 10 ft/day offshore from Huntington Beach (offshore core data supplied by Poseidon for evaluation of the horizontal well technology) (ISTAP Phase 1 Report). The higher infiltration rate reduces the area of the required gallery to about 50% of that required in an offshore gallery for the same hydraulic capacity.

Information presented by Dr. Scott Jenkins, a consultant retained by Poseidon Resources LLC, and reports generated by the U. S. Army Corps of Engineers (COE) have documented the high-energy nature of the beach and the long-term patterns of coastal erosion. The beach requires periodic re-nourishment with a current cycle of about 5 years to maintain the width of the beach. Therefore, the surf zone migrates landward after a re-nourishment cycle and re-establishes its position seaward after sand is added to the beach. Direct observation of the surf zone at Huntington Beach shows that it is a relativity narrow zone approximately 150-200 feet wide (mean low water seaward to wave scour point).

The very rapid rate of shoreline change modifies the design considerations used to deem the beach infiltration gallery technically feasible, as the beach renourishment schedule and its impact on the design were not considered in detail during Phase 1. The assumed infiltration rate was based on the fact that the sand beach has a substantially higher natural hydraulic conductivity compared to the offshore sand. The COE implements a beach nourishment program to maintain the beach sand at Huntington Beach by importing sand approximately every 5 years. The past history shows that the COE has renourished the beach at intervals between 2 and 8 years.

If it is assumed that the beach infiltration gallery is constructed immediately after the completion of a re-nourishment cycle (when the surf zone is in its seaward maximum position), then the gallery would function well under a seasonal equilibrium condition within the surf zone where its position is relativity stable. However, there will be a landward migration of the surf zone as the normal seasonal pattern of erosion occurs (between the Corps nourishment cycles). Ultimately, the surf zone will move landward but the beach infiltration gallery structure will remain at the original location, then underlying the ocean and located seaward of the surf zone. Variation of the surf zone position would be on the order of 600 to 900 feet between cycles of re-nourishment.

This surf zone migration will impact the beach infiltration gallery design in two ways: 1) the natural degree of self-cleaning by turbulence will be reduced because the gallery would be ultimately too far offshore from the surf zone, and 2) the hydraulic conductivity of the sand lying above the gallery will be reduced to that occurring within an offshore condition wherein minor amounts of silts and clays are deposited within a lower energy environment. The result of the transition of the beach infiltration gallery to an offshore gallery within a dynamic environment would necessitate a design change to be made with a reduction in the infiltration rate and a resulting increase in the required area of the gallery closer to that used in an offshore gallery design. Therefore, the required unit area of the gallery with the reduced infiltration rate would be closer to 5 MGD/acre instead of 10 MGD/acre. If an elongated design were to be used, the length of the gallery would increase from one mile to as great as two miles.

A second design issue that must be considered is beach infiltration gallery "stranding". In the event that the gallery was constructed at some time after a re-nourishment event, when re-nourishment does occur, the gallery would no longer lie within the surf zone, but would be located in the mid- or back beach. This position would lengthen the recharge flow path from the ocean and cause impacts to the landward area similar to impacts of shallow wells. Also, the longer flow path and would cause the recharge rate to be reduced, thereby causing failure to achieve the design flow rate based on direct recharge. The greater the distance of the gallery from the ocean results in a greater the loss of recharge that will occur with ultimate failure of the system (dewatering).

Based on this re-analysis, the area required for the beach infiltration gallery would have to be increased considerably and the construction of the gallery could occur only at the end of a re-nourishment cycle. This would affect both the construction complexity and the schedule.

Another factor complicating the use of a beach infiltration gallery is the impact of sea level rise on the rate of shoreline erosion. The five-year cycle required for re-nourishment will likely change to a required shorter frequency period because increased sea levels will cause more rapid erosion of the beach (Bruun, 1962; Niedoroda et al, 1985).

3.2.2 Construction Complexity

The coastal area of Huntington Beach is considered a high-energy shoreline with high wave heights and accompanying strong long-shore currents. The construction method required would be to build an up-gradient temporary groyne and a trestle in the offshore area to allow gallery construction. The Phase 1 report stated that work from the top of the trestle would include installation of sheet piling, dredging, installation of the basal intake screens and graded filter, extraction of the sheet piles, and finally the removal of the trestle (ISTAP 2014). The construction method would require temporary closure of about 1,500 feet of beach as each module or cell of the gallery system is constructed (ISTAP 2014, p. 57). Based on the one-mile length of the project based on the higher infiltration rate, the construction period was estimated to be four to five years.

Based on the design re-evaluation, the increased area of the beach infiltration gallery needed to adapt to periodic positioning in the offshore would affect the complexity and duration of construction. If the gallery width was to be maintained, the length of the gallery would have to be doubled. The increased area required could also be achieved by increasing the width to provide an overall area closer to that of the offshore gallery. Therefore, the construction duration would have to increase based on the complexity of the new area required to meet the required raw water need. If the width of the gallery were to be increased, then the complexity of the trestle would have to be increased with serious cost implications.

Construction of a beach infiltration gallery at Huntington Beach cannot be completed in a continuous manner because of weather considerations and beach closure during specific times of the year based on environmental considerations. Stormy weather and high wave action would reduce the allowable construction period to no more than about 60% of the year. Further, the issue of union-related closures could eliminate the months of April and May from the construction schedule. Given the larger required gallery size, the 4 to 5 year estimate for construction based on the 15.24 acres of required gallery would have to be increased to perhaps 7 to 9 years or greater based on doubling of the gallery area.

3.2.3 Construction Schedule: Beach Infiltration Gallery Intake Component vs. SWRO plant

Construction scheduling is a key part of any major infrastructure project, particularly a seawater desalination facility. A typical SWRO plant with an open ocean intake can be constructed after design within a 2-year period. Based on the initial construction duration contained with the Phase 1 ISTAP report and the re-analysis of the design, the beach infiltration gallery intake construction would require 7 to 9 years to be completed. This schedule is out of phase with the SWRO plant and would cause significant expenses and loss of potential revenue.

3.2.4 Conclusion on Technical Feasibility of a Beach Infiltration Gallery Intake System

Based on this additional information on the beach infiltration gallery design considerations and construction scheduling, the technical feasibility of this subsurface intake option was found by the Phase 2 ISTAP committee to be infeasible. The high energy nature of the Huntington Beach shoreline and periodic changes in the position of the surf zone due to replenishment render the development of this intake type at this location less feasible than initially considered. Also, the timing of beach retreat during a period of greater rates of sea level rise will exacerbate the design and construction issues. The actual construction could last longer that a single beach re-nourishment cycle.

Based on the revised analyses, the Phase 2 ISTAP concludes that the beach galley subsurface option is infeasible to construct to meet the target intake capacity of 106 MGD at the proposed Huntington Beach site. Because of the unstable littoral zone position, it is also unlikely that the smaller intake capacity systems could be successfully constructed and operated for a SWRO facility at this location. This information was presented at the February 18, 2015 workshop in Huntington Beach, and no stakeholders or members of the public questioned the conclusion. As a result, the panel eliminated the beach infiltration gallery technology from further study.

The conclusion eliminating the beach infiltration gallery intake system as a technically feasible option resulted in a further analysis of only two technical options for the SWRO intake system:

- The open-ocean intake in Poseidon's original proposal to the CCC in 2012, and
- A seafloor infiltration gallery (SIG).

3.3 Seabed Infiltration Gallery Construction Site

Poseidon's proposed location for the desalination facility is approximately 2 miles south of the Huntington Beach Municipal Pier, and 1 mile north of the mouth of the Santa Ana River. The proposed optimum location for the SIG, based on studies conducted for Poseidon, is approximately 3400 feet offshore (Jenkins and Wasyl, 2014).

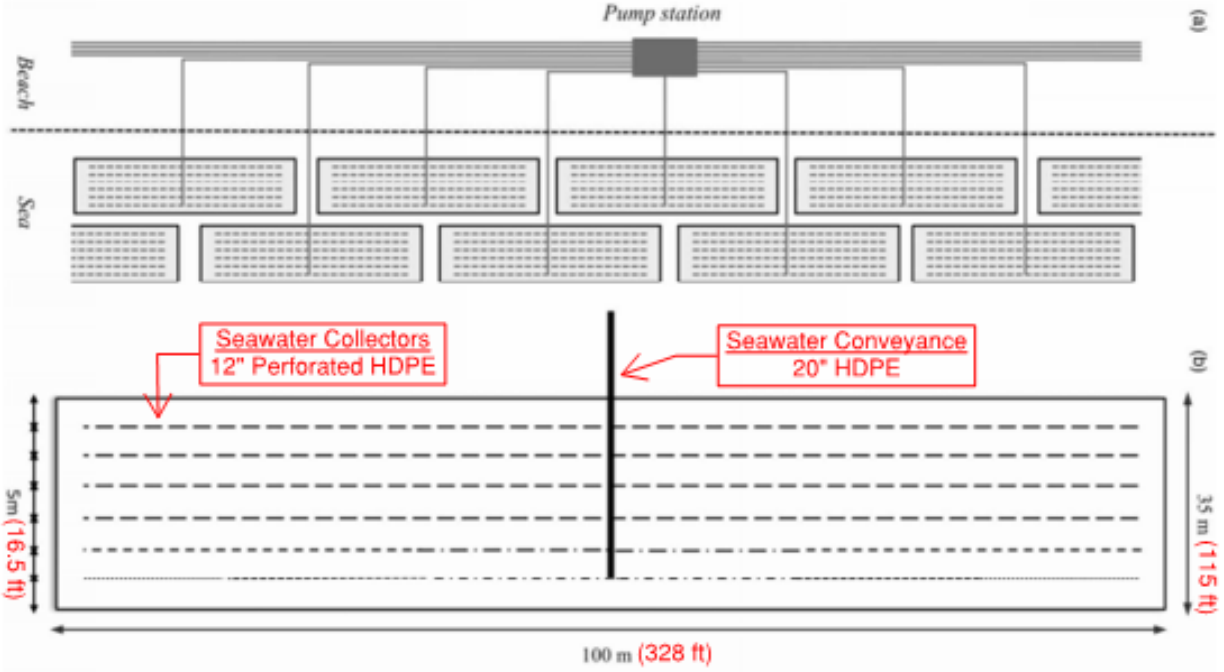
At this location the seafloor is approximately 42 feet below Mean Sea Level (MSL), and the area is subject to almost continuous long-period ocean swells that prevent the efficient use of conventional marine floating equipment. Further, the change in location would have not a material effect on the complexity and economics of construction. These are:

- SIG-Trestle: Performing all work off of a trestle elevated above the waves, and
- SIG-Float-In: Prefabricating all major SIG components off-site and using floating equipment to transport and install modular units.

The ISTAP has received a comment from the staff of the California Coastal Commission regarding the proposed location of the SIG with the suggestion that it could be moved slightly closer to the coast. The potential advantage of a location nearing the shoreline is possible reduction in costs of materials of construction (shorter intake pipes) and lower energy costs. The ISTAP does not believe that these costs would reduce the life cycle cost materially, and consider such an option to have cost impacts within the cost ranges consistent with a Category IV construction cost estimate (i.e, -30%/+50%). Furthermore, such a location a few hundred yards nearer the shoreline would not have a material impact on construction costs, as the complexity and cost of the construction using either method is relatively independent of the distance from the shoreline once the construction moves beyond the higher energy zones of the surf zone. Finally, the ISTAP was not provided technical documentation that supported shifting the SIG to a nearer shore location.

3.3.1 SIG Size and Configuration

Based on an intake capacity demand of 106 MGD, which is necessary to produce 50 MGD of product water, a design loading rate of 5MGD/acre and a design redundancy of 20%, the required total SIG area is 25.44 total acres. The conceptual cell layout is illustrated in Figure 3.1 below.



Cell Layout and Sizing (Mantilla and Missimer)

Figure 3.1 Cell Layout and Sizing

A total of 30 cells will be required for the 106 MGD intake capacity scale, 328-ft by 115-ft in plan or 0.866 acres per cell. The typical cross section of the SIG is illustrated in Figure 3-2 below.

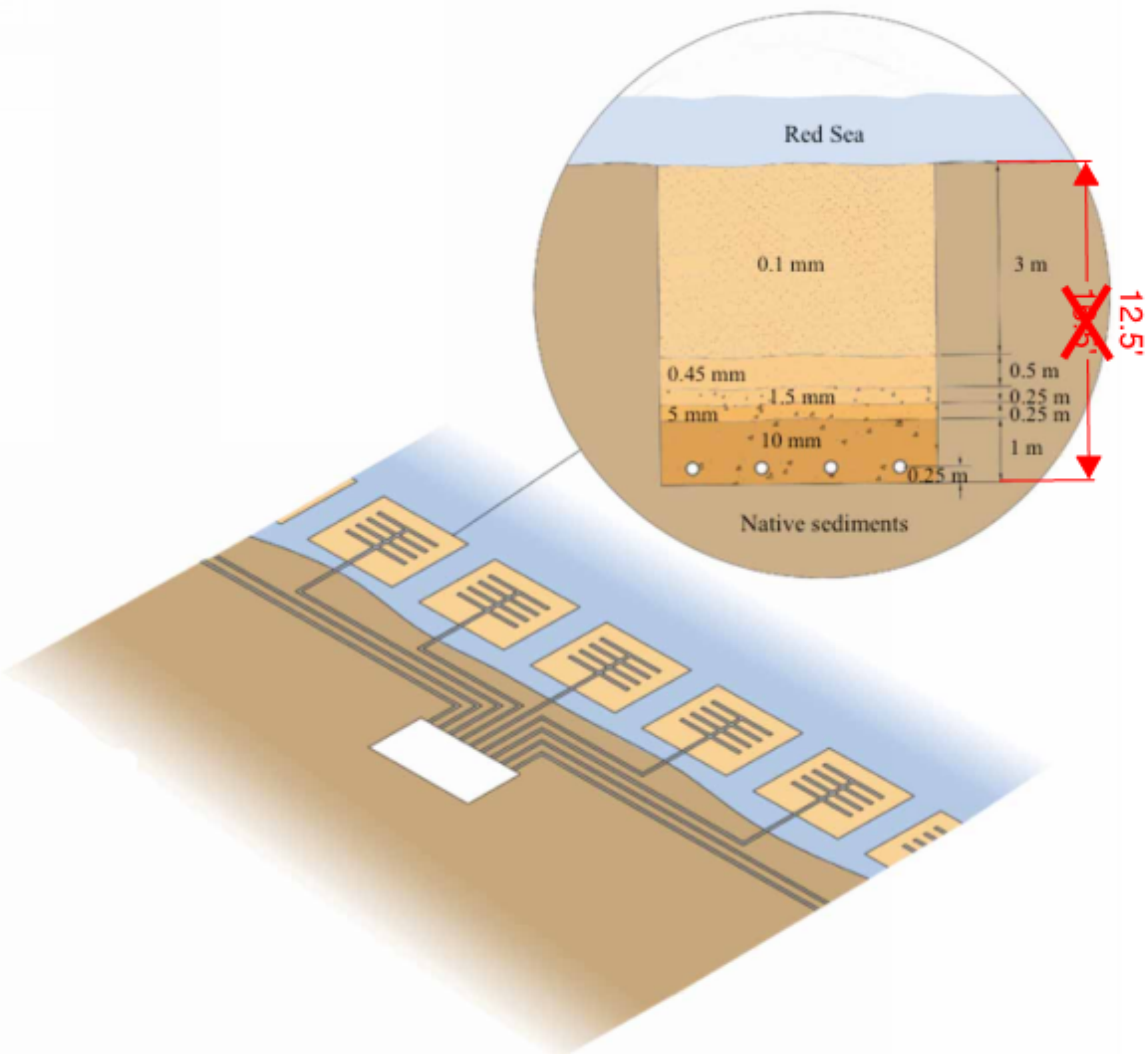


Figure 3.2 Typical SIG cross-section

3.3.2 SIG-Trestle Construction Option

At the first ISTAP Phase I meeting in Huntington Beach on June 9th, 2014, Poseidon Resources presented a conceptual design and layout for a SIG. On the second day of the meeting, Poseidon presented a conceptual construction method for building the SIG at the proposed site.

Due to the restrictions created by the almost constant swell conditions, the construction methods proposed by Poseidon were based on performing all work off of temporary access trestles. With this method, an elevated pile supported platform is built on the beach and a crane is positioned on top of the platform. The crane then continues to build a continuation of the platform or trestle out through the surf zone into deeper water. As the trestle and crane advance offshore, additional construction materials are delivered to the crane working out on the end of the trestle. See Figure 3.3 for a photo of a typical trestle construction method.

Figure 3.3 Typical trestle construction

The trestle method is a proven and reliable method for near shore construction in this area of the Southern California Coast, and in fact, this same method was used to successfully build the Huntington Beach municipal pier in 1989.

However, due to the long distance from shore and the extensive area required for the SIG (25+ acres), the total length of required access trestle in the Poseidon construction concept would be over 3.3 miles

(17,408 ft.). See Figure 3.4 for a plan view layout of the SIG and temporary access trestle required for construction of the SIG. While this method of construction is a proven method in this area, it would be very slow and expensive.

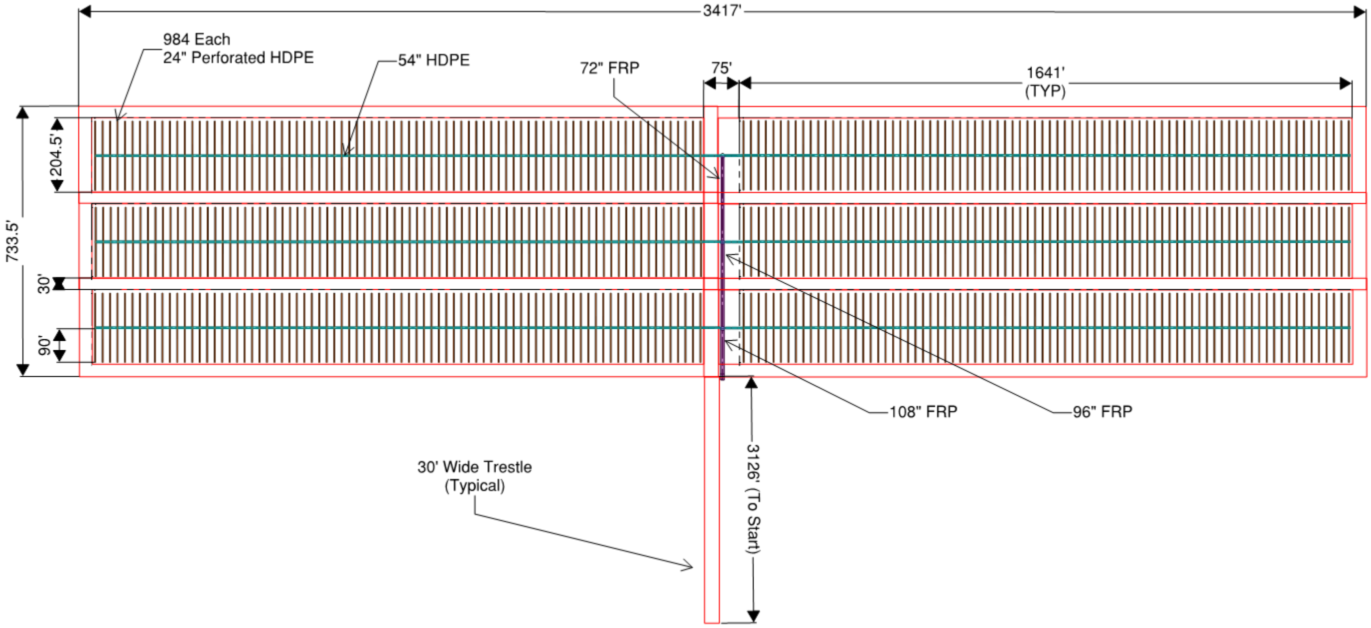


Figure 3.4 Plan of Proposed Trestle Layout

3.3.3 SIG-Float In Construction Option

Pursuant to the objectives of the ISTAP Phase 2, an alternative to the trestle option was proposed by an ISTAP member that utilized off-site pre-fabrication and float-in of large pre-assembled SIG elements. The primary objective of this alternate approach is to shift fabrication and assembly of large modular units to a protected harbor area where work can be conducted without concern for ocean swell conditions, and to transfer these modular units to the installation site by a flat-deck barge for final installation using bottom founded equipment. See Figure 3.5 for a plan view of the proposed SIG layout and Figure 3.6 for a section through a typical SIG cell using float-in construction. See Figures 3.7 through 3.10 for construction stages 1 through 6 using the float-in method.

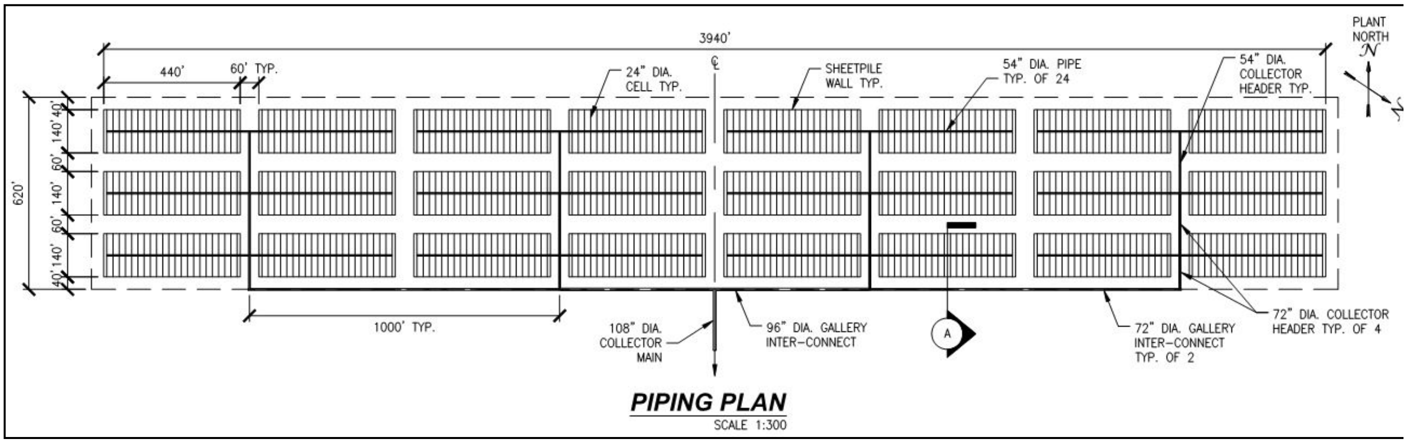


Figure 3.5 Plan of SIG using float-in construction methods

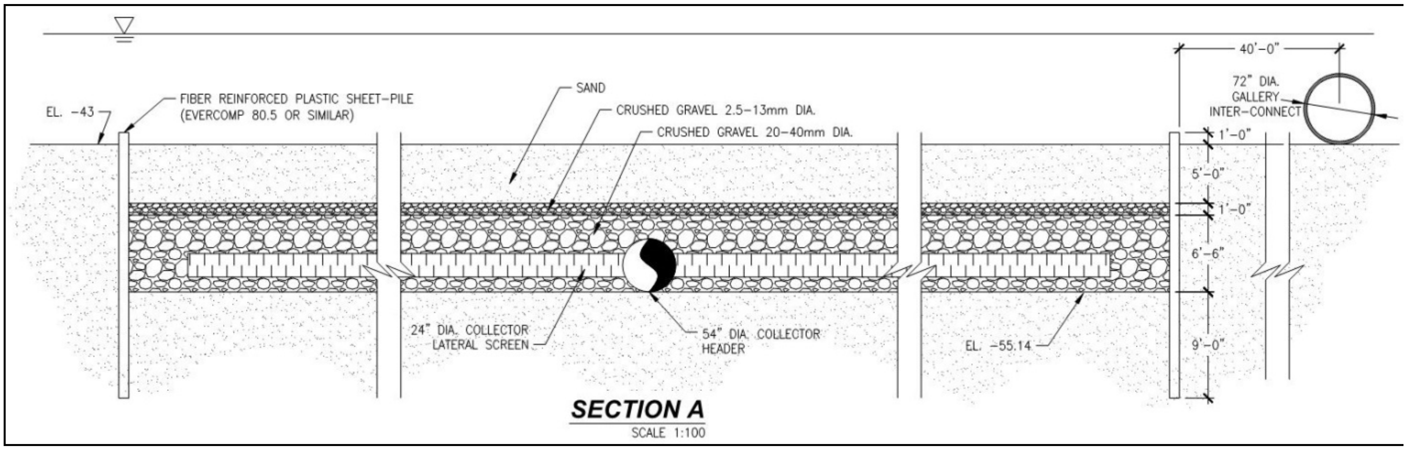
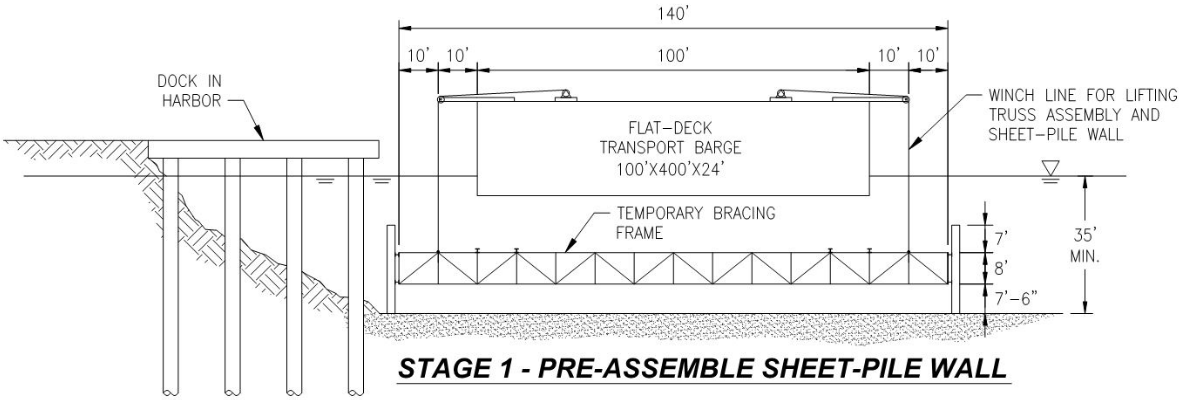
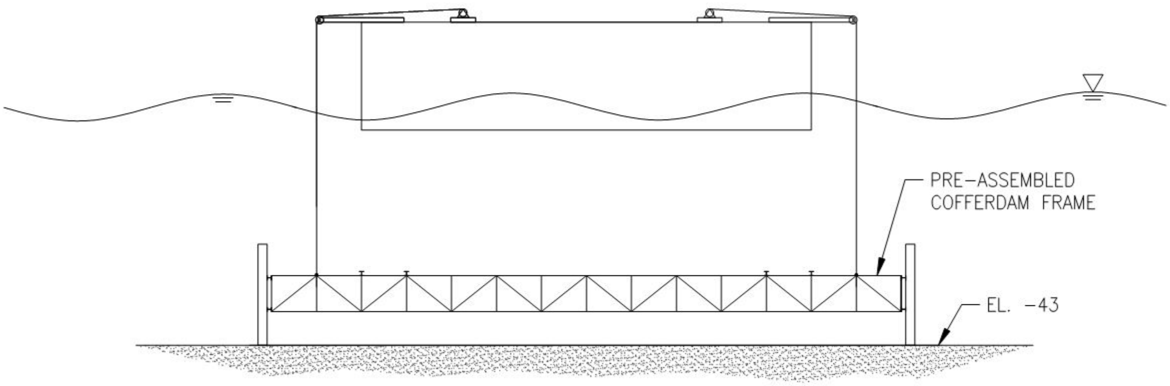


Figure 3.6 Section of SIG using float-in construction methods



STAGE 1 - PRE-ASSEMBLE SHEET-PILE WALL

1. PRE-ASSEMBLE SHEET-PILE WALL TO BRACING FRAME ON SEA-BED AT DOCK SIDE.
2. FLOAT IN TRANSPORT BARGE (100'x400'x24') OVER TOP OF PRE-ASSEMBLED SHEET-PILE WALL AND LIFT SHEET-PILE WALL TIGHT TO BOTTOM OF BARGE FOR TRANSPORT TO INSTALLATION SITE.

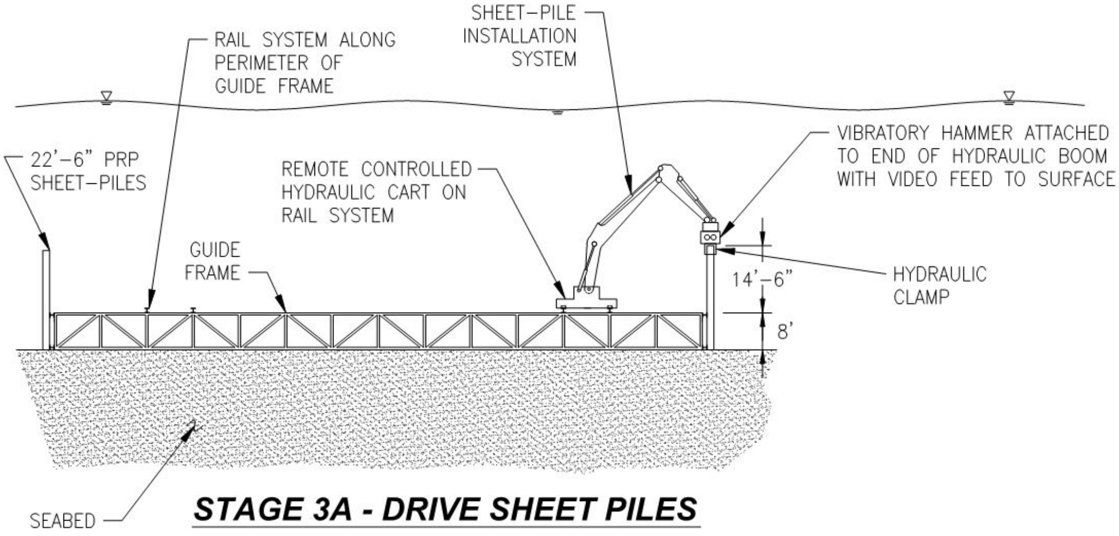


STAGE 2 - POSITION AT INSTALLATION SITE

STEP 3. TOW TRANSPORT BARGE WITH PRE-ASSEMBLED COFFERDAM FRAME TO INSTALLATION SITE.

4. LOWER COMPLETE WALL AND TRUSS ASSEMBLY TO SEA-BED AND DISCONNECT.

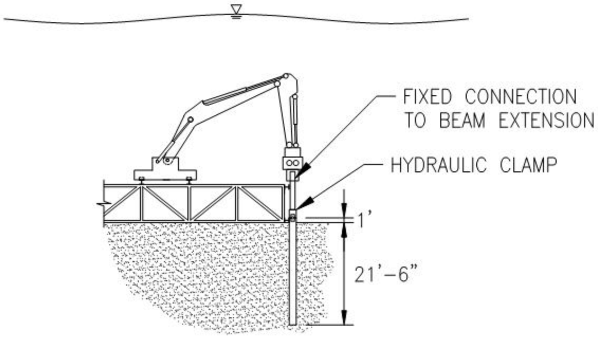
Figure 3.7 Float-In Construction Stages 1 and 2



STAGE 3A - DRIVE SHEET PILES

STEP 5. SET SHEET–PILE INSTALLATION SYSTEM ON RAILS.

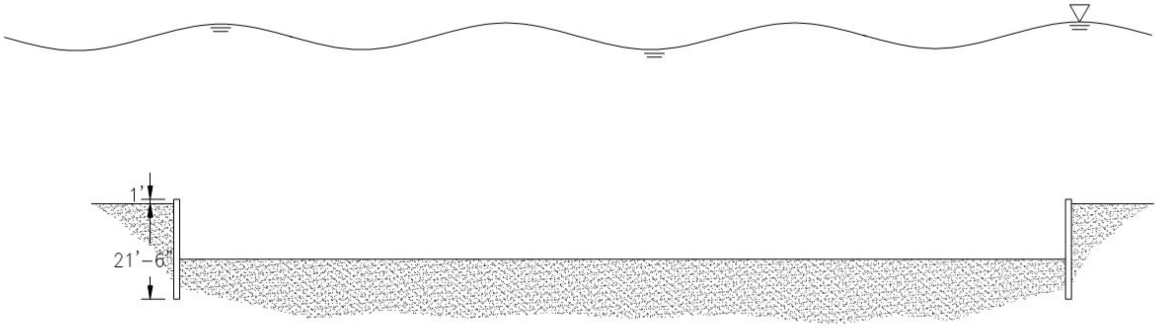
6. DRIVE SHEET–PILES' INITIAL 12–FT USING A REMOTE CONTROLLED PILE DRIVER ON RAILS



STAGE 3B - DRIVE SHEET PILES

STEP 7. DRIVE REMAINING 8½–FT OF SHEET–PILES TO FINISHED GRADE (ALONG ENTIRE PERIMETER)

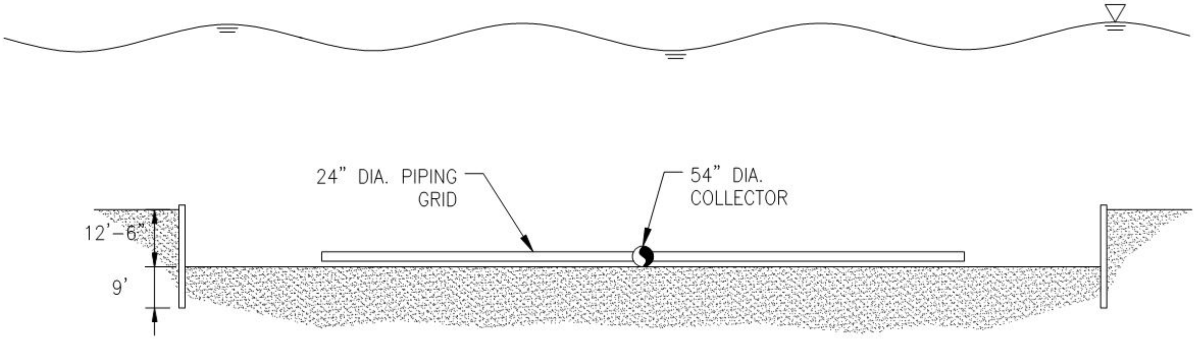
Figure 3.8 Float-In Construction Stages 3A and 3B



STAGE 4 - EXCAVATE SIG CELL

STEP 8. REMOVE GUIDE FRAME WITH TRANSPORT BARGE.

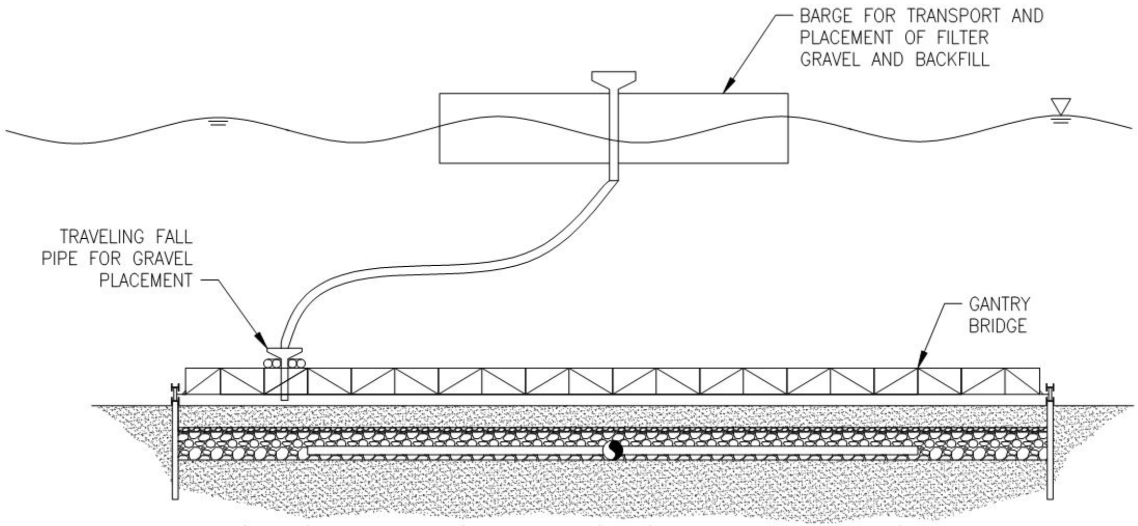
9. EXCAVATE BETWEEN SHEETS USING SUCTION DREDGE OPERATING OFF GANTRY BRIDGE TRAVELING ON TOP OF SHEET–PILES.



STAGE 5 - PLACE PIPING IN SIG CELL

STEP 10. USE TRANSPORT BARGE TO BRING IN AND SET PIPING GRID.

Figure 3.9 Float-In Construction Stages 4 and 5



STAGE 6 - PLACEMENT OF GRAVEL BEDDING

STEP 11. INSTALL GANTRY BRIDGE WITH TRAVELING FEED PIPE FOR GRAVEL PLACEMENT.

12. PLACE FILTER BEDDING LAYERS AND BACKFILL.

13. REMOVE GANTRY BRIDGE.

14. CONNECT–UP 54" DIA. COLLECTOR PIPES BETWEEN SIG CELLS.

Figure 3.10 Float-In Construction Stage 6

This alternate float-in construction method significantly reduces on-site work and the sensitivity of construction operations to high energy wave conditions. This construction method provides the same shored-excavation for minimizing dredging quantities as the trestle method. However, the sheet piles used for the shoring would be pre-assembled onto a trussed frame into modular units within a protected harbor and then picked up as one unit by a transport barge. The barge would then be towed to site and positioned by work boats at the proposed offshore SIG installation site and then lowered to the sea floor. Once on the sea floor, a bottom founded hydraulically operated vibratory pile driver mounted to the outer rails of the assembly truss would walk its way around the edge of the truss and vibrate the sheet piles to grade. This driving installation would be performed in two stages, the first would be to drive the sheet piles approximately12-ft into the sea bed and the second stage would drive the sheet piles to grade. Following pile driving, the truss frame and vibratory pile hammer would be removed by the same transport barge and taken back to harbor for assembly, pickup and transport of the next sheet pile cell.

After all sheet piles in a given cell are driven to grade, a traveling truss bridge with a span of 140-ft would be lowered onto the top of the sheet pile walls. This truss bridge would ride the top of the installed sheets and be equipped with a small hydraulic suction dredge. This dredge would be used to excavate to a depth of 12.5 feet within the sheet pile cell. The material dredged from within the sheet pile enclosed cell could be pumped to a bottom-dump barge for transport to deep water disposal or could be pumped ashore for temporary storage and later re-use for backfill.

Once dredging has been completed, the traveling truss and dredge would be lifted off the cofferdam walls and transported back to the harbor using the transport barge. A pre-assembled intake-piping grid for the SIG cell would then be picked-up from an assembly area in the harbor using the same truss frame and transport barge used for the cofferdam sheet piles. The piping grid would then be transported to site and lowered to grade within the pre-excavated SIG cell. The final step would be to bring back the traveling truss bridge, but this time equipped with a hopper for placement of the crushed gravel filter layers and sand backfill to bring the bedding in the cell back to original seabed elevation. Feed for this infill hopper would be from a floating barge positioned over the top of the cell. The final step would then be to use divers to connect the single 54" diameter collector header at the end of each of the 24 SIG cells to the four 72" diameter gallery inter-connect pipes.

3.3.4 Construction of Onshore Pumping Station

Both of the SIG construction methods would require the construction of an onshore gallery in which the seawater collector pipes would be gathered into a single intake tunnel connecting it to an onshore pumping station. In a scenario developed by Poseidon, this facility would be constructed below the State Park parking lot. After construction, the lot would be returned to parking use.

Both the trestle and the float-in construction methods would require construction on 4 acres of the State Beach parking lot for subsurface installation of pipe headers and pumps, and connection of piping to the existing seawater intake. The trestle option would take 7 years to construct, and the float-in option would require 4.5 years to construct.

Figure 3.11 Location of Onshore Pumping Station Facilities

3.3.5 Maintenance of SIG

Poseidon states that, based on the analysis of the core samples recently obtained from the SIG area, it is estimated that the SIG bed will have to be maintained on a 1 to 3 year basis in order to prevent clogging, due to the limited permeability of the natural sediments. This maintenance would consist of raking the top of the bed from a vessel to disturb the sediments or the use of a mini-dredge to remove a small amount of the sediments. While erosion of the manufactured filter bed is not expected to require regular maintenance, it is likely that augmentation of manufactured media filter bed may be required. The exact timing of maintenance is not precisely known. The only example of an operating SIG is the Fukuoka, Japan facility, which reportedly has not required maintenance over its more than 8-year operating life.

3.4 Pretreatment Options

Pretreatment of seawater is necessary because the primary desalination process (membranes) must be protected from fouling with natural sediments (clay) and organic matter (algae, bacteria, and dissolved organic compounds). Seawater percolation through the SIG provides a considerable amount of pretreatment as demonstrated at the facility located at Fukuoka, Japan, wherein the natural background Silt Density Index (SDI) was lowered from greater than 15 to less than 3 which meet membrane manufacturer's warranty requirements. The SDI value is commonly used by manufacturers to establish warranties on membrane life which is a very important operational consideration for all SWRO facilities.

There are several choices in pretreatment that could be used to protect the membrane process at the facility when using a SIG intake (protection is required to avoid particulate entry into the primary process). First, a conventional process train using coarse and fine granular media filtering could be used without a coagulant (this process is known as "direct filtration" in the drinking water industry). In no case should application of any chlorine be used when operating a subsurface intake system of any type. The second possible pretreatment system is similar to the Fukuoka, Japan facility and would use membrane filtration using ultrafiltration (UF) membranes from the outlet of the SIG to the cartridge filter. Since the effluent from the SIG in Japan has a very high quality with an SDI value of about 2.5, the use of the membrane filtration system could contain a bypass if the water quality meets the SWRO process membrane manufacturer standards. The membrane filtration process would only be used during upsets of the SIG treatment or if standards are not being met. It is likely that the bypass could be used at least 60% of the time (very conservative). The membrane filtration pretreatment process should be considered as a plant operational reliability process to meet the feedwater quality requirements under all operating conditions.

3.5 Scales Considered

Seabed filtration is a modular process as it has been described herein. Therefore, the number of cells can be designed to meet the requirements of virtually any capacity SWRO plant. There is however a cost associated with scale that is likely at about the same ratio as found in the overall cost of SWRO treatment costs in general, with an increase in unit cost as the facilities product capacity is reduced (Ghaffour et al., 2013). As in almost any product capacity treatment process, the overall unit cost to operate a facility goes down as the product capacity of the facility increases. For example, the overall unit operating cost of a 10 MGD is higher than a 50 MGD plant based on a lower unit construction cost and other operational efficiencies.

Chapter IV. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

4.1 Introduction

Among the three additional feasibility factors considered by the Panel, the environmental and social factors are the most difficult to quantify. Consideration of these two factors to evaluate the feasibility of specific subsurface intake options is driven in part by the Coastal Commission's concerns about the environmental impacts of the proposed intake on the coastal environment and marine ecosystems. However, both SIG options have additional environmental impacts that must be considered in the feasibility determination. These impacts are not considered or evaluated in detail as they would be in an Environmental Impact Report (EIR), but they are considered here in an effort to determine how they might affect the feasibility of the SIG options. The costs associated with mitigation activities required to offset environmental and social impacts are included in the economic analysis described in Chapter V. However, these costs do not capture the full extent of potential and likely impacts.

It must be noted that this report does not compare the potential environmental impacts of Poseidon's proposed open ocean intake with the potential impacts of the SIG options. The impact discussion presented here should not be taken to imply that the potential SIG impacts are more severe than those of the open intake; that comparison was simply not within the scope of this panel's work.

The SIG construction options that are found by the Panel to be feasible could not be approved and implemented until an EIR is prepared and certified (or equivalent analysis prepared by the Coastal Commission). This CEQA documentation would include detailed analysis in environmental and economic disciplines, and would consider both construction and operational phases. Mitigation measures or permit conditions would be defined and adopted for any potential significant impacts.

4.2 Regulatory Background

The primary reason that the ISTAP is considering seawater intake alternatives to the previously proposed Poseidon Huntington Beach Desalination facility is that the CCC Staff Report determined that "… Poseidon's proposed use of an open water intake will result in adverse effects to marine life. Poseidon's use of the intake will entrain … fish larvae, eggs, and invertebrates … that originate in areas along about 100 miles of shoreline, including areas within Marine Life Protected Areas (MLPAs)."

The CCC is required to evaluate the environmental impacts of projects requesting permits; this process occurs under the CCC's approved certified regulatory program for compliance with the California Environmental Quality Act (CEQA). CEQA requires consideration of alternatives, as follows:

> **CEQA Guidelines Section 1516.6(a)** Alternatives to the Proposed Project. An EIR shall describe a range of reasonable alternatives to the project, or to the location of the project, which would feasibly attain most of the basic objectives of the project but *would avoid or substantially lessen any of the significant effects of the project, and evaluate the comparative merits of the alternatives*. An EIR need not consider every conceivable alternative to a project. Rather it must consider a reasonable range of potentially feasible alternatives that will foster informed decision making and public participation. An EIR is not required to consider alternatives which are infeasible. The lead agency is responsible for selecting a range of project alternatives for examination and must publicly disclose its reasoning for selecting those alternatives. There is no ironclad rule governing the nature or scope of the alternatives to be discussed other than the rule of reason.

This information on CEQA is not intended to imply that the Panel is attempting a CEQA-compliant assessment, but only to clarify the CEQA requirements for consideration of alternatives.

4.3 Environmental Concerns Driving Consideration of Intake Alternatives

Some of the environmental and social impacts are quantified in the economic analysis (see Sections 4.3.1-4.3.3 below and Chapter V), and other impacts are described in this chapter in a qualitative manner (see Section 4.4). These two categories are explained below.

4.3.1 Quantified Impacts

Certain environmental effects can be monetized and included in the life cycle cost analysis of the different intake alternatives. The effects included in Chapter V, Economic Analysis, are the following:

- Mitigation costs for effects on the marine ecosystem due to entrainment and impingement resulting from open ocean intake, including an initial cost for coastal land acquisition and/or restoration and ongoing annual maintenance costs for restored or acquired habitat; and
- Compensation for loss of beach access or recreation opportunities by construction activities.

4.3.2 Construction and Operational Activities that Create Environmental Impacts

Table 4.1 summarizes the construction and operational requirements of the two SIG options and the specific aspects of these options that create environmental impacts. The requirements defined in Table 4.1 were derived by the Panel based on its review of Poseidon's construction estimates for the two SIG options. Two options are presented for the construction requirements: the first assumes that the construction would be shut down during the summertime due to high beach use, and the second assumes year-round construction.

Table 4.1 Construction and Operational Requirements of SIG Construction Options That Create Impacts

<table>
<tr><th>SIG-Trestle</th><th>SIG-Float In</th></tr>
<tr><td colspan="2"><u>CONSTRUCTION REQUIREMENTS -- With</u> Summer Beach Closure (Assumes no construction from Memorial Day to Labor Day in order to reduce impacts on beach recreation)</td></tr>
<tr><td>• 7.0 years of onshore construction in HB on 4 acres of State Beach parking lot for pipe headers and pumps
• 1.8 years of onshore and nearshore marine construction to install the 3,000 foot long trestle from shore to offshore gallery
• 7.0 years of construction traffic passing through HB and other coastal communities carrying all components needed to construct trestle and install SIG via trestle
• 3.0 years of offshore construction of the 25.44 acre SIG
• 3.0 years disposal of dredged marine sediments at approved offshore site</td><td>• 4.5 years of onshore construction in HB on 4 acres of State Beach parking lot for pipe headers and pumps
• 2.9 years of marine vessel traffic between Port of LA/LB and SIG site to carry SIG components to site
• 2.9 years of offshore construction of the 25.44 acre SIG
• 2.9 years of use of construction yard at Port of LA/LB with SIG components carried to port via local roadways
• 2.9 years disposal of dredged marine sediments at approved offshore site</td></tr>
<tr><td colspan="2"><u>CONSTRUCTION REQUIREMENTS -- Without</u> Summer Beach Closure (year-round construction)</td></tr>
<tr><td>• 4.9 years of onshore construction in HB on 4 acres of State Beach parking lot for pipe headers and pumps
• 1.0 year of onshore and nearshore marine construction to install the 3,000 foot long trestle from shore to offshore gallery
• 4.9 years of construction traffic passing through HB and other coastal communities carrying all components needed to construct trestle and install SIG via trestle
• 2.2 years of offshore construction of the 25.44 acre SIG
• 2.2 years disposal of dredged marine sediments at approved offshore site</td><td>• 4.3 years of onshore construction in HB on 4 acres of State Beach parking lot for pipe headers and pumps
• 2.5 years of marine vessel traffic between Port of LA/LB and SIG site to carry SIG components to site
• 2.5 years of offshore construction of the 25.44 acre SIG
• 2.5 years of use of construction yard at Port of LA/LB with SIG components carried to port via local roadways
• 2.5 disposal of dredged marine sediments at approved offshore site</td></tr>
<tr><td colspan="2">LONG-TERM OPERATIONAL REQUIREMENTS</td></tr>
<tr><td>• Scraping or light dredging of seabed above SIG (to remove 5 to 10 cm of sediment in order to prevent clogging of natural sediments) would be required every 1 to 3 years to ensure continued effective intake
• Approximately 11,655 linear feet of 20-inch conveyance pipe would be left on the seafloor</td><td>• Scraping or light dredging of seabed above SIG (to remove 5 to 10 cm of sediment in order to prevent clogging of natural sediments) would be required every 1 to 3 years to ensure continued effective intake
• Approximately 21,495 linear feet of 20-inch conveyance pipe would be left on the seafloor</td></tr>
</table>

4.3.3 Environmental Impacts Resulting from Intake Construction and Operation

A range of environmental impacts would be generated, directly or indirectly, as a result of constructing and operating the different SIG construction options. The potential environmental impacts associated with each of the construction activities described in Table 4.1 are broadly described below. SIG construction options addressed here include the trestle and float-in options.

Onshore construction in Huntington Beach State Beach parking lot for pipe headers and pumps (Trestle and Float-in Option)

- **Construction noise:** The construction of the 4-acre gallery for intake pipes and pumps adjacent to the Pacific Coast Highway and Huntington Beach's recreational areas and/or of the trestle would create disturbing levels of noise.
- **Onshore traffic:** A large number of vehicles would be required to construct pipe headers and pump gallery, adding to traffic density on local and regional roadways.
- **Air emissions:** Construction at the beach lot would result in the emissions from construction vehicles including haul trucks, cranes, drills/bores, pile driving, and worker commuting vehicles, and dust from construction activities and drilling.
- **Greenhouse gas emissions** (GHG): Construction vehicle use of fossil fuels results in emission of carbon dioxide (CO_2). Construction emissions of GHG are amortized over the operational life of the project and added to operational emissions.
- **Degradation of coastal views:** The presence of large-scale industrial construction operations on and adjacent to the Huntington Beach recreational area would degrade the existing beach and sunset views.
- **Recreational disturbance:** Recreationists at or adjacent to the beach (beachgoers, trail users, surfers, hotel guests, and oceanfront viewers) would experience a disturbance due to the noise, traffic, dust, and equipment emissions created by construction activities.
- **Disturbance of sensitive biological resources:** Coastal species may be disturbed by onshore or nearshore construction activities. Nearby sensitive species are listed in Appendix F, and include California least tern, snowy plover, California brown pelicans and other wildlife at the Huntington Beach Wetlands.
- **Potential loss of income** to State Beach from loss of parking revenue and to beachfront businesses (retail, hotels, support facilities) if beach visitors opt to go to other beaches during construction.

Onshore and nearshore construction to install the trestle (Trestle only)

- **Air emissions and GHG:** Construction of the trestle would result in air emissions (including CO_2) from construction vehicles, dredges, barges, haul trucks, cranes, drills/bores, pile drivers, and worker commuting vehicles. Impacts would be similar to those associated with demolition of the Huntington Beach Generating Station, just east of Highway 1.

- **Degradation of coastal views:** The multi-year presence of large-scale industrial construction operations on and adjacent to the Huntington Beach recreational area would degrade the existing beach and sunset views.
- **Onshore traffic:** A large number of vehicles would be required to construct the trestle, adding to traffic density on local and regional roadways.

Offshore construction of the SIG (Trestle and Float-in Option)

- **Air emissions and GHG:** Construction of a seafloor infiltration gallery would result in the emissions (including CO_2) from construction vehicles, dredges, barges, haul trucks, cranes, drills/bores, pile driving, and worker commuting vehicles, and dust from onshore construction and drilling.
- **Commercial/recreational fishing:** The construction of a SIG could prevent fishing access to the construction and operational zones.
- **Risk of offshore contamination from construction accidents**: Accidental spills of marine fuels or other contaminants could contaminate the ocean, affecting marine life or recreation.
- **Short-term impact to benthic habitat (marine ecology):** Seafloor disturbance during SIG construction would result in loss of benthic habitat over a 26-acre area, with potential loss of marine life including infaunal invertebrates, epifaunal invertebrates[5], demersal invertebrates, and demersal fishes.

Use of construction yard at Port of LA/LB (Float-in only)

- **Land use disruption:** Conflicts may arise from displacement of existing coastal operations in the Port areas during float-in construction activities.
- **Onshore traffic:** A large number of vehicles would be required to support SIG construction at the Port, adding to traffic density on local and regional roadways.

Disposal of dredged marine sediments at approved offshore site (Trestle and Float-in Option)

- **Marine biology:** Disposal of sediments may affect marine resources in the disposal zone.

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[5] **Infauna** are benthic organisms that live within the bottom substratum of a body of water, especially within the bottom-most oceanic sediments, rather than on its surface. **Epifauna** are aquatic animals (such as starfish, flounder, or barnacles) that live on the surface of a sea or lake bottom or on the surface of a submerged substrate, such as rocks or aquatic plants and animals, but that do not burrow into or beneath the surface.

Operation and maintenance of SIG (Trestle and Float-in Option)

- **Marine ecology (long-term)**: Long-term impingement and entrainment impacts associated with the SIG are expected to be minor due to the filtering of seawater through marine sediments.
- **Marine ecology:** Periodic maintenance (scraping of seabed surface at 1 to 3 year intervals) may be required to ensure adequate continuous intake; this seafloor disturbance may result in longer-term or periodic disturbance to benthic habitat over 20 to 23 acre area.
- **Seafloor obstructions:** The presence of 11,655 to 12,495 linear feet of intake and gathering pipes on the seafloor has the potential to catch anchors of marine vessels.

4.4 Qualitative Comparison of Impacts among SIG Intake Options

In Table 4.2, we list the primary marine and coastal impacts that would likely result from construction and operation of the SIG options. These impacts are characterized as to their likely severity in a qualitative manner. These impacts will be described and evaluated in detail in an EIR if Poseidon proceeds with an application including these intake technologies.

Table 4.2 Qualitative Environmental Impacts of Poseidon Huntington Beach SIG Construction Options

Intake Option>>>>>	SIG-Trestle	SIG-Float In
Entrainment	• **Minor concern** due to small amount of entrainment of some marine organisms	• **Minor concern** due to small amount of entrainment of some marine organisms
Impingement	• **No concern** for SIG given filtration of intake water through marine sediments and gravel	• **No concern** for SIG given filtration of intake water through marine sediments and gravel
Construction effects on marine habitat at SIG/trestle site	• **Moderate concern** due to short-term disturbance to habitat (primarily during construction) due to seafloor disturbance from construction of trestle and SIG	• **Moderate concern** due to short-term disturbance to habitat (primarily during construction), due to seafloor disturbance from construction of SIG
Maintenance effects on marine habitat at SIG site	• **Minor concern** due to periodic maintenance requiring site scraping	• **Minor concern** due to periodic maintenance requiring site scraping
Degradation of coastal views	• **Major concern** (but short-term during construction) due to large-scale beachfront construction of intake system and trestle	• **Major concern** (but short-term during construction) due to large-scale beachfront construction of intake system

Table 4.2 Qualitative Environmental Impacts of Poseidon Huntington Beach SIG Construction Options

Intake Option>>>>>	**SIG-Trestle**	**SIG-Float In**
Air emission during construction	• **Major concern** during the 5 to 7 year construction period due to vehicles and equipment required	• **Major concern** during the 5 to 7 year construction period due to vehicles and equipment required
Greenhouse gas	• **Moderate concern**, but cumulatively important, when amortized over operational life of the SWRO plant	• **Moderate concern**, but cumulatively important, when amortized over operational life of the SWRO plant
Operational energy use	• **Minor concern**	• **Minor concern**
Onshore vehicle traffic	• **Moderate concern** during the 5 to 7 year construction period due to vehicle traffic passing through beachfront communities	• **Moderate concern** during the 5 to 7 year construction period due to vehicle traffic passing through beachfront communities
Construction noise	• **Major concern** during the 5 to 7 year construction period due to beachfront activity	• **Major concern** during the 5 to 7 year construction period due to beachfront activity
Recreational effects	• **Major concern** during the 5 to 7 year construction period due to beachfront activity	• **Major concern** during the 5 to 7 year construction period due to beachfront activity
Onshore biological resources	• **Potential concern** due to sensitive avian species nesting nearby. Potential for disturbance of reserve south of Talbert Channel, 1.5 miles south	• **Potential concern** due to sensitive avian species nesting nearby
Recreational and commercial fishing	• **Minor concern** due to infrequent use of SIG area for fishing	• **Minor concern** due to infrequent use of SIG area for fishing
Seafloor obstructions	• **Minor concern** for anchor catch during life of project	• **Minor concern** for anchor catch during life of project
Potential loss of tourist income	• **Major concern** during the 5 to 7 year construction period due to reduction of beachfront parking and construction disturbance to beachgoers	• **Major concern** during the 5 to 7 year construction period due to reduction of beachfront parking and construction disturbance to beachgoers

4.5 Effects of Environmental Impacts on Project Feasibility

The Panel considered whether the environmental impacts defined broadly in Section 4.3.2 might result in any of the intake options being infeasible with respect to the social and environmental factors. A finding of infeasibility related to environmental impacts could result from:

(a) Impacts so severe that a lead agency would be unable to make a finding that there was an overriding benefit to the project and would therefore deny project approval;

(b) Conflict with existing regulations or policies that would prevent agency approval, or

(c) Mitigation costs that could be so high as to cause Poseidon to find that the project would not be economically viable.

The third item, mitigation cost, is considered in Section 5, economic analysis. Most of the impacts described in Section 4.3.2 are not anticipated to result in any of these situations. However, the extensive and lengthy beachfront disturbance required for construction of the SIG (including the trestle or the pipe and pump gallery), as defined in Table 4.1, may be of serious concern to the City of Huntington Beach due to the importance of beach tourism, recreation, and tourist income to the City. The City would consider the potential severity of these impacts in the context of the industrial character of the power plant site and nearby oil and gas development.

While many of the SIG impacts have the potential to be severe and to create substantial disturbance over a period of as long as 7 years, there is a range of typical mitigation measures that would likely be implemented to reduce the severity of these effects.

Examples of typical mitigation for a major coastal construction project are:

- Purchase of air emissions credits; use of specific low-emission engines
- Installation of fencing, screening, or noise barriers around beachfront construction sites
- Use of shuttle buses to carry beachgoers to additional parking locations
- Implementation of seasonal noise limitations to protect nesting bird species
- Notification of construction activities and processes to local businesses to allow planning of events at lower impact times
- Implementation of traffic control plans to avoid peak traffic times and maximize use of designated roadways
- Publication of marine vessel traffic patterns and frequency.

The costs of implementing these types of mitigation are not generally so high that they would affect the financial viability of a major infrastructure project.

At the February 18, 2015 workshop, representatives of the City of Huntington Beach and the Chamber of Commerce spoke about the extremely high value of beach tourism and recreational opportunities to city and business interests. The City would have to consider whether these types of mitigation measures could effectively mitigate the effects of the onshore and nearshore construction activities required for the SIG. These impacts would likely be compared with the impacts of the open ocean intake. In approving a revised project, the City would have to consider whether the desalination project itself has long-term benefits that would outweigh the severity of the beachfront construction impacts.

Chapter V. ECONOMIC ANALYSIS FRAMEWORK

5.1 Introduction

In this section we present the ISTAP's economic analysis of the three intake design/construction alternatives for the proposed desalination facility in Huntington Beach, California. Based on the results of this analysis, we also partially characterize the feasibility of each intake option based on economic and financial considerations. This section is organized as follows:

- Section 5.2 describes the range of capital, operation and maintenance (O&M), and social and environmental mitigation costs that we used to characterize the economic and financial feasibility of the intake options.
- Section 5.3 provides an overview of the life cycle cost analysis of the intake design alternatives, and describes the impact of different assumptions on the life cycle costs. The life cycle cost, presented as an annualized unit cost per acre-foot (AF) of water produced (unit cost), allows the cost of the product water to be directly compared across design and financial scenarios.
- Section 5.4 examines the price that Orange County Water District (OCWD) might be willing to pay for water supplied by the proposed desalination facility (the water price). Using OCWD's Water Purchase Agreement Term Sheet as a starting point, we based the OCWD water price on the amount that OCWD will likely have to pay for water supplied by the Metropolitan Water District (MWD) of Southern California in the future because OCWD would rely on MWD water if the desalination facility is not constructed. On top of this price, we have factored in a subsidy that MWD provides local communities for developing local water supplies, as well as a premium that OCWD has indicated it is willing to pay for the increased water supply reliability that the desalination plant will provide relative to MWD supplies. Ultimately, the OCWD water price will be based on negotiations between OCWD and Poseidon.
- Section 5.5 evaluates the likelihood that project revenues will cover project costs over the life of the project. In this section, we compare the unit cost (to Poseidon) of water supplied by the project with the amount that OCWD might pay for that water as identified in its current Term Sheet.
- Section 5.6 discusses several factors that affect the economic viability of the project alternatives. This evaluation is based on two criteria. One is the likelihood that project revenues will cover project costs, as discussed in Section 5.5. The other criteria include difficult to quantify risks associated with the different project alternatives, as well as uncertainty about the unit cost of water and the OCWD water price.
- Section 5.7 presents conclusions regarding economic viability of the intake options.

5.2 Costs of the Intake Design Alternatives

In this section, we describe the capital and operating and maintenance (O&M) costs of the three different intake design alternatives. For this analysis, we analyzed data provided by Poseidon, Coastal Commission staff, and members of the ISTAP to develop a range of cost estimates. We then used the lower and upper end of this range to develop two sets of cost estimates for further analysis – a high cost estimate and a low cost estimate.

To form the basis for our "high cost estimate", we relied primarily on capital and O&M cost information provided by Poseidon for a 50 MGD product capacity desalination facility and each intake alternative. We then revised these figures, using Panel expertise and recommendations from Coastal Commission staff. These costs form the basis of our "low cost estimates". Relative to the higher cost estimates provided by Poseidon, the low cost estimates reflect O&M savings associated with reduced SIG pretreatment requirements and a shorter period of continuous construction for the SIG alternatives. In some cases, we also revised Poseidon's capital cost estimates; these revisions are reflected in the low cost estimate scenario. The "high" and "low" estimate terminology refers to the relative magnitude of the annualized cost estimates—they do not necessarily represent high bound and low bound estimates of the capital or O&M costs of the different options.

Both sets of costs include comprehensive estimates for each intake design alternative. This includes the costs associated with constructing and operating the alternative intake options, as well as the desalination facility itself. Both scenarios also include costs associated with decommissioning the desalination facility at the end of its expected life (we assume these costs are same across all intake design alternatives). The cost estimates do not include costs associated with constructing distribution pipelines or the cost of delivering water to customers[6].

For the open ocean intake, both sets of capital costs include estimates for traveling screens. On April 24, 2015, partway through the Phase 2 ISTAP process, the State Water Resources Control Board released a draft Final desalination amendment to the Ocean Plan indicating that all surface water intakes must be screened with 1.0 mm (0.04 in) passive screens. However, the Panel chose not to evaluate a design using passive screens as these were not contained in the original Poseidon proposal, nor were detailed costs estimated. Such a work effort may be required in the future if and when new passive screen designs are proposed.

Both sets of estimates for the open ocean intake also include costs associated with environmental mitigation that Coastal Commission staff has indicated it will require Poseidon to implement to further offset impingement and entrainment impacts. In the high cost scenario, we included Poseidon's estimate of upfront environmental mitigation costs of $5.9 million, and ongoing annual maintenance requirements of $300,000. In the second set of cost estimates (i.e., the revised or low cost estimates), we used the

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[6] The OCWD estimates that the distribution pipeline(s) and delivery costs would be an additional $100 to $250 per acre-foot.

Coastal Commission staff estimates of $53 million for capital and $1,000,000 for annual O&M mitigation costs[7], which are significantly higher. Both Poseidon's and the Coastal Commission's environmental mitigation cost estimates are based on the costs for similar mitigation that Poseidon has implemented at its Carlsbad desalination facility in San Diego County, with the main difference being the amount of mitigation acreage Coastal Commission staff and Poseidon expect to be required. Coastal Commission staff has indicated that it is unlikely to require environmental mitigation for impingement and entrainment effects if Poseidon constructs one of the SIG design alternatives. We have therefore not included environmental mitigation costs for the SIG alternatives under either cost scenario.

As described in Section 3, both SIG alternatives would require construction of pipe galleries and pumps below the State Beach parking lot. Under both sets of capital costs for the SIG alternatives, we have included mitigation costs associated with anticipated Coastal Commission policies to offset the impacts of this aspect of construction on beach recreation. Coastal Commission staff estimates that these costs will amount to approximately $18,000 for each month that beach access or recreation opportunities are impeded over the construction period. These costs are minimal in comparison to the costs of constructing and operating the SIG.

Once we developed two sets of comprehensive cost estimates for each intake alternative at a 50 MGD product/106 MGD intake capacity, we applied scaling factors from peer-reviewed literature to estimate the capital costs associated with alternative product scales (e.g., 12.5, 25, and 100 MGD product capacity facilities). Our scalars reflect the economies of scale associated with constructing larger facilities. Specifically, we estimated that relative to a 50 MGD product capacity facility, the capital costs of a 12.5 MGD product capacity facility would be about 28% more per AF, the 25 MGD product capacity facility would cost about 12.5% more per AF, and the 100 MGD product capacity facility would cost about 8% less. For O&M costs, we assume the same per AF cost across all project scales.

Table 5.1 presents the high and low capital cost estimates for each intake design at a 50 MGD product capacity scale (see Appendix D for the capital and mitigation costs associated with the different project scales). These estimates include inflation. For the life cycle analysis described in Section 4, we take out inflation so that we can compare all costs in present value terms.

Table 5.1 shows that the open ocean intake alternative has significantly lower capital costs than either of the SIG alternatives under both cost scenarios. The capital cost of the open ocean intake facility ranges between $850 and $899 million across estimates. The difference between the high and low cost estimates for the open ocean intake is primarily due to the different assumptions about the cost of environmental mitigation.

The capital costs for the SIG-trestle alternative vary significantly between estimates. The high estimate sets construction costs for this option at $2.35 billion; the low estimate at only $1.94 billion. The cost

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[7] This estimate represents the mid-point of the Coastal Commission staff estimates for mitigation costs associated with a 50 MGD open ocean intake, which range from $35 to $71 million.

differential is largely explained by different assumptions about the construction period—the low estimate assumes 4.83 years of construction and the high estimate, 7 years. The longer construction time period increases overall construction and administration costs, as well as financing costs, which account for a large portion of total project costs.

For the SIG-Float-in option, the high and low estimates are very similar – both assume it will cost about $2.12 billion to construct the desalination plant with this intake design. In this case, the high and low estimates both assume a 5.25-year construction period.

Table 5.2 shows the estimated O&M costs for the open ocean and SIG intake designs for both cost estimate scenarios (the O&M costs of the SIG are assumed to be the same under the Trestle or Float-in construction methods). A primary explanation for the difference between the high and low O&M cost estimates is that the ISTAP used different assumptions for calculating the ad valorem tax. The high estimate assumes that these taxes will be based on construction costs, rather than property value (which does not always directly correlate with construction costs) or expected revenues from the desalination facility. The ISTAP does not agree that property taxes would necessarily be based on the costs associated with constructing the desalination facility. We have therefore not included the ad valorem tax in the low estimate for O&M costs.

Table 5.1 ISTAP High and low capital cost estimates for alternative intake designs, 50 MGD product capacity facility

	High Estimate			**Low Estimate**		
	Proposed	**SIG - Trestle**	**SIG Float In**	**Proposed**	**SIG - Trestle**	**SIG Float In**
Construction period (years)	2.75	7.0	5.25	2.75	4.83	5.25
Construction Costs						
RO & Facility	353,140,679	353,140,679	353,140,679	353,140,679	353,140,679	353,140,679
Intake Pump Station	42,547,070			42,547,070		
Pretreatment	49,992,807	41,483,393	41,483,393	49,992,807	41,483,393	41,483,393
Screen Retrofit	8,700,000			8,700,000		
Diffuser	30,468,125	30,468,125	30,468,125	30,468,125	30,468,125	30,468,125
SIG[a]		696,528,961	722,018,641		640,618,094	718,296,639
Power Substation	13,215,277	13,215,277	13,215,277	13,215,277	13,215,277	13,215,277
Owners Project Management and Inspection	11,805,207	39,702,383	29,138,219	11,805,207	26,682,562	29,138,219
Construction Insurance	3,754,864	16,591,408	12,368,154	3,754,864	10,765,942	12,340,198
Construction Beach SLC Rent		37,246,819	27,935,115		25,718,042	27,935,115
Project Contingency	30,000,000	90,786,915	92,826,089	30,000,000	86,314,045	92,528,329
Subtotal	**543,624,029**	**1,319,163,960**	**1,322,593,692**	**543,624,029**	**1,228,406,159**	**1,318,545,974**
Non-construction capital costs						
Construction Period Financing Costs	146,288,372	806,020,071	576,702,012	146,288,372	493,935,028	574,789,736
Closing Related Costs	116,576,712	172,571,695	170,466,903	116,576,712	168,949,757	170,411,363
Reserves	30,160,871	39,193,306	35,677,485	30,160,871	35,046,600	35,655,949
Subtotal	**293,025,955**	**1,017,785,072**	**7,828,464,00**	**293,025,955**	**697,931,385**	**780,857,048**
Mitigation costs						
Marine Life mitigation	5,951,900			53,000,000		
Mitigation for lost recreation		1,008,000	756,000		695,520	756,000
Subtotal	**5,951,900**	**1,008,000**	**756,000**	**53,000,000**	**695,520**	**756,000**
Decommissioning costs	**9,000,000**	**9,000,000**	**9,000,000**	**9,000,000**	**9,000,000**	**9,000,000**
Total Project Capital Cost	**851,601,884**	**2,346,957,032**	**2,115,196,091**	**898,649,984**	**1,936,033,064**	**2,109,159,022**

a. With the exception of the cost estimates for SIG construction, all costs shown here represent Category II cost estimates, meaning that they might range from -15% to +25% of the estimates shown here .The cost estimates for the SIG represent Category IV cost estimates, meaning they have a range of uncertainty of -30% to +50%

Table 5.2 High and low annual O&M cost estimates for alternative intake designs, 50 MGD product capacity facility

	High Estimate		**Low Estimate**	
	Open ocean intake	**SIG (Trestle and Float In)**	**Open ocean intake**	**SIG (Trestle and Float In+)**
General Maintenance				
Chemicals	3,761,112	2,880,374	3,912,561	2,637,754
Maintenance (Repair and Replacement)	2,960,910	3,446,050	2,749,000	2,000,000
Labor	4,032,780	4,032,780	3,745,000	3,400,000
Membrane Replacement	1,120,217	861,513	1,040,000	800,000
Disposal	1,030,993	161,534	957,000	150,000
Operator Fee	4,545,918	4,545,918	4,221,000	4,221,000
Subtotal	**17,451,930**	**15,928,169**	**16,624,561**	**13,208,754**
Power (assuming cost of $0.10/kWh)	**22,676,623**	**20,038,403**	**22,676,623**	**20,038,403**
Miscellaneous maintenance costs (e.g., management, insurance, taxes)	**13,948,000**	**21,893,000**	**9,100,000**	**8,400,000**
Annual marine life mitigation	**300,000**		**1,000,000**	
TOTAL Annual O&M costs	**54,376,552**	**57,859,572**	**49,401,184**	**41,647,157**

5.3 Life Cycle Cost Analysis

This section presents the results of the life cycle cost analyses that we conducted for the desalination facility with the different intake options. These analyses compare the present value capital, O&M, and mitigation costs that occur over the lifetime of the desalination facility under various scenarios. These scenarios are based on the following components:

- The two comprehensive capital and O&M cost estimates (i.e., high and low estimates) described in Section 3
- Four facility project scales: 12.5, 25, 50, and 100 MGD product capacity (Equivalent to 25, 50, 100 and 200 MGD intake capacity)
- Two project analysis periods, including 30-year and 50-year expected project life times
- Two discount rates, 3% and 7%, based on the U.S. Office of Management and Budget's recommendations for the range of discount rates to include in benefit cost analyses of public projects

Thus, for each of the three intake options, we evaluated 32 scenarios (a total of 96 scenarios) for the life cycle cost analysis. Table 5.3 provides an example of a life cycle cost analysis for each intake option assuming the low cost estimate, a 3% discount rate, and a 50-year project life. The capital costs reflected in this table differ slightly from those presented in Section 3 because we have taken out inflation in order to compare real costs over time.

As shown in Table 5.3, the costs associated with the SIG alternatives are closer to the costs of the open ocean intake when evaluated over time due primarily to O&M cost savings associated with the SIG alternatives. The difference is somewhat greater when we assume a 30-year project life.

Table 5.3 Example life cycle cost analysis for alternative intake options, using ISTAP's low capital and O&M cost estimates, 3% discount rate, and 50-year analysis period

	Open Ocean intake			**SIG - Trestle**			**SIG Float In**		
Year	**Capital**	**O&M**[b]	**PV total**	**Capital**	**O&M**	**PV total**	**Capital**	**O&M**	**PV total**
2015	326,345,449		326,345,449	398,971,649		398,971,649	400,030,290		400,030,290
2016	320,480,653		311,146,265	391,801,678		380,389,979	392,841,294		381,399,315
2017	236,040,940		222,491,225	384,760,560		362,673,730	385,781,493		363,636,057
2018		49,401,184	45,209,081	377,845,978		345,782,596	378,848,564		346,700,104
2019		49,401,184	43,892,312	307,976,198		273,632,863	372,040,228		330,552,924
2020		49,401,184	42,613,895		41,647,157	35,925,203	100,007,572		86,267,411
2021		49,401,184	41,372,714		41,647,157	34,878,838		41,647,157	34,878,838
2022		49,401,184	40,167,683		41,647,157	33,862,950		41,647,157	33,862,950
2023		49,401,184	38,997,751		41,647,157	32,876,650		41,647,157	32,876,650
.....		......	.....	.....	.....	.....	.....	.....	.....
.....		.....	.....	.....	.....	.....	.....	.....	.....
2065		49,401,184	19,759,838		41,647,157	16,658,327		41,647,157	16,658,327
2066		49,401,184	19,759,838		41,647,157	16,658,327		41,647,157	16,658,327
2067		49,401,184	19,184,309		41,647,157	16,173,133		41,647,157	16,173,133
2068	9,000,000[a]		3,393,236		41,647,157	15,702,071		41,647,157	15,702,071
2069			0		41,647,157	15,244,729		41,647,157	15,244,729
2070			0	9,000,000		3,198,451		41,647,157	14,800,708
2071			0			0	9,000,000		3,105,292
Total			$2,059,977,251			$2,715,299,130			$2,832,933,100

a. The $9,000,000 at the end of each option's expected life represent estimated decommissioning costs

b. For each option, we evaluated costs associated with 50-years of plant operation. Due to the different construction periods, the analysis period for each option ends in a different year.

To provide a more direct comparison of project costs over time, we developed unit costs that reflect the cost of water per acre-foot of production. To develop these estimates, we divided the total present value costs over time (as demonstrated in Table 5.3 above) by the amount of water that the desalination facility will produce over time (in present value terms). The unit costs provide a quick way to examine the key variables that affect total costs, including discount rates, project life, and construction period. As described in more detail in Section 5.4, we also use these estimates to compare the cost of desalinated water to the amount that Orange County Water District (OCWD) has initially proposed that it is willing to pay for water on a per-AF basis.

Tables 5.4 through 5.7 present the unit costs under various scenarios for each project scale. Cost estimates for the open ocean intake range from about $1,500/AF to $2,600/AF, depending on project scale, discount rate, expected project life, and the source of the cost estimates. These estimates are similar to estimates reported in the desalination literature (e.g., Raucher and Tchobanoglous, 2014). However, the unit costs of the SIG trestle and SIG Float In alternatives, between $2,000/AF and $5,800/AF, are generally higher than the reported estimates in the desalination literature.

Table 5.4 Unit cost of desalination facility with alternative intake options, across life cycle cost analysis scenarios, 50 MGD product capacity facility

Project life (years)	Discount rate	Cost estimate	Open Ocean ($/AF)	SIG – Trestle ($/AF)	SIG – Float In ($/AF)
30	3%	High	1,754	3,250	3,050
30	3%	Low	1,716	2,553	2,762
30	7%	High	2,259	4,995	4,601
30	7%	Low	2,254	3,847	4,314
50	3%	High	1,567	2,721	2,568
50	3%	Low	1,517	2,121	2,279
50	7%	High	2,128	4,595	4,241
50	7%	Low	2,115	3,533	3,953
		Minimum	1,517	2,121	2,279
		Maximum	2,259	4,995	4,601

Note: These costs do not include construction and operation of the water distribution pipeline.

Table 5.5 Unit cost of alternative intake options, across life cycle cost analysis scenarios, 12.5 MGD product capacity facility

Project life (years)	**Discount rate**	**Cost estimate**	**Open Ocean ($/AF)**	**SIG – Trestle ($/AF)**	**SIG –Float In ($/AF)**
30	3%	High	1,974	3,842	3,540
30	3%	Low	1,950	3,048	3,243
30	7%	High	2,596	5,776	5,170
30	7%	Low	2,613	4,559	4,868
50	3%	High	1,734	3,171	2,941
50	3%	Low	1,694	2,497	2,646
50	7%	High	2,431	5,297	4,751
50	7%	Low	2,437	4,173	4,450
		Minimum	1,694	2,497	2,646
		Maximum	2,613	5,776	5,170

Table 5.6 Unit cost of alternative intake options, across life cycle cost analysis scenarios, 25 MGD product capacity facility

Project life (years)	**Discount rate**	**Cost estimate**	**Open Ocean ($/AF)**	**SIG – Trestle ($/AF)**	**SIG – Float In ($/AF)**
30	3%	High	1,863	3,540	3,228
30	3%	Low	1,833	2,765	2,932
30	7%	High	2,458	5,469	4,715
30	7%	Low	2,466	4,149	4,414
50	3%	High	1,650	2,941	2,704
50	3%	Low	1,605	2,282	2,410
50	7%	High	2,307	5,020	4,342
50	7%	Low	2,305	3,805	4,043
		Minimum	1,605	2,282	2,410
		Maximum	2,466	5,469	4,715

Table 5.7 Unit cost of alternative intake options, across life cycle cost analysis scenarios, 100 MGD product capacity facility

Project life (years)	**Discount rate**	**Cost estimate**	**Open Ocean ($/AF)**	**SIG – Trestle ($/AF)**	**SIG – Float In ($/AF)**
30	3%	High	1,692	3,125	2,871
30	3%	Low	1,650	2,408	2,601
30	7%	High	2,156	4,971	4,317
30	7%	Low	2,145	3,599	4,029
50	3%	High	1,519	2,624	2,432
50	3%	Low	1,466	2,011	2,156
50	7%	High	2,036	4,573	3,985
50	7%	Low	2,016	3,310	3,696
		Minimum	1,466	2,011	2,156
		Maximum	2,156	4,971	4,317

The large unit cost variation in Tables 5.4 – 5.7 is explained by five variables—differences in intake technology, discount rate, source of cost data, project life cycle and project scale. Of these, the intake technology has the largest influence on unit cost.

Table 5.8 highlights the influence of these variables on unit cost (Table 5.8). Technology has the largest single impact on unit cost. Averaged over project scales and life cycle scenarios, the open ocean intake unit cost ($1,997/AF) is 45% lower than the average SIG intake unit cost ($3,607/AF) (Table 5.8).

The choice of a discount rate also has a large impact on unit cost. The unit cost balances discounted future operating revenue with up front construction cost. Discounting increases the unit cost as needed to maintain this balance. The average unit cost of the intake options estimated with a 3% discount rate ($2,426/AF) is 36% lower than the unit cost of these options based on a 7% discount rate ($3,714/AF).

The data source and assumptions have relatively less importance in explaining unit cost differences. With the exception of the SIG trestle, the low and high capital cost estimates are relatively similar. The average low unit cost estimate ($2,859/AF) is 13% lower than the average high unit cost estimate ($3,281/AF) (Table 5.8).

Table 5.8 Sensitivity of Unit Cost to Intake Option and Lifecycle Scenario

	Open Ocean Intake ($/AF)	**SIG – Trestle ($/AF)**	**SIG – Float In ($/AF)**	**Average ($/AF)**	**Unit cost impact (decrease)**
Technology					
SIG		$3,643	$3,570	$3,607	
Open Ocean	$1,997			$1,997	45%
Discount rate					
7%	$2,295	$4,479	$4,368	$3,714	
3%	$1,699	$2,806	$2,773	$2,426	35%
Data source					
High	$2,008	$4,119	$3,716	$3,281	
Low	$1,986	$3,166	$3,425	$2,859	13%
Project Life					
30 years	$2,086	$3,868	$3,791	$3,249	
50 years	$1,908	$3,417	$3,350	$2,892	11%
Project scale					
25 MGD-product	$2,061	$3,746	$3,598	$3,135	
50 MGD-product	$1,914	$3,452	$3,471	$2,946	6%

5.4 Expected Costs to OCWD

The price that OCWD might pay Poseidon for water from the desalination facility will depend on the outcome of ongoing contract negotiations. In the current term sheet, OCWD has indicated that it might be willing to pay an amount equal to the price of MWD water, plus a reliability premium and MWD's local water supply subsidy.

To help evaluate the economic feasibility of the different desalination facility intake options, we estimated OCWD's costs for water from the desalination facility based on established forecasts of MWD water rates (as developed by MWD). The base rate that MWD charges for treated water (Tier 1 rate) is currently (2015) $1,081/AF. In recent history, the Tier 1 rate has increased between 1% and 5% annually in real dollars. In this analysis, we assume the Tier 1 rate will increase in the near future as it has in the recent past, by 3.3% between 2015 and 2025, on average[8]. We assume the annual rate of increase will drop back to 3% per year after 2025.

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[8] These assumptions are based on MWD's forecasted rates, minus inflation

In addition to the MWD rates, OCWD has indicated that it is willing to pay a reliability premium for locally produced water. Consistent with our understanding of the ongoing contract discussions, in our projections we assume that the reliability premium amounts to 20% of MWD's Tier 1 water price for 10 years after construction. The premium drops to 15% of the Tier 1 price for the next ten years, to 10% for 10 more years, to 5% for ten years, and then finally to 0%.

As noted above, MWD currently provides a subsidy to communities that develop local water supplies (including desalination) to offset reliance on MWD water. We assume that MWD will continue to provide this subsidy into the future. The subsidy varies according to the unit cost of the local supplies that are developed. There are currently three subsidy options that may be available to OCWD, including a sliding scale of up to $340/AF for 25 years, a sliding scale for up to $475/AF for 15 years and a fixed $305/AF for 25 years. OCWD's current term sheet is based on the second option, a maximum of $475/AF for up to 15 years, provided that the cost of the local supply exceeds MWD rates by this amount.

We used these assumptions to project the amount that OCWD might be willing to pay for desalinated water under the current term sheet. Specifically, we estimate that in 2020, OCWD will be willing to pay $1,977/AF for water; this amount increases to $2,260/AF in 2025, $3,020/AF in 2040 and about $3,700/AF in 2050 for the SIG options (Figure 5.1)[9]. Appendix E provides additional information about these projections.

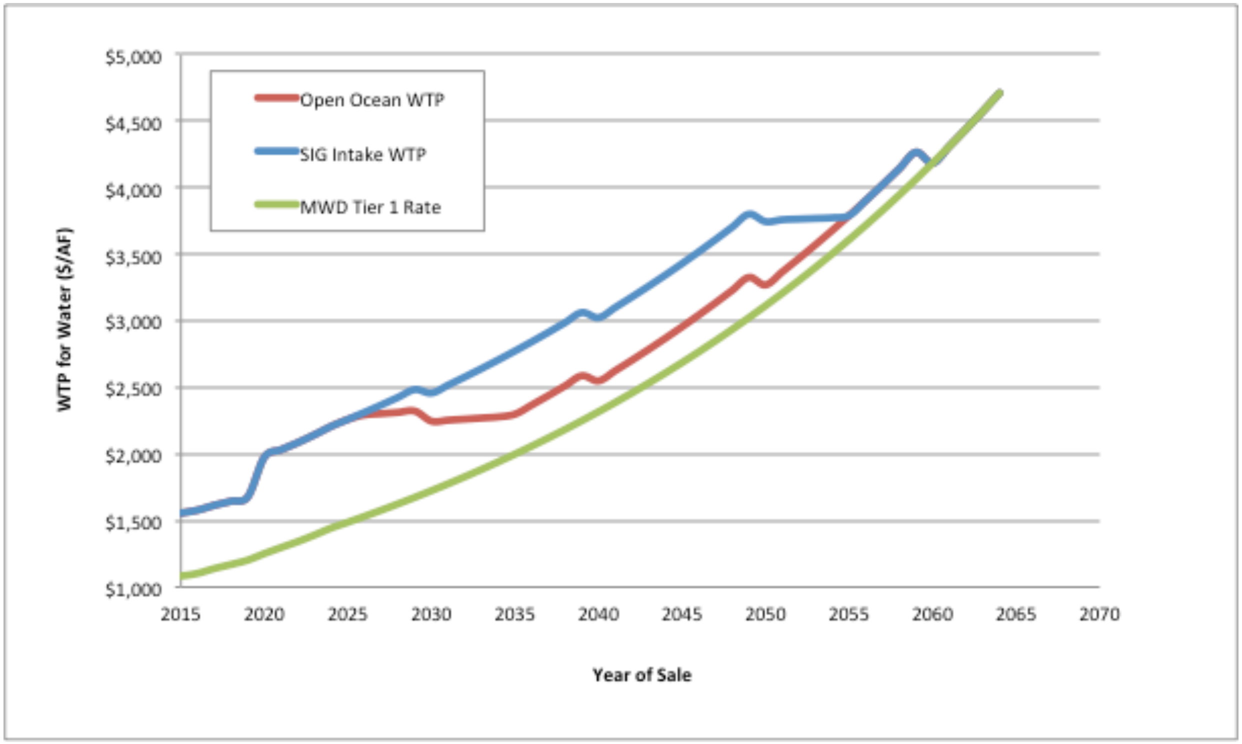

Figure 5.1 Forecast Price that Orange County Water District Would Pay for Water from a Huntington Beach Desalination Facility

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[9] These amounts are for the SIG alternatives, which would likely receive a higher MWD subsidy amount in later years (i.e., the full $475 for 15 years) compared to the open ocean intake.

5.5 Characterizing Components of Economic Feasibility

Although there are several criteria that may be used to assess the feasibility of project alternatives, in this section we focus primarily on cost recovery and risk.

In this context, economic feasibility relies in large part on the likelihood that anticipated plant revenues will cover the project costs within a reasonable time frame. Thus, our principal consideration for determining economic feasibility is the likelihood in any given year that OCWD will be willing to pay Poseidon's costs to construct and operate the desalination facility.

As described above, the amount that OCWD will pay for water will rise over time, from around $1500/AF today (2015) to about $3700/AF after 2050 (for the SIG options), due in large part to expected increases in MWD water rates. It follows that the economic feasibility of a given water supply alternative will change over time. For example, constructing a desalination facility with a SIG intake system may not currently be economically feasible, but may become feasible in the future as OCWD's willingness to pay for water increases. For the purposes of this report, we assume project feasibility to occur in the first year that expected revenues equal expected costs—termed the cost recovery year.

Figure 5.2 shows the relationship between the desalination facility unit cost and cost recovery year. The unit cost of selected project scenarios are displayed on the y-axis and the associated cost recovery years are indicated on the x-axis. As shown, the average unit cost of the selected scenarios range from a low of $1,639/AF, for the open ocean intake, 3% discount rate, 50 MGD scenario to over $4,666/AF for the SIG Trestle intake, 25 MGD, 7% discount rate scenario. The associated cost recovery years range from 2018 for the open ocean intake, 3% discount rate, 50 MGD scenario, to 2064 for the SIG Trestle, 7% discount rate, 25 MGD scenario.

In general, the unit costs of the open ocean intake facility scenarios are low, compared to those of the SIG intake scenarios, and cost recovery occurs much sooner. For example, at a 7% discount rate, unit costs for a 50 MGD desalination facility with an open ocean intake average $2,189/AF, and range between $2,115 and $2,259/AF. We expect that OCWD would be willing to pay this amount for water in 2024, although the cost recovery year would vary with the actual cost.

Comparatively, for a 50 MGD desalination facility with a SIG trestle intake system, the unit costs associated with a 7% discount rate average $4,243/AF, and range from $3,533/AF to $4,995/AF. Based on the average unit cost, cost recovery for this facility would not be expected to occur until 2059.

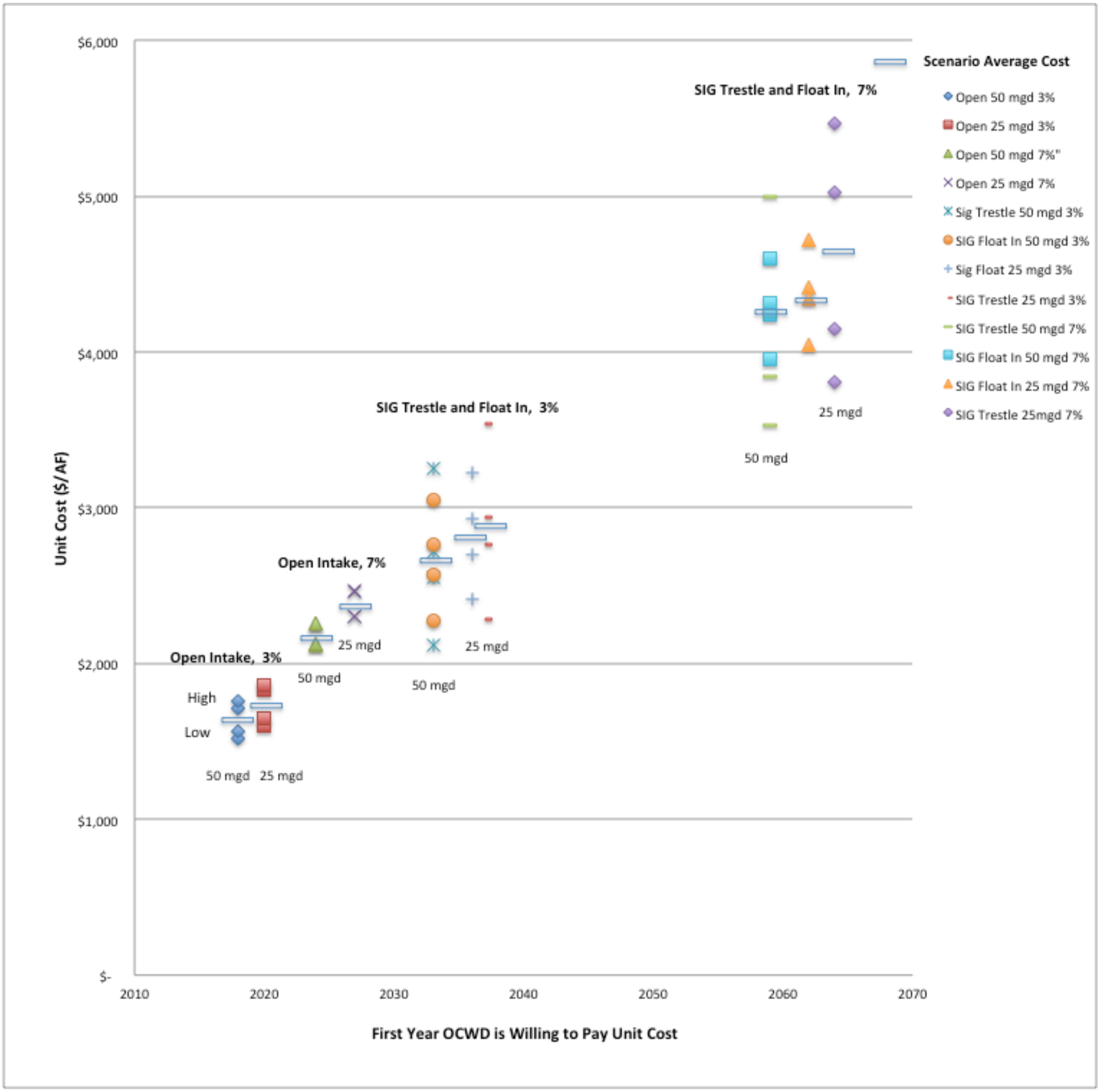

Figure 5.2 The Unit Cost to Produce Water and First Year of Project Feasibility[10]

5.6 Discussion Regarding Economic Feasibility

In section 5.5 above, we provided estimates of the costs associated with supplying desalinated water using different technologies and financial assumptions, as well as estimates for the price that OCWD might be willing to pay for water under the current term sheet. These cost and price estimates are both preliminary and uncertain. We have a relatively high degree of confidence about the cost of supplying water for the open ocean intake alternative—costs derived from construction of a similar plant in San Diego. We are less confident about costs associated with building the Trestle and Float In SIG alternatives. Engineers have classified these costs as Category IV, meaning that the actual cost could be 50% above or 30% below the estimated cost. (See e.g., ASTM Standard E2516-11, Standard Classification for Cost Estimate

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[10] This figure categorizes cost estimates by technology, scale and discount rate to allow for a fair comparison of alternatives. The range of cost estimates within these categories represent differences in the data source and expected project lifespan. Project feasibility is determined for each category's average unit cost.

Classification System, March 2015). Finally, we are uncertain about the price that OCWD might pay for water since this price is subject to ongoing negotiation, and we cannot predict how MWD water rates will increase over time.

Despite this uncertainty, these cost and price estimates provide the best available information for evaluating the economic feasibility of alternative intake options for the proposed desalination plant in Huntington Beach. Following, we assume that economic feasibility occurs when the projected price OCWD might pay for water exceeds the estimated unit cost to supply water. Comparing expected cost and price projections suggests that OCWD might be willing to pay for water produced from an open ocean intake facility in 2018. The expected cost estimates for the 50 MGD Trestle and Float-in scenarios indicate feasibility might be achieved between 2033 (given 3% discounting) and 2059, (given 7% discounting).

It has been suggested that the cost recovery year for the SIG option could be decreased by considering a hybrid alternative consisting of initial construction and operation of desalination facility with an open ocean intake, and simultaneously constructing the SIG intake structure. With this option, the project proponent could potentially provide product water using the open ocean intake until the cost that the OCWD might be willing to pay begins to approach the unit cost of production. We see a number of limitations of this approach including increased desalination construction costs to modify pretreatment facilities, construction complexities on the pump stations during the change over from the open ocean intake to the SIG, and high financing costs due to higher risk premiums of an even more complex project. However, we did not have sufficient information at our disposal to assess the full merits or risks of this alternative.

Finally, it should be noted that cost and price are not the only criteria that need to be considered in making a judgment about the feasibility of the different intake options. Other criteria include several factors that are difficult to monetize, but that will likely weigh heavily in agency permitting and in Poseidon's decision making. These other factors of concern are addressed in other sections of this report and include construction risks or challenges (see Section 3), which may occur since the SIG options have not been constructed at this scale, and a range of environmental and social concerns (see Section 4).

Chapter VI. CONCLUSIONS

6.1 The beach infiltration gallery is infeasible at the Huntington Beach location

At the initiation of Phase 2, we reconsidered the feasibility of the beach infiltration gallery technology that had been retained as likely feasible by the Phase 1 ISTAP. Several factors lead us to find that this technical option is infeasible at the Huntington Beach location. First, our additional engineering design assessment concluded that a substantially larger gallery would likely be required compared to the considerations in Phase 1. Second, we further considered the periodic beach re-nourishment schedule, which means that the surf zone migrates following nourishment cycles, reducing the effectiveness of the intake filtration through the sand. Third, construction of a larger-than-anticipated gallery would require many years to construct due to construction constraints on a highly used public beach.

6.2 Two construction methods are feasible for constructing the SIG

In addition to the trestle construction method suggested by Poseidon, the panel suggested consideration of a second, more efficient and less disruptive construction method for the SIG. This "float-in" construction method would not require construction of a trestle and would involve use of pre-fabricated cells brought to the offshore site from industrial port construction sites (Ports of Los Angeles or Long Beach).

6.3 The environmental impacts of the SIG options would not likely prohibit their implementation

The construction of either SIG option would create highly visible and disruptive activities at the Huntington Beach waterfront and in the nearshore environment. The Panel concludes that, while the environmental impacts of the SIG options, regardless of construction methods, would be potentially severe, they would still be short-term in comparison with the operational life of the desalination facility (30 to 50 years). Therefore, assuming implementation of commonly-used coastal mitigation techniques and serious consideration of methods to protect coastal recreation and tourism income, the environmental effects are not considered likely to result in either SIG option being found to be infeasible.

6.4 The open ocean intake option for a product capacity of 50 MGD may be economically feasible in the near future, depending on outcome of negotiations with OCWD

Based on our economic analysis, the facility with a product capacity of 50 MGD and an open ocean intake has an average unit cost of $1,639/AF using a 3% discount rate. Under the current term sheet, OCWD might be willing to pay these water costs in 2018 (Figure ES1). The corresponding unit cost using a 7% discount rate is $2,189/AF. Our analysis indicates that OCWD would be willing to pay this amount for water in 2025. Therefore this option may be economically viable, consistent with the Ocean Amendment definition of economic feasibility.

6.5 The higher unit costs for the SIG options regardless of construction method significantly extend the period of time before the unit cost could be comparable to costs of other available water supplies

The average unit cost of the SIG-trestle intake option for the 50 MGD product capacity facility is $2661/AF using a 3% discount rate. The corresponding unit cost of a SIG-float intake option is $2665/AF. OCWD might not be willing to pay this water cost until 2033 assuming conditions included in the current term sheet (Figure 6.1). Using a 7% discount rate, the unit costs of the 50 MGD SIG trestle and SIG-float intake options are $4243/AF and $4277/AF, respectively. OCWD might be willing to pay these water costs after 2058.

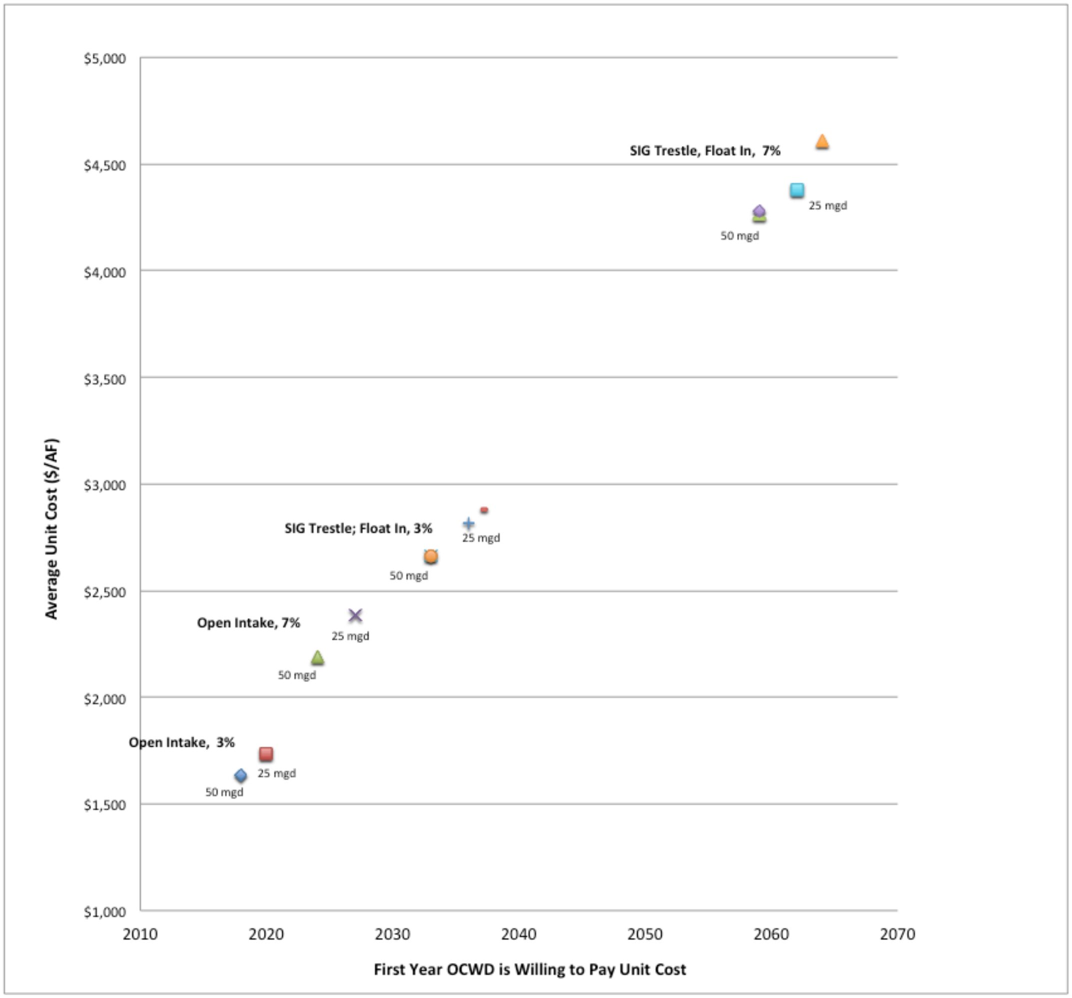

Figure 6.1 The Unit Cost to Produce Water and First Year OCWD is Willing to Pay Unit Cost [11]

6.6 The SIG option is not economically viable at the Huntington Beach location within a reasonable time frame, due to high capital costs and only modest reduction in annual operating costs

The economic viability of the SIG, regardless of construction technique, and for a product capacity of 50 MGD at this off shore location, is highly uncertain and thus the SIG option faces financing risks that pose significant barriers to implementation. We conclude that it is unlikely that the unit price for produced water from a SWRO plant with the SIG intake technology would find a buyer under current and likely future estimates of alterative waters sources through 2033. The very high capital cost adds operating cost in the form of additional interest that overwhelms the savings in pretreatment operating costs provided by the SIG intake.

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[11] Unit costs are averaged over high and low cost estimates and 30 and 50-year life cycle scenarios

Chapter VII. BIBLIOGRAPHY

Bruun, P., 1962, Sea level rise as a cause of beach erosion, Journal of Waterways and Harbors Division, American Society of Civil Engineers Proceedings, v. 88, p. 117-130.

California State Water Resources Control Board, 2015, Final Desalination Amendment to the Ocean Plan. Adopted on May 6, 2015. http://www.swrcb.ca.gov/water_issues/programs/ocean/desalination/

Independent Scientific Advisory Panel (ISTAP), 2014, Final report: Technical feasibility of subsurface intake designs for the proposed Poseidon desalination facility at Huntington Beach, California: Prepared under the auspices of the California Coastal Commission and Poseidon Resources (Surfside) LLC, 79 pp.

Ghaffour, N., Missimer, T. M., and Amy, G., 2013, Technical review and evaluation of the economics of desalination: Current and future challenges for better supply sustainability: Desalination, v. 309, p. 197-207, Doi: 10.1016/j.desal.2012.10.015.

Jenkins, S., and Wasyl, J., 2014, Oceanographic and Sediment Transport Analysis of Optimal Siting of a Seabed Infiltration Gallery (SIG) at the Huntington Beach Desalination Facility.

Maliva, R. G., Missimer, T. M., 2010, Self-cleaning beach gallery design for seawater desalination plants, Desalination and Water Treatment v. 13, no. 1-3,p. 88-95.

Merkel & Associates, 2004. Huntington Beach Wetlands Habitats and Sensitive Species, Prepared for: Moffatt & Nichol. August 18.

Missimer, T. M., 2015, Passive screen intakes: Design, construction and environmental impacts, Chapter 5 in Missimer, T. M., Jones, B, and Maliva , R. G. (editors), Intakes and outfalls for seawater reverse osmosis desalination facilities: Innovations and environmental impacts, Springer, New York, p. 79-104.

Niedoroda, A. W., Swift, D. J. P., and Hopkins, T. S., 1985, The shoreface, Chapter 8: in R. A. Davis, Coastal sedimentary environments, 2nd. Springer-Verlag, New York, p. 533-624.

Pankratz, T., 2015, Overview on intake systems for seawater reverse osmosis facilities, Chapter I in Missimer, T. M., Jones, B, and Maliva , R. G. (editors), Intakes and outfalls for seawater reverse osmosis desalination facilities: Innovations and environmental impacts, Springer, New York, p. 3-17.

Rosas, J, Lopez, O., Missimer, T. M., Coulibaly, K., Dehwah, A. H. E., Sesler, K., Lujan, L. R., and Mantilla, D., 2014, Determination of hydraulic conductivity from grain size distribution for different depositional environments: Ground Water, v. 52, no. 3, p. 399-413, doi: 10.1111/gwat.12078, p. 1-15.

Tenera Environmental (Tenera), 2010, City of Santa Cruz Water Department & Soquel Creek Water District SCWD2 Desalination Program: Open Ocean Intake Study Effects. ESLO2010-017.1.

APPENDICES A & B

For appendices C, D and E, see ISTAP Phase 2 Report: Supplementary Appendices.

APPENDIX A: Biographies of Panelists

Robert Bittner, P.E.

Mr. Robert Bittner is a professional engineer and President of Bittner-Shen Consulting Engineers, Inc., a firm specializing in the design of innovative marine structures including bridge foundations, marine terminals, offshore GBS structures, locks and dams. He has 40 years experience in construction engineering and project management on major marine structures worldwide, including the Itaipu Dam in Brazil and the Oresund Tunnel connecting Denmark and Sweden. One focus of his work has been minimizing construction cost of major marine structures through the design and development of innovative construction methods and equipment.

Prior to starting his own firm in 2009, Mr. Bittner was President of Ben C. Gerwick, Inc. While at Gerwick, he provided construction-consulting services worldwide and managed the design of several marine structures, including an innovative float-in dam on the Monongahela River in Pennsylvania for the US Army Corps of Engineers. Additionally, he led the Gerwick team that developed a new float-in cofferdam system that has been successfully used on the foundations for the New Carquinez Straits Bridge in the San Francisco Bay Area, the New Bath-Woolwich Bridge in Maine, the new Port Mann Bridge in Canada, and three major bridges in Asia. Mr. Bittner was Chairman of the Marine Foundations Committee for the Deep Foundations Institute (DFI) for 6 years from 2003 to 2008, and is currently President of DFI.

Mr. Bittner holds a B.S. in Civil Engineering and an M.S. in Construction Management, both from Stanford University.

Janet Clements

Ms. Clements has more than 14 years of experience in water resources planning and natural resource and environmental economics. She conducts benefit-cost, triple-bottom line (TBL), and economic impact analyses to evaluate the economic, social, environmental implications of policies and programs, including those related to desalination and water reuse. Ms. Clements is a noted economic expert in the water sector, specifically in the fields of integrated water resources management, TBL analysis, green infrastructure, and affordability of water and wastewater services. She also works on climate variability and adaptation planning in relation to water resources. Ms. Clements has experience evaluating water use and behavior across sectors and applying that information to help water utilities with water conservation, water demand management, and drought planning.

Ms. Clements is an active member of the water resources community and has participated as an invited expert in several workshops and panels. Examples include events sponsored by the Johnson Foundation, the Great Lakes Protection Fund, the World Meteorological Organization, and the Border Environment Cooperation Commission. Her clients include research foundations such as the Water Research Foundation, WateReuse Foundation, and Water Environment Federation; nonprofit organizations; and local, state, federal, and international government agencies and organizations.

Before attending graduate school, Ms. Clements worked as a natural resources planner in a rural California County. In this role, she managed and participated in the preparation of Environmental Impact Statements, served as the assistant program manager to the Five Counties Salmon Conservation Program, and worked with government agencies, Native American tribes, and nonprofit organizations on watershed planning efforts.

Ms. Clements has an M.S. in agricultural and resource economics from Colorado State University. Her B.S. in Sustainable Resource Management was awarded by The Ohio State University.

Larry Dale

Larry Dale is an environmental economist at Lawrence Berkeley National Laboratory (LBNL) and was Associate Director of the U.C. Berkeley Climate Change Center. He currently teaches at UC Berkeley, manages a policy economics group at LBNL, and performs selected energy studies for the California Energy Commission and the U.S. Department of Energy.

At U.C. Berkeley, Dr. Dale teaches classes in benefit cost analysis and the impact of climate change on urban and agricultural water use. He has led research teams evaluating the impacts of climate change on water use in East Africa and urban air quality in Mongolia. As associate director of the California Climate Change Center, Dr. Dale managed studies of (1) the impacts of climate change on hydropower, (2) California water supplies and groundwater and (3) the relationship between climate and demand management programs on household electricity and water usage.

For the California Energy Commission and the U.S. Department of Energy, Dr. Dale regularly performs economic studies to determine the cost effectiveness of energy efficiency programs. These include studies to estimate the price elasticity of demand for selected appliances, appropriate discount rates to use in benefit cost analysis, methods to estimate the regional employment impacts of efficiency standards, retrospective price analysis, and life cycle cost methodology.

He holds B.S and M.S. degrees in Economics from U.C. Davis and a Ph.D. in Resource Economics from the University of Hawaii.

Michael C. Kavanaugh PhD, P.E., BCEE

Dr. Michael Kavanaugh is a professional engineer and Senior Principal with Geosyntec Consultants, Inc. He is a registered professional engineer in California, a Board Certified Environmental Engineer (BCEE), and an elected Fellow of the Water Environment Federation. Dr. Kavanaugh has over 40 years of consulting experience advising private and public sector clients on water quality, water and wastewater treatment, and groundwater restoration issues.

In addition to his consulting practice, Dr. Kavanaugh has broad experience in science advising for policy. He completed several assignments with the National Research Council including chair of the Water Science and Technology Board and the Board on Radioactive Waste Management. He also chaired the NRC committee on alternatives for ground water cleanup (1994) and recently chaired a NRC study on the future of subsurface remediation efforts in the U.S. with a report released 2013. For the past ten years, he has been a regular contributor to the Princeton Groundwater professional courses offered in the U.S. and Brazil. Dr. Kavanaugh was elected into the National Academy of Engineering (NAE) in 1998.

He has a B.S. and M.S. degrees in Chemical Engineering from Stanford and the University of California, Berkeley, respectively and a PhD in Civil/Environmental Engineering from UC Berkeley.

Susan Lee

Ms. Lee is a Vice President of Aspen Environmental Group, and manages Aspen's San Francisco Office. She has over 30 years of experience in environmental impact assessment for both the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA).

Ms. Lee has specialized in analysis of large energy and infrastructure projects, including gas and solar power generation facilities, offshore oil and gas facilities, pipelines, and electric transmission lines. She managed numerous complex alternatives analyses for proposed projects, including nearly 100 alternatives to the Sunrise Powerlink Transmission Line and dry-cooling alternatives to proposed once-through cooling at coastal power plants. For the California Energy Commission, she has prepared alternatives analyses for 17 gas and solar power projects around the state.

Ms. Lee has a BA in Geology from Oberlin College and a MS in Applied Earth Science from Stanford University.

Thomas M. Missimer, Ph.D.

Dr. Thomas Missimer is a hydrogeologist and president of Missimer Hydrological Services, Inc., a Florida-based consulting firm. He is licensed as a professional geologist in four states. Dr. Missimer is currently a visiting professor at the U. A. Whitaker College of Engineering, Florida Gulf Coast University.

He has 42 years of experience as a hydrogeologist and has completed projects in groundwater development, water resources management, and the design and construction of various water projects. He has worked on a large number of artificial aquifer recharge projects used for storage and treatment of impaired waters (domestic wastewater and stormwater) and for seasonal and strategic storage of potable water (aquifer storage and recovery projects). He is the author of nine books and more than 350 technical papers of which about 80 are published in peer-reviewed journals.

Dr. Missimer has specialized in the design, permitting, and construction of intake systems for brackish-water and seawater reverse osmosis desalination systems. His book entitled “Water supply development, aquifer storage, and concentrate disposal for membrane water treatment systems” (Schlumberger, 2009) is a widely used reference in this field and has won two publishers awards in technical communication. His latest book entitled “Intakes and outfalls for seawater reverse osmosis desalination facilities: Innovations and environmental impacts” was recently released by Springer, New York, Doi: 10.1007/978-3-319-13203-7_7, 544 p (Missimer, Jones, and Maliva). His first wellfield project used to supply feed water for an RO system was completed in 1977, and he has worked on over 80 other systems worldwide. He and his students have completed and published 6 technical feasibility investigations over the last three years along the shorelines of the Red Sea and Arabian Gulf to assess the use of seabed gallery intake systems. In 1991, he won the best paper presentation award from the International Desalination Association for his paper on use of subsurface intake systems to supply large-capacity seawater desalination systems.

He has a BA in geology from Franklin & Marshall College, an MS in geology from Florida State University, and a PhD in marine geology and geophysics from the University of Miami.

APPENDIX B: Terms of Reference

Terms of Reference
for an Independent Scientific and Technical Advisory Panel (ISTAP)
to Examine the Feasibility of Subsurface Intakes
and Advise the California Coastal Commission on Poseidon Water's Proposed Huntington Beach Desalination Project
April 18, 2014

Headings Included Here
A. Background
B. Mission Statement and Purpose
C. Criteria to Guide the Panel's Assessment of Feasibility
D. Initial Work Program
E. Qualifications and Recruitment Criteria for Panel Members
F. Method of Panel Recruitment
G. Administrative Arrangements/Operating Procedures
H. Meeting Formats
I. Authorship Attribution, Distribution and Dissemination of the Panel's Report
J. Final Report as Part of Public Record
K. Statement of Concurrence

A. Background
As part of its review of a permit application from Poseidon Resources to construct and operate a desalination facility in Huntington Beach, the California Coastal Commission directed the applicant to undertake a more complete independent analysis of intake alternatives. Due to concerns over impacts on the coastal environment and marine ecosystems [California Coastal Act Sections 30230 and 30231 in particular], the Commission recommended that Poseidon examine in more detail the feasibility of subsurface intakes.

In order to establish a review process that is responsive to the Commission's guidance and appropriately engages Poseidon, both parties have agreed to undertake an independent scientific review. To help implement this guidance, Poseidon has agreed to contract with CONCUR, Inc., a firm specializing in analysis and resolution of complex environmental issues and in structuring independent review processes. While the Commission is not contracting with CONCUR, the agency staff agrees on the choice of CONCUR as the facilitator and convener of this independent review.

This Terms of Reference document (TOR) sets the structure and operating procedures of the scientific review and sets the specific charge to the Panelists. The intention of this Terms of

Reference is that, while Poseidon and the agency staff may have some divergent interests, they will collaborate and strive to reach agreement on these elements of the review process.[12]

CONCUR will convene a Panel of scientific experts—the Independent Scientific and Technical Advisory Panel — to review the issues at hand and make recommendations to bolster the scientific underpinning of the permit application and review process.

Both parties agree that this "joint fact-finding process" is a credible and effective way to respond to the guidance provided by the Commission. The Panel will consider a defined set of questions, deliberate, and prepare reports that will be delivered to both parties. These reports will provide evidence for the Commission and agency staff to consider when staff prepares its recommendation to the Commission regarding the proposed project. The Panel's final reports will be part of the Commission's record for Poseidon's permit application.

B. Mission Statement and Purpose

The broad goal of the Independent Scientific and Technical Review Panel is to provide credible, legitimate and independent scientific advice and guidance to support permit review.

The Panel's specific and limited purpose is to investigate whether alternative intakes would be a feasible method to provide source water to Poseidon's proposed desalination facility. It will focus on the extant site at Huntington Beach, but may investigate alternate sites on the Orange County coast. If subsequent phases of work are initiated, the expectations are that the Panel will compare the relative degree of feasibility of alternative intakes as described below.

Poseidon will fund the Panel and CONCUR. To ensure the Panel's independence, it will be guided by CONCUR and will report directly to agency staff with input from but without alteration by Poseidon. To provide transparency, the public will be invited to participate in some Panel meetings (but not Panel work sessions) and to comment at intervals on the Panel's interim and final work products for each of work as may be undertaken.

C. Criteria to Guide the Panel's Assessment of Feasibility

Both parties will set forth criteria they find important to the consideration of "feasibility" as defined in the California Coastal Act, which will be reviewed and considered by the Panel in determining the feasibility criteria to be used for each phase that is undertaken.

D. Initial Work Program

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[12] In this TOR, Poseidon Resources (Surfside) LLC will be referred to simply as "Poseidon", the term "Commission" refers to the agency and its governing board, and the staff of the Coastal Commission will be referred to as "agency staff". The term "both parties" means Poseidon and agency staff.

The scope of work may include one or more phases as set forth below.

After each phase, both parties will consider the results of the phase and advise on next steps.

Both parties agree that the intent of the review is to work through to a final product for each phase that is undertaken. Both parties commit to at least the first phase of work outlined. Both parties would need to concur to go beyond Phase 1 and involve the Panel in later phases. Both parties anticipate that the disciplines composing the Panel would need to be rethought between Phase 1 and Phase 2. The disciplinary composition of the Panel may be revised at each phase to provide the necessary expertise.

Both parties agree that multiple phases will be necessary to generate the information the Commission needs to proceed to a final decision.

The Phase 1 scope of work is as follows:

Phase 1: Technical Feasibility at Huntington Beach.[13] Investigate whether alternative subsurface intake designs would be technically feasible at the proposed site at Huntington Beach. This assessment of technical feasibility will include a characterization of the geophysical, hydrogeological and geochemical features of the site and will identify the expected size and hydrogeological effects of the range of subsurface intakes that could be accommodated on the site, including those that could provide source water for the proposed 50 mgd facility. For Phase 1, both parties agree that the working definition of technically feasible is: able to be built and operated using currently available methods. This phase will include gaining command of the project and context, clarification of the goals and scope of this phase, review of published literature, case reports, and on-site studies. The Panel would prepare a report at the end of this phase that describes technically feasible alternative intake designs at or near the site and may also be asked to prepare interim informal reports.

At the end of Phase 1, both parties would consider the Panel report and the makeup of the Panel needed for the next Phase. Based upon the discussions to develop the Phase 1 scope of work, both parties have developed the following scope of work for Phase 2, if both parties decide to initiate a second phase.

Phase 2: Additional Review of Components of Feasibility at Huntington Beach. Still focused on the Huntington Beach site, the Panel would characterize the technically feasible subsurface intakes identified in Phase 1 relative to a broader range of evaluation criteria, as recommended by the parties and determined by the Panel, such as size, scale, cost, energy use, and

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[2] The parties are aware that State Water Board staff is developing an amendment to the Ocean Plan that would address issues associated with desalination facilities. The parties intend that the ISTAP process would be able to receive briefings on the progress and outputs of the SWRCB process (perhaps with State Board staff as technical advisors to this process).

characteristics related to site requirements and environmental concerns consistent with the California Coastal Act's definition of feasible, and as compared to the proposed open intake. The Panel would prepare a report at the end of this Phase and may also be asked to prepare interim informal reports.

Both parties will decide after Phase 2 whether to conclude the ISTAP or whether to conduct additional studies and review. For instance, if initial review indicates that constructing a subsurface intake at the Huntington Beach site may not be feasible, a potential third phase could consider other locations on the Orange County Coast that might offer superior conditions for construction of subsurface intakes. The Panel could perform a reconnaissance-level review to identify alternative sites that should be the subject of a more in-depth analysis by the Panel or others and studied concurrently or at a later date. This reconnaissance level review should be considered a coarse screening. A fourth phase may entail a more in-depth analysis of alternate sites and if the ISTAP is involved may require additional expertise.

E. Qualifications and Recruitment Criteria for Panel Members

In Phase 1, the Panel is expected to include disciplines that as a whole should provide coverage of all of the following areas:

- Subsurface intake design, construction, and/or operation
- Geophysical and/or hydrogeological study design and modeling
- Coastal processes and/or physical oceanography – hydrodynamics, sediment transport, sediment characterization, etc.
- Coastal engineering/construction methods/cost analysis
- Geophysical and/or hydrogeological characteristics of Orange County coastal areas
- Groundwater geochemistry

At each later phase both parties will work to define needed qualifications and disciplinary recruitment criteria. Other later phases of the Panel may include such disciplines as marine ecology or cost-benefit analysis.

Additional Recruitment Criteria

Panel members should possess demonstrated aptitude and capability in the following areas:

- Able to operate as an independent expert representing their professional discipline and experience in their participation in this ISTAP
- Experience providing scientific advice for developing public policy
- Ability to integrate multiple disciplinary perspectives
- Experience with highly contentious issues and high stakeholder interest
- Experience preparing reports for policy audiences
- Availability to work in a team setting

- Willingness to work with the expectation that the Panelists will author the report, accept attribution to the entire report, and sign the final report (Note: CONCUR will support the drafting and production of the report in all stages of work.)

Method of Panel Selection

Both parties, working with CONCUR, will jointly select the Panel. The credentials of potential members will be considered on their merits relative to the selection criteria listed above.

F. Technical Advisors

Individuals may also be considered for a potential Technical Advisor role. It is expected that a small number of Technical Advisors may be asked to make short presentations to contribute to the deliberations of the Panel and provide additional detail and context to support the Panel's work. It is understood that Technical Advisors are not expected to meet the Panelists' rigorous criteria for independence. Technical Advisors are not expected to participate in the entire duration of the Panel's work, but may be called in for specific topics. Technical Advisors will not participate in the internal Panel deliberations, nor will they be asked to co-author or co-sign the final Panel report.

G. Method of Panel Recruitment

Both parties will consider criteria for the recruitment of Panelists and will use their professional networks to identify and suggest potential candidates. CONCUR will also use its professional network and make suggestions for potential candidates. Together, all parties will form a pool of candidates, which the agency staff, Poseidon, and CONCUR will jointly review with the aim of reaching agreement on the full Panel.

H. Administrative Arrangements and Operating Procedures

Both parties agree to the following provisions to ensure proper administration of the independent Panel:

1. Poseidon will provide funds to CONCUR, Inc. in advance of convening the Panel in an amount outlined by the Scope of Work developed by the facilitator.

2. Panel members will be remunerated by CONCUR, with the panelist's client understood to be the ISTAP.

3. Poseidon and agency staff will work with the facilitator to draft and proceed jointly to agree to the Terms of Reference (TOR). By mutual agreement of all parties, supplemental Terms of Reference may be incorporated at a later time.

4. The Panel, once constituted, will be asked to verbally communicate with Poseidon or agency staff only with representatives of both parties participating via the facilitator *(or with cc's to*

CONCUR). Questions or comments (including requests for additional information, data, or documents) should be stated in writing, with copies to both parties.

5. The Panel's work products are to reflect its independent scientific and technical judgment. Both agency staff and Poseidon will contribute information and review, but neither agency staff nor Poseidon will alter the work products, and there will be clear identification as to their independent status. Both parties will not alter work products, but will have opportunities to comment on draft work products, as will members of the public.

6. Questions will be posed to the Panel via a written program of work and supplementary memoranda. The Panel will respond with written statements, which may be supplemented with briefings.

7. CONCUR shall designate Principal Scott McCreary as the facilitator for directing the activities of the Panel and as the point of administrative contact. The Poseidon point of contact is Stan Williams. The Coastal Commission point of contact is Tom Luster.

8. The Panel's formal contacts with agencies, stakeholders and the public will be via procedures established through the Terms of Reference in consultation with Poseidon, agency staff, and CONCUR to strike a balance between the Panel's independence and ensuring fair and open access to the Panel and its work products.

I. Meeting Formats

Meetings of the Panel will be of three types:

- **Panel meetings** with structured opportunities for observers, representatives of agencies, and Technical Advisors (as described in F. above) to hear and make presentations and public comments.
- **Work sessions**, where the Panel may interact with invited Technical Advisors
- **In person or by-telephone work sessions** of the Panel.

CONCUR will prepare summaries of deliberations of all meetings. Summaries will be made available to the public. CONCUR will be the primary point of contact for handling press inquiries. Agency staff and Poseidon may consider the use of short, joint statements at intervals.

Panel members will need to review critical Commission and other documents so that their comments and recommendations are based on:

- The best possible understanding of the physical requirements of desalination, local land use conditions and limitations, marine ecosystems in the region of the proposed project;
- An understanding of the policy and administrative context of Commission deliberations;
- The timelines and targets for Commission permit review and related actions;

- The timelines and targets for Poseidon's corporate planning.

J. Authorship, Attribution, Distribution and Dissemination of the Panel's Report

The expectation is that Panel members will author, accept attribution, and sign the final report in its entirety. The Panel will submit the results of its review to Poseidon and agency staff simultaneously. If requested, the Panel may present the findings of its report in a Workshop format or briefing to the Commission.

K. Final Report Becomes Part of the Public Record

Upon its presentation, this Report becomes part of the public record.

L. Statement of Concurrence

We hereby concur and agree to this Terms of Reference document and funding requirements as described in this document.

Coastal Commission:	Poseidon Resources (Surfside) LLC:
_________________________ Date: ______	________________________ Date: ______
_________________________ Date: ______	________________________ Date: ______

Appendix C: Proposed Project Background and Panel Process

In 2002, Poseidon Water submitted a coastal development permit (CDP) application to the City of Huntington Beach for Poseidon's proposed seawater desalination facility. In 2003, the City declined to certify the associated Final Environmental Impact Report (EIR) for the proposed project. In 2005, Poseidon re-applied to the City with a modified proposal. Later that year, the City certified the project EIR and in early 2006, approved a CDP for the portions of the project within the City's permit jurisdiction. That CDP was then appealed to the Coastal Commission. In May 2006, Poseidon submitted a CDP application to the Coastal Commission for portions of the proposed project in coastal waters offshore of Huntington Beach, which are within the Commission's retained permit jurisdiction.[14] While the Commission was reviewing the CDP application and the appeal, Poseidon modified some components of its proposed facility and submitted to the City a proposed project re-configuration for the long term stand-alone operation of the desalination facility, which required the City to conduct additional CEQA review and consider a new CDP for the project. In 2010, the City certified a Supplemental EIR and approved a new CDP, which was also appealed to the Commission. Also by the end of 2010, the Coastal Commission had approved and issued a number of CDPs for desalination facilities that used surface, subsurface, or screened intakes, including one to Poseidon for its Carlsbad Desalination Project, the first large-scale project approved in the State. In addition, the State Water Resources Control Board had approved the Once Through Cooling Policy, which resulted in the retirement of most of the state's coastal power plants using open intakes. These events provided information that was useful for the Huntington Beach Project.

Commission Action

In November 2013, the Commission held a public hearing to determine whether to issue a CDP to Poseidon for the offshore portions of its proposed project and to determine how to resolve the appeal of the City's CDP. At that hearing, Commission staff recommended the Commission conditionally approve

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[14] The California Coastal Act, established by voter initiative in 1972 and made permanent by the Legislature in 1976, includes specific policies meant to provide public access to the coast, protect coastal resources, and ensure appropriate development within the state's Coastal Zone. The Coastal Zone extends along the length of the state and includes coastal waters to three miles offshore as well as areas ranging from several hundred feet to several miles inland from the shoreline.

Many forms of development proposed within the Coastal Zone are subject to provisions of the Coastal Act and of Local Coastal Programs (LCPs), which are developed by local governments in association with the Coastal Commission. LCPs generally include more specific policies than those in the Act that reflect and more closely address locally important coastal resource issues.

Once the Coastal Commission certifies an LCP and an associated Land Use Plan (LUP), the local jurisdiction takes on most of the permitting authority provided by the Act. The Commission retains its permitting authority over state tidelands (i.e., offshore areas) and in areas of the Coastal Zone that aren't covered by a certified LCP or LUP. There are also areas or types of projects within local jurisdictions where the local government has permitting authority, but where those permits can be appealed to the Commission. Proposed projects that would be located within both the permit jurisdiction of a local government and the Commission may require a CDP from each. This is the case for the proposed Poseidon Water desalination facility in Huntington Beach. Additionally, the proposed project is within the Commission's appeal jurisdiction.

both CDPs with a requirement that Poseidon construct a subsurface intake unless Poseidon presented additional information showing that intake method to be infeasible.

The hearing included several hours of public testimony and Commission deliberation, with one of the key issues being whether subsurface intakes were feasible at or near the proposed site. Near the end of the hearing, several Commissioners recommended to Poseidon that it work with Commission staff to develop independent verification of whether any of several subsurface intake designs would be feasible for this project. Poseidon then withdrew its CDP application and the Commission voted to continue the appeal of the local CDP.

Shortly after that hearing, and in anticipation of Poseidon submitting a new CDP application, Coastal Commission staff and Poseidon started discussing how to provide the independent scientific and technical review recommended by the Commissioners. In January 2014, the two parties (the "Conveners") agreed to undertake an independent review. As part of this process, Poseidon agreed to contract with CONCUR, Inc., a firm specializing in analysis and resolution of complex environmental issues and in structuring independent review processes. While the Commission is not contracting with CONCUR, the agency staff agreed on the choice of CONCUR as the facilitator and convener of this independent review. CONCUR has now convened two panels of scientific experts – the Independent Scientific and Technical Advisory Panel (ISTAP), Phase 1 and Phase 2, – to review the issues at hand and make recommendations to bolster the scientific underpinning of the permit application and review process. The two Panels' specific and limited purpose was to investigate whether alternative intakes would be a feasible method to provide source water to Poseidon's proposed desalination facility. Working with CONCUR, Coastal Commission staff and Poseidon agreed on the Panel's initial scope of work and on its structure and operating procedures. These are described in Appendix B of this report, the Terms of Reference.

The Conveners anticipated that multiple phases of work would be necessary for the Panel Process, and that the composition of the Panel might be revised at each phase to provide the necessary expertise. The Phase 1 Panel's work was limited to evaluating the technical feasibility of subsurface intake methods – i.e., whether subsurface intakes can be built and operated at this site using currently available methods. For any intake methods deemed feasible in Phase 1, the Panel in Phase 2 would evaluate them for other components of feasibility – environmental, economic, and social. If no methods made it through either Phase 1 or 2, the Conveners could ask the Panel to conduct a Phase 3 evaluation to investigate whether subsurface intakes would be feasible at other sites, or Poseidon could choose to re-apply to the Commission based on the Phase 1/Phase 2 work. For this first phase, the two parties and CONCUR identified the expertise needed on the Panel and jointly agreed on the Panel members selected. The parties also jointly developed a bibliography and jointly provided data sources for the Panel to use in its deliberations.

Phase 1 Panel Deliberation Process

The Phase 1 Panel started its work in June 2014. The Panel's initial organizational meeting, convened via conference call, was focused on introducing the Panel members, the parties, and Concur, describing and answering questions about the Terms of Reference, and establishing the expected schedule, review process, and other considerations. The parties posted relevant data, reports, and information for the Panel on the Coastal Commission's FTP site, with most being available to the interested public. The Panel's first public meeting was in June 2014, in Huntington Beach. It included presentations, discussions among the Panel members, and opportunities for public comment.

The Panel's work continued in subsequent weeks through conference calls, drafting of writing assignments, and exchange of several iterations of its draft reports. To maintain the Panel's independence, the report preparations and Panel deliberations occurred without input from the two parties. Only when the Panel had completed a final draft of its report were the parties asked to review and propose edits, though the suggested edits were limited to concluding whether the report was consistent with the agree-upon scope of work as defined in the Terms of Reference and recommending correction of factual points, as needed. The parties were not provided the opportunity to modify the Panel's conclusions or question its technical review.

As a final step of this first phase of this independent review process, the Panel accepted public comments and convened a meeting in Huntington Beach on September 29, 2014 to address relevant comments on the report. After that meeting, the Panel prepared a final Phase I report, which will be used by Panel members in the Phase 2 work and which will become part of the Commission's record for Poseidon's upcoming CDP application. All Phase 1 Panel members were joint authors of, the final Phase I report.

Phase 1 ISTAP REPORT

The ISTAP Phase 1 joint fact-finding process produced the Panel's unanimous Report – "Technical Feasibility of Subsurface Intake Designs for the Proposed Poseidon Water Desalination Facility at Huntington Beach, California" which was posted on Coastal Commission website on October 13, 2014.

The Panel evaluated nine different subsurface intake methods, including several types of wells and two types of infiltration galleries. The different well methods did not survive the Panel's "fatal flaw" analysis due primarily to their effect at full scale production on the nearby Orange County groundwater basin or due to the Panel's concerns about technical components of some well systems. Only the seabed infiltration gallery and the surf zone (beach) gallery survived the fatal flaw analysis, and both were deemed technically feasible. Both gallery types would face constructability challenges related to subsea construction. The surf zone gallery was judged to have particularly challenging construction issues (and thus a lesser degree of technical feasibility) related to construction in a high-energy environment. The Phase 1 ISTAP did not consider the existing scale of use of any particular subsurface intake compared to the capacity requirement at Huntington Beach to be a fatal flaw for technical feasibility (e.g., the only existing seabed infiltration gallery has a capacity of 27 MGD compared to the lower hydraulic capacity of 100 MGD required for the proposed Huntington Beach project, and no large scale implementation of a beach gallery has been constructed and operated as of September 2014). The Panel did address the broad issue of downward scalability where it saw relevance, but did not consider alternative intake capacities for any of the nine technologies.

As noted, the ISTAP was not asked to evaluate the economic considerations of using a subsurface intake versus a conventional open-ocean intake during Phase 1 of the assessment. The Phase 1 ISTAP recommended that in the next phase, the Phase 2 Panel should focus primarily on the constructability of the seabed infiltration and beach gallery intake systems, because this greatly affects the economic viability of their potential use.

The Phase 1 ISTAP also recommended that in the Phase 2 evaluation of the subsurface intake options, a detailed lifecycle cost analysis should be provided to the succeeding committee. This lifecycle cost analysis should contain at least four scenarios, including: 1) the lifecycle cost over an appropriate operating period obtaining the feed water from a conventional open-ocean intake without considering the cost of potential environmental impact of impingement and entrainment, 2) the lifecycle cost over an appropriate operating period obtaining feed water from a conventional open-ocean intake considering the cost of potential environmental impact of impingement and entrainment, 3) the lifecycle cost over an appropriate operating period obtaining the feed water from a seabed gallery intake system (or beach gallery intake system) using the same pretreatment design as used in treating open-ocean seawater, and 4) the lifecycle cost over an appropriate operating period obtaining the feed water from a seabed gallery intake system (or beach gallery intake system) using a reduced degree of pretreatment, such as mixed media filtration and entry into the cartridge filters.

In each of these scenarios, the Phase 1 ISTAP recommended that the selected design hydraulic capacity match both the minimum and maximum flow rates consistent with the desired production rate of a 50 MGD desalination facility using the SWRO technology. The definition of an “appropriate” operating period should follow accepted industry standards for such lifecycle cost analyses (e.g., 30 years and 50 years). In addition, the Phase 1 ISTAP questioned whether the proposed facility needed to use flow augmentation – i.e., bringing in additional seawater to dilute its discharge.

After the Phase I ISTAP Report

Following the release of the final Phase 1 ISTAP report, stakeholders responded to an invitation to submit recommendations for Phase 2 scope of work which had been described in the Terms of Reference as “…conduct additional review of other feasibility components for technically feasible intake alternatives.”

Coastal Commission staff and Poseidon Water also agreed to develop additional information about the effects of wells operating at different intake volumes on the Talbert Aquifer that the Commission staff has requested in order to evaluate and help complete Poseidon’s Coastal Development Permit application.

This information would be developed in parallel with the Phase 2 process, and involve a Well Investigation Team (WIT) comprised of ISTAP Phase 1 Panelists: Dr. Bob Maliva, a principal Hydrogeologist with Schlumberger Water; and Martin Feeney, consulting Hydrogeologist. The WIT was asked to provide advice on the creation of a supplemental model to cover an area appropriate for Poseidon’s proposed desalination facility. This supplemental model would, in turn, be used to determine the effects of select alternative well intake methods and extraction volumes on the Talbert Aquifer and regional groundwater resources. The WIT would investigate the potential use of wells into the Talbert Aquifer for desalination source water and seawater intrusion control. The WIT was formed and reports to CONCUR Inc. Its report is being produced separately but is expected to be published about the same time as this Phase 2 report.

Phase 2 Panel Deliberation Process

As in the first phase, the Conveners and CONCUR identified the expertise needed on the Phase 2 Panel and jointly agreed on the Panel members selected. The parties also jointly developed a bibliography and jointly provided data sources for the Panel to use in its deliberations.

Panel members for Phase 2 included three former Phase 1 Panelists: Michael Kavanaugh, Robert Bittner, and Dr. Tom Missimer. They were joined by new Panelists: Dr. Larry Dale, Scientist and environmental economist at Lawrence Berkeley National Laboratory; Janet Clements, Senior Economist at Stratus Consulting; and Susan Lee, Vice President, San Francisco Operations, Aspen Environmental Group.

The task in Phase 2 was to characterize the technically feasible subsurface intakes identified in Phase 1 relative to a broader range of evaluation criteria, as recommended by the parties and determined by the Panel, such as size, scale, cost, energy use, and characteristics related to site requirements and environmental concerns consistent with the Coastal Act's definition of feasible, and as compared to the proposed open intake.

The Panel would prepare a report at the end of this Phase. The objectives for Phase 2 were:

- Investigate whether offshore and beach infiltration galleries could be a feasible method to provide water to Poseidon's proposed desalination facility at or near the Huntington Beach site.
- Investigate at what scale those intake methods could feasibly be sited and operated at or near the Huntington Beach site.

ISTAP Phase 2 Panel had an organizing teleconference call with the CONCUR and the Conveners on December 12, 2014 and it had a work session on January 19, 2015 to discuss and define the technologies to be investigated, the criteria for review, and the evaluation methodology. In Phase 1, the ISTAP examined the technical feasibility of a variety of alternate subsurface intake technologies for a proposed desalination facility at Huntington Beach. Two potential alternate technologies were identified as feasible: the Seafloor Infiltration Gallery (SIG) and the Beach Gallery. The Phase 2 ISTAP's charge was to closely examine the issues of constructability and economics of these two technologies. The analysis was to take into account the technology, social, and environmental costs.

The purpose of the January work meeting was to outline a framework for the Phase 2 analysis and to identify information needs, criteria, and a near term work-plan to develop the necessary information for analysis which then would be reviewed in a public workshop meeting. The Phase 2 Panelists developed several proposals regarding the scope of the analysis, including that they would undertake a life cycle cost analysis with three main elements: economic, environmental and social. The Phase 2 Panel proposed to investigate alternative intakes including a Seafloor Infiltration Gallery, and an open ocean intake. They decided that the beach gallery was still under consideration; however it might encounter additional construction or feasibility challenges. The Panel members also proposed to analyze three to four yield/intake volumes and to examine two time frames (30-year time period and 50-year time period).

A public work session was held by the Phase 2 Panel on February 18 in Huntington Beach. The meeting included an introduction of the Panel and the Panel's process, briefings by both Commission staff and Poseidon on the Panel's role and the proposed project, presentations from the Panel on their proposed framework for the Phase 2 process including the technologies and scales to be examined, the proposed lifecycle cost analysis, and the proposed analytic methodology. The meeting also considered additional information the Panel needed to complete its review.

Phase 2 Panel members presented an alternate construction concept for a seabed infiltration gallery (SIG) at the potential Huntington Beach desalination facility, new information pertaining to construction challenges and uncertainty pertaining to the beach gallery intake option, and the proposed framework and elements of the economic analysis. Members of the public provided several comments intended to address the Panel's charge. CONCUR asked that further written comment be provided to in the following two weeks, which was in turn provided to the Panel and Conveners.

A Phase 2 Panel work team comprised of M. Kavanaugh, S. Lee, J. Clements, and L. Dale met with CONCUR and the Conveners at the Coastal Commission office in San Francisco on March 10, 2015 and discussed the scope of public comments received by the Panel. The work team took stock of proposed information sources and inputs, refined data categories, confirmed sufficiency of data or data gaps and then refined the work plan.

On March 31 and April 1 the Phase 2 Panel members participated in work sessions during which they further discussed the scope of public comment received by the Panel and identified elements that the Panel should consider in its analysis and ongoing process. During these meetings Panel members presented the current thinking on the economic framework, posed questions regarding model assumptions, presented available information on evaluation of entrainment, fishing and beach recreation impacts, received information on projected construction and maintenance costs, refined information needs, and developed a draft work plan and report outline.

The Panel discussed the elements of the Phase 2 Panel's charge – to characterize feasibility of alternative subsurface intake technologies relative to a variety of evaluation criteria, including economic, environmental, energy use, etc. Panelists noted that a determination of economic feasibility is not based solely on a comparison of two options, but rather on willingness of purchasers and financiers to pay, how project costs are reflected in water rates, the value assigned to a project's reliability, and others. Panelists discussed several elements of economic feasibility, including: (1) willingness of the Orange County Water District to purchase the water; willingness of investors (bondholders, equity partners, etc.) to back the project; and: (3) willingness of Poseidon to produce the water. The Panel noted that item (1) is based on several elements, including cost per acre-foot, reliability of water, reduced reliance on imports and risk. Item (2) is based on the rate of return and risk. Item (3) is based on items (1) and (2). Conveners noted that many components that go into determining or characterizing feasibility are outside the Panelist purview. Accordingly, panelists agreed to first analyze the economic, social and environmental costs and then work with the Conveners to consider the degree to which they could characterize the economic feasibility of the project and alternatives.

The Panel also determined that due to the uncertainties associated with costs of construction and maintenance of innovative SIG technology, that it would run multiple analyses using different estimates to establish a range of high and low end costs.

An additional Phase 2 ISTAP meeting was held on April 21st 2015 to: receive updates from conveners; present an update on the proposed economic framework; review and discuss the economic framework; receive updates on Panel requested revisions to the conceptual designs and cost estimates; scan status of progress on chapter drafting assignments; and develop plan for work flow. The Panel determined that among the project variants they would review are open ocean and SIG options with float in construction methods, multiple discount rates, three project scales, and that they would assess project alternatives without flow augmentation.

The Phase 2 Panel's work continued in subsequent weeks through conference calls, drafting of writing assignments, and exchange of several iterations of its draft reports. To maintain the Panel's independence, the report preparations and Panel deliberations occurred without input from the two parties. Only when the Panel had completed a final draft of its report were the parties asked to review and propose edits, though the suggested edits were limited to concluding whether the report was consistent with the agree-upon scope of work as defined in the Terms of Reference and recommending correction of factual points, as needed. The parties were not provided the opportunity to modify the Panel's conclusions or question its technical review.

The Panel then published its draft report on August 17, 2015 and established a 24-day public comment period, including a public meeting scheduled for August 27, 2015 in Huntington Beach to address relevant comments on the report. After that meeting, the Panel will prepare a final Phase 2 report, which will become part of the Commission's record for Poseidon's upcoming CDP application. Pursuant to the Terms of Reference all Phase 2 Panel members are expected to accept, and be joint authors of, the final Phase 2 report.

Note: During much of this same period as the ISTAP process, the State was developing a policy meant to help guide development of seawater desalination and clarify the regulatory requirements for proposed intake and discharge facilities. Starting in 2007, the State Water Resources Control Board ("State Board") convened its own expert panels and held public workshops and hearings, and in August 2014, released a draft amendment to the Ocean Plan that identified the proposed performance standards, study methods, mitigation measures, and other requirements desalination facilities will be required to meet. The State Board adopted the Proposed Desalination Amendment on May 6, 2015. Both Conveners participated in the policy development and believe the Panels' work is thus far consistent with the approaches anticipated in the policy.

ISTAP Phase 2 Report: Supplementary Appendix

Appendices D, E and F

Authored by the Independent Scientific
Technical Advisory Panel

Under the Auspices of the California
Coastal Commission and Poseidon
Resources (Surfside) LLC

Convened and Facilitated by CONCUR, Inc.

CONCUR
NEGOTIATING EFFECTIVE ENVIRONMENTAL AGREEMENTS

August 17, 2015

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APPENDIX D: Life Cycle Costs Associated with Different Project Scales

Appendix D shows the life cycle cost analysis for each project scale (12.5 MGD, 25 MGD, 50 MGD, 100 MGD), intake option, discount rate (3% and 7%), and project life (30-year and 50-year) assumption. In each life cycle cost table, we show the capital costs for the desalination facility with different intake options over the expected construction period, as well as the operations and maintenance (O&M) costs over the project life. We also show decommissioning costs of $9,000,000 at the end of each project life.

To perform the life cycle cost analysis, we adjusted all costs to 2015 dollars, taking out the inflation that was built in to the original capital cost estimates. We then applied the discount rate to these real cost estimates over time to estimate total present value (PV) capital and O&M costs. We also applied the discount rate to the expected water production at each facility over time so that we could determine the unit cost (i.e., PV costs/PV water production) of water over time.

Please note that the tables below are very large and difficult to present legibly on a single page. We recommend that you magnify your screen size by 200% or more in order to easily read these data.

		Low cost estimate									High cost estimate								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	14,002	$ 196,096,438		$ 196,096,438	$ 213,709,991		$ 213,709,991	$ 256,709,253		$ 256,709,253	$ 208,104,344		$ 208,104,344	$ 254,768,305		$ 254,768,305	$ 255,486,664		$ 255,486,664
1	13,594	$ 72,214,637		$ 70,111,298	$ 209,869,382		$ 203,756,681	$ 252,095,898		$ 244,753,299	$ 77,658,500		$ 75,396,602	$ 250,189,831		$ 242,902,748	$ 250,895,281		$ 243,587,651
2	13,198		$ 13,594,138	$ 12,813,779	$ 206,097,792		$ 194,266,936	$ 154,728,406		$ 145,846,363		$ 12,350,296	$ 11,641,338	$ 103,191,328		$ 97,267,723	$ 155,223,438		$ 146,312,978
3	12,814		$ 13,594,138	$ 12,440,562	$ 101,196,991		$ 92,609,582		$ 14,464,893	$ 13,237,426		$ 12,350,296	$ 11,302,270		$ 10,411,789	$ 9,528,262		$ 10,411,789	$ 9,528,262
4	12,440		$ 13,594,138	$ 12,078,216		$ 14,464,893	$ 12,851,870		$ 14,464,893	$ 12,851,870		$ 12,350,296	$ 10,973,078		$ 10,411,789	$ 9,250,740		$ 10,411,789	$ 9,250,740
5	12,078		$ 13,594,138	$ 11,726,423		$ 14,464,893	$ 12,477,544		$ 14,464,893	$ 12,477,544		$ 12,350,296	$ 10,653,474		$ 10,411,789	$ 8,981,301		$ 10,411,789	$ 8,981,301
6	11,726		$ 13,594,138	$ 11,384,877		$ 14,464,893	$ 12,114,120		$ 14,464,893	$ 12,114,120		$ 12,350,296	$ 10,343,178		$ 10,411,789	$ 8,719,710		$ 10,411,789	$ 8,719,710
7	11,385		$ 13,594,138	$ 11,053,278		$ 14,464,893	$ 11,761,282		$ 14,464,893	$ 11,761,282		$ 12,350,296	$ 10,041,921		$ 10,411,789	$ 8,465,737		$ 10,411,789	$ 8,465,737
8	11,053		$ 13,594,138	$ 10,731,338		$ 14,464,893	$ 11,418,720		$ 14,464,893	$ 11,418,720		$ 12,350,296	$ 9,749,438		$ 10,411,789	$ 8,219,163		$ 10,411,789	$ 8,219,163
9	10,731		$ 13,594,138	$ 10,418,775		$ 14,464,893	$ 11,086,136		$ 14,464,893	$ 11,086,136		$ 12,350,296	$ 9,465,473		$ 10,411,789	$ 7,979,769		$ 10,411,789	$ 7,979,769
10	10,419		$ 13,594,138	$ 10,115,315		$ 14,464,893	$ 10,763,239		$ 14,464,893	$ 10,763,239		$ 12,350,296	$ 9,189,780		$ 10,411,789	$ 7,747,349		$ 10,411,789	$ 7,747,349
11	10,115		$ 13,594,138	$ 9,820,695		$ 14,464,893	$ 10,449,746		$ 14,464,893	$ 10,449,746		$ 12,350,296	$ 8,922,117		$ 10,411,789	$ 7,521,698		$ 10,411,789	$ 7,521,698
12	9,821		$ 13,594,138	$ 9,534,655		$ 14,464,893	$ 10,145,385		$ 14,464,893	$ 10,145,385		$ 12,350,296	$ 8,662,249		$ 10,411,789	$ 7,302,619		$ 10,411,789	$ 7,302,619
13	9,535		$ 13,594,138	$ 9,256,947		$ 14,464,893	$ 9,849,888		$ 14,464,893	$ 9,849,888		$ 12,350,296	$ 8,409,951		$ 10,411,789	$ 7,089,922		$ 10,411,789	$ 7,089,922
14	9,257		$ 13,594,138	$ 8,987,327		$ 14,464,893	$ 9,562,998		$ 14,464,893	$ 9,562,998		$ 12,350,296	$ 8,165,001		$ 10,411,789	$ 6,883,419		$ 10,411,789	$ 6,883,419
15	8,987		$ 13,594,138	$ 8,725,560		$ 14,464,893	$ 9,284,464		$ 14,464,893	$ 9,284,464		$ 12,350,296	$ 7,927,185		$ 10,411,789	$ 6,682,931		$ 10,411,789	$ 6,682,931
16	8,725		$ 13,594,138	$ 8,471,417		$ 14,464,893	$ 9,014,043		$ 14,464,893	$ 9,014,043		$ 12,350,296	$ 7,696,296		$ 10,411,789	$ 6,488,283		$ 10,411,789	$ 6,488,283
17	8,471		$ 13,594,138	$ 8,224,677		$ 14,464,893	$ 8,751,498		$ 14,464,893	$ 8,751,498		$ 12,350,296	$ 7,472,132		$ 10,411,789	$ 6,299,304		$ 10,411,789	$ 6,299,304
18	8,225		$ 13,594,138	$ 7,985,123		$ 14,464,893	$ 8,496,600		$ 14,464,893	$ 8,496,600		$ 12,350,296	$ 7,254,497		$ 10,411,789	$ 6,115,829		$ 10,411,789	$ 6,115,829
19	7,985		$ 13,594,138	$ 7,752,547		$ 14,464,893	$ 8,249,126		$ 14,464,893	$ 8,249,126		$ 12,350,296	$ 7,043,201		$ 10,411,789	$ 5,937,698		$ 10,411,789	$ 5,937,698
20	7,752		$ 13,594,138	$ 7,526,745		$ 14,464,893	$ 8,008,861		$ 14,464,893	$ 8,008,861		$ 12,350,296	$ 6,838,059		$ 10,411,789	$ 5,764,755		$ 10,411,789	$ 5,764,755
21	7,527		$ 13,594,138	$ 7,307,519		$ 14,464,893	$ 7,775,593		$ 14,464,893	$ 7,775,593		$ 12,350,296	$ 6,638,893		$ 10,411,789	$ 5,596,850		$ 10,411,789	$ 5,596,850
22	7,307		$ 13,594,138	$ 7,094,679		$ 14,464,893	$ 7,549,119		$ 14,464,893	$ 7,549,119		$ 12,350,296	$ 6,445,527		$ 10,411,789	$ 5,433,835		$ 10,411,789	$ 5,433,835
23	7,095		$ 13,594,138	$ 6,888,038		$ 14,464,893	$ 7,329,242		$ 14,464,893	$ 7,329,242		$ 12,350,296	$ 6,257,793		$ 10,411,789	$ 5,275,568		$ 10,411,789	$ 5,275,568
24	6,888		$ 13,594,138	$ 6,687,415		$ 14,464,893	$ 7,115,769		$ 14,464,893	$ 7,115,769		$ 12,350,296	$ 6,075,527		$ 10,411,789	$ 5,121,910		$ 10,411,789	$ 5,121,910
25	6,687		$ 13,594,138	$ 6,492,636		$ 14,464,893	$ 6,908,513		$ 14,464,893	$ 6,908,513		$ 12,350,296	$ 5,898,570		$ 10,411,789	$ 4,972,728		$ 10,411,789	$ 4,972,728
26	6,493		$ 13,594,138	$ 6,303,530		$ 14,464,893	$ 6,707,295		$ 14,464,893	$ 6,707,295		$ 12,350,296	$ 5,726,767		$ 10,411,789	$ 4,827,892		$ 10,411,789	$ 4,827,892
27	6,303		$ 13,594,138	$ 6,119,932		$ 14,464,893	$ 6,511,937		$ 14,464,893	$ 6,511,937		$ 12,350,296	$ 5,559,968		$ 10,411,789	$ 4,687,274		$ 10,411,789	$ 4,687,274
28	6,120		$ 13,594,138	$ 5,941,682		$ 14,464,893	$ 6,322,268		$ 14,464,893	$ 6,322,268		$ 12,350,296	$ 5,398,027		$ 10,411,789	$ 4,550,751		$ 10,411,789	$ 4,550,751
29	5,942		$ 13,594,138	$ 5,768,623		$ 14,464,893	$ 6,138,125		$ 14,464,893	$ 6,138,125		$ 12,350,296	$ 5,240,803		$ 10,411,789	$ 4,418,205		$ 10,411,789	$ 4,418,205
30	5,769		$ 13,594,138	$ 5,600,605		$ 14,464,893	$ 5,959,344		$ 14,464,893	$ 5,959,344		$ 12,350,296	$ 5,088,158		$ 10,411,789	$ 4,289,519		$ 10,411,789	$ 4,289,519
31	5,601		$ 13,594,138	$ 5,437,480		$ 14,464,893	$ 5,785,771		$ 14,464,893	$ 5,785,771		$ 12,350,296	$ 4,939,960		$ 10,411,789	$ 4,164,582		$ 10,411,789	$ 4,164,582
32	5,437	$ 2,880,000		$ 1,118,411		$ 14,464,893	$ 5,617,254		$ 14,464,893	$ 5,617,254	$ 2,880,000		$ 1,118,411		$ 10,411,789	$ 4,043,283		$ 10,411,789	$ 4,043,283
33	5,279			$ -		$ 14,464,893	$ 5,453,644	$ 2,880,000		$ 1,085,836			$ -	$ 2,880,000		$ 1,085,836	$ 2,880,000		$ 1,085,836
34	5,125				$ 2,880,000		$ 1,054,209			$ -			$ -			$ -			$ -
Total PV costs		271,191,075		$ 526,016,541	733,754,157		$ 964,856,796	666,413,558		$ 915,637,928	288,642,844		$ 519,639,989	611,029,463		$ 788,385,497	664,485,383		$ 838,834,014
Unit cost				$ 1,974.19			$ 3,841.73			$ 3,539.57			$ 1,950.26			$ 3,047.65			$ 3,243

Table D.1.1 Life cycle cost analysis, 12.5 MGD facility, 3% discount rate, 30-year project life

		Low cost estimate									**High cost estimate**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	14,002	$196,096,438		$ 196,096,438	$ 213,709,991		$ 213,709,991	$ 256,709,253		$ 256,709,253	$208,104,344		$ 208,104,344	$ 254,768,305		$ 254,768,305	$ 255,486,664		$ 255,486,664
1	13,086	$ 72,214,637		$ 67,490,315	$ 209,869,382		$ 196,139,609	$ 252,095,898		$ 235,603,643	$ 77,658,500		$ 72,578,038	$ 250,189,831		$ 233,822,272	$ 250,895,281		$ 234,481,571
2	12,230		$ 13,594,138	$ 11,873,647	$ 206,097,792		$ 180,013,794	$ 154,728,406		$ 135,145,783		$ 12,350,296	$ 10,787,227	$ 103,191,328		$ 90,131,302	$ 155,223,438		$ 135,578,162
3	11,430		$ 13,594,138	$ 11,096,866	$ 101,196,991		$ 82,606,889		$ 14,464,893	$ 11,807,661		$ 12,350,296	$ 10,081,520		$ 10,411,789	$ 8,499,121		$ 10,411,789	$ 8,499,121
4	10,682		$ 13,594,138	$ 10,370,903		$ 14,464,893	$ 11,035,198		$ 14,464,893	$ 11,035,198		$ 12,350,296	$ 9,421,982		$ 10,411,789	$ 7,943,104		$ 10,411,789	$ 7,943,104
5	9,983		$ 13,594,138	$ 9,692,433		$ 14,464,893	$ 10,313,269		$ 14,464,893	$ 10,313,269		$ 12,350,296	$ 8,805,590		$ 10,411,789	$ 7,423,462		$ 10,411,789	$ 7,423,462
6	9,330		$ 13,594,138	$ 9,058,348		$ 14,464,893	$ 9,638,569		$ 14,464,893	$ 9,638,569		$ 12,350,296	$ 8,229,524		$ 10,411,789	$ 6,937,815		$ 10,411,789	$ 6,937,815
7	8,720		$ 13,594,138	$ 8,465,746		$ 14,464,893	$ 9,008,008		$ 14,464,893	$ 9,008,008		$ 12,350,296	$ 7,691,144		$ 10,411,789	$ 6,483,939		$ 10,411,789	$ 6,483,939
8	8,149		$ 13,594,138	$ 7,911,912		$ 14,464,893	$ 8,418,699		$ 14,464,893	$ 8,418,699		$ 12,350,296	$ 7,187,985		$ 10,411,789	$ 6,059,756		$ 10,411,789	$ 6,059,756
9	7,616		$ 13,594,138	$ 7,394,310		$ 14,464,893	$ 7,867,943		$ 14,464,893	$ 7,867,943		$ 12,350,296	$ 6,717,743		$ 10,411,789	$ 5,663,323		$ 10,411,789	$ 5,663,323
10	7,118		$ 13,594,138	$ 6,910,570		$ 14,464,893	$ 7,353,218		$ 14,464,893	$ 7,353,218		$ 12,350,296	$ 6,278,264		$ 10,411,789	$ 5,292,826		$ 10,411,789	$ 5,292,826
11	6,652		$ 13,594,138	$ 6,458,477		$ 14,464,893	$ 6,872,166		$ 14,464,893	$ 6,872,166		$ 12,350,296	$ 5,867,537		$ 10,411,789	$ 4,946,566		$ 10,411,789	$ 4,946,566
12	6,217		$ 13,594,138	$ 6,035,960		$ 14,464,893	$ 6,422,585		$ 14,464,893	$ 6,422,585		$ 12,350,296	$ 5,483,679		$ 10,411,789	$ 4,622,959		$ 10,411,789	$ 4,622,959
13	5,810		$ 13,594,138	$ 5,641,084		$ 14,464,893	$ 6,002,416		$ 14,464,893	$ 6,002,416		$ 12,350,296	$ 5,124,934		$ 10,411,789	$ 4,320,522		$ 10,411,789	$ 4,320,522
14	5,430		$ 13,594,138	$ 5,272,041		$ 14,464,893	$ 5,609,735		$ 14,464,893	$ 5,609,735		$ 12,350,296	$ 4,789,658		$ 10,411,789	$ 4,037,871		$ 10,411,789	$ 4,037,871
15	5,075		$ 13,594,138	$ 4,927,141		$ 14,464,893	$ 5,242,743		$ 14,464,893	$ 5,242,743		$ 12,350,296	$ 4,476,316		$ 10,411,789	$ 3,773,712		$ 10,411,789	$ 3,773,712
16	4,743		$ 13,594,138	$ 4,604,805		$ 14,464,893	$ 4,899,760		$ 14,464,893	$ 4,899,760		$ 12,350,296	$ 4,183,473		$ 10,411,789	$ 3,526,833		$ 10,411,789	$ 3,526,833
17	4,433		$ 13,594,138	$ 4,303,556		$ 14,464,893	$ 4,579,215		$ 14,464,893	$ 4,579,215		$ 12,350,296	$ 3,909,787		$ 10,411,789	$ 3,296,106		$ 10,411,789	$ 3,296,106
18	4,143		$ 13,594,138	$ 4,022,015		$ 14,464,893	$ 4,279,640		$ 14,464,893	$ 4,279,640		$ 12,350,296	$ 3,654,007		$ 10,411,789	$ 3,080,473		$ 10,411,789	$ 3,080,473
19	3,872		$ 13,594,138	$ 3,758,892		$ 14,464,893	$ 3,999,663		$ 14,464,893	$ 3,999,663		$ 12,350,296	$ 3,414,960		$ 10,411,789	$ 2,878,946		$ 10,411,789	$ 2,878,946
20	3,618		$ 13,594,138	$ 3,512,984		$ 14,464,893	$ 3,738,003		$ 14,464,893	$ 3,738,003		$ 12,350,296	$ 3,191,551		$ 10,411,789	$ 2,690,604		$ 10,411,789	$ 2,690,604
21	3,382		$ 13,594,138	$ 3,283,162		$ 14,464,893	$ 3,493,461		$ 14,464,893	$ 3,493,461		$ 12,350,296	$ 2,982,758		$ 10,411,789	$ 2,514,583		$ 10,411,789	$ 2,514,583
22	3,160		$ 13,594,138	$ 3,068,376		$ 14,464,893	$ 3,264,917		$ 14,464,893	$ 3,264,917		$ 12,350,296	$ 2,787,624		$ 10,411,789	$ 2,350,078		$ 10,411,789	$ 2,350,078
23	2,954		$ 13,594,138	$ 2,867,641		$ 14,464,893	$ 3,051,324		$ 14,464,893	$ 3,051,324		$ 12,350,296	$ 2,605,256		$ 10,411,789	$ 2,196,334		$ 10,411,789	$ 2,196,334
24	2,760		$ 13,594,138	$ 2,680,038		$ 14,464,893	$ 2,851,705		$ 14,464,893	$ 2,851,705		$ 12,350,296	$ 2,434,819		$ 10,411,789	$ 2,052,649		$ 10,411,789	$ 2,052,649
25	2,580		$ 13,594,138	$ 2,504,709		$ 14,464,893	$ 2,665,145		$ 14,464,893	$ 2,665,145		$ 12,350,296	$ 2,275,532		$ 10,411,789	$ 1,918,364		$ 10,411,789	$ 1,918,364
26	2,411		$ 13,594,138	$ 2,340,849		$ 14,464,893	$ 2,490,789		$ 14,464,893	$ 2,490,789		$ 12,350,296	$ 2,126,665		$ 10,411,789	$ 1,792,863		$ 10,411,789	$ 1,792,863
27	2,253		$ 13,594,138	$ 2,187,710		$ 14,464,893	$ 2,327,841		$ 14,464,893	$ 2,327,841		$ 12,350,296	$ 1,987,538		$ 10,411,789	$ 1,675,573		$ 10,411,789	$ 1,675,573
28	2,106		$ 13,594,138	$ 2,044,588		$ 14,464,893	$ 2,175,552		$ 14,464,893	$ 2,175,552		$ 12,350,296	$ 1,857,512		$ 10,411,789	$ 1,565,956		$ 10,411,789	$ 1,565,956
29	1,968		$ 13,594,138	$ 1,910,830		$ 14,464,893	$ 2,033,226		$ 14,464,893	$ 2,033,226		$ 12,350,296	$ 1,735,992		$ 10,411,789	$ 1,463,510		$ 10,411,789	$ 1,463,510
30	1,839		$ 13,594,138	$ 1,785,823		$ 14,464,893	$ 1,900,211		$ 14,464,893	$ 1,900,211		$ 12,350,296	$ 1,622,423		$ 10,411,789	$ 1,367,767		$ 10,411,789	$ 1,367,767
31	1,719		$ 13,594,138	$ 1,668,993		$ 14,464,893	$ 1,775,898		$ 14,464,893	$ 1,775,898		$ 12,350,296	$ 1,516,283		$ 10,411,789	$ 1,278,287		$ 10,411,789	$ 1,278,287
32	1,607	$ 2,880,000		$ 330,454		$ 14,464,893	$ 1,659,718		$ 14,464,893	$ 1,659,718	$ 2,880,000		$ 330,454		$ 10,411,789	$ 1,194,660		$ 10,411,789	$ 1,194,660
33	1,501			$ -		$ 14,464,893	$ 1,551,138	$ 2,880,000		$ 308,836			$ -	$ 2,880,000		$ 308,836	$ 2,880,000		$ 308,836
34	1,403				$ 2,880,000		$ 288,632			$ -			$ -			$ -			$ -
Total PV costs				$ 421,571,618	733,754,157		$ 819,280,672	666,413,558		$ 784,545,795			$ 424,242,117			$ 691,879,278			$ 738,703,797
Unit cost				$ 2,596.18			$ 5,776.48			$ 5,169.70			$ 2,612.62			$ 4,559.08			$ 4,868

Table D.1.2 Life cycle cost analysis, 12.5 MGD facility, 7% discount rate, 30-year project life

		Low cost estimate									**High cost estimate**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	14,002	$ 196,096,438		$ 196,096,438	$ 213,709,991		$ 213,709,991	$ 256,709,253		$ 256,709,253	$ 208,104,344		$ 208,104,344	$ 254,768,305		$ 254,768,305	$ 255,486,664		$ 255,486,664
1	13,594	$ 72,214,637		$ 70,111,298	$ 209,869,382		$ 203,756,681	$ 252,095,898		$ 244,753,299	$ 77,658,500		$ 75,396,602	$ 250,189,831		$ 242,902,748	$ 250,895,281		$ 243,587,651
2	13,198		$ 13,594,138	$ 12,813,779	$ 206,097,792		$ 194,266,936	$ 154,728,406		$ 145,846,363		$ 12,350,296	$ 11,641,338	$ 103,191,328		$ 97,267,723	$ 155,223,438		$ 146,312,978
3	12,814		$ 13,594,138	$ 12,440,562	$ 101,196,991		$ 92,609,582		$ 14,464,893	$ 13,237,426		$ 12,350,296	$ 11,302,270		$ 10,411,789	$ 9,528,262		$ 10,411,789	$ 9,528,262
4	12,440		$ 13,594,138	$ 12,078,216		$ 14,464,893	$ 12,851,870		$ 14,464,893	$ 12,851,870		$ 12,350,296	$ 10,973,078		$ 10,411,789	$ 9,250,740		$ 10,411,789	$ 9,250,740
5	12,078		$ 13,594,138	$ 11,726,423		$ 14,464,893	$ 12,477,544		$ 14,464,893	$ 12,477,544		$ 12,350,296	$ 10,653,474		$ 10,411,789	$ 8,981,301		$ 10,411,789	$ 8,981,301
6	11,726		$ 13,594,138	$ 11,384,877		$ 14,464,893	$ 12,114,120		$ 14,464,893	$ 12,114,120		$ 12,350,296	$ 10,343,178		$ 10,411,789	$ 8,719,710		$ 10,411,789	$ 8,719,710
7	11,385		$ 13,594,138	$ 11,053,278		$ 14,464,893	$ 11,761,282		$ 14,464,893	$ 11,761,282		$ 12,350,296	$ 10,041,921		$ 10,411,789	$ 8,465,737		$ 10,411,789	$ 8,465,737
8	11,053		$ 13,594,138	$ 10,731,338		$ 14,464,893	$ 11,418,720		$ 14,464,893	$ 11,418,720		$ 12,350,296	$ 9,749,438		$ 10,411,789	$ 8,219,163		$ 10,411,789	$ 8,219,163
9	10,731		$ 13,594,138	$ 10,418,775		$ 14,464,893	$ 11,086,136		$ 14,464,893	$ 11,086,136		$ 12,350,296	$ 9,465,473		$ 10,411,789	$ 7,979,769		$ 10,411,789	$ 7,979,769
10	10,419		$ 13,594,138	$ 10,115,315		$ 14,464,893	$ 10,763,239		$ 14,464,893	$ 10,763,239		$ 12,350,296	$ 9,189,780		$ 10,411,789	$ 7,747,349		$ 10,411,789	$ 7,747,349
11	10,115		$ 13,594,138	$ 9,820,695		$ 14,464,893	$ 10,449,746		$ 14,464,893	$ 10,449,746		$ 12,350,296	$ 8,922,117		$ 10,411,789	$ 7,521,698		$ 10,411,789	$ 7,521,698
12	9,821		$ 13,594,138	$ 9,534,655		$ 14,464,893	$ 10,145,385		$ 14,464,893	$ 10,145,385		$ 12,350,296	$ 8,662,249		$ 10,411,789	$ 7,302,619		$ 10,411,789	$ 7,302,619
13	9,535		$ 13,594,138	$ 9,256,947		$ 14,464,893	$ 9,849,888		$ 14,464,893	$ 9,849,888		$ 12,350,296	$ 8,409,951		$ 10,411,789	$ 7,089,922		$ 10,411,789	$ 7,089,922
14	9,257		$ 13,594,138	$ 8,987,327		$ 14,464,893	$ 9,562,998		$ 14,464,893	$ 9,562,998		$ 12,350,296	$ 8,165,001		$ 10,411,789	$ 6,883,419		$ 10,411,789	$ 6,883,419
15	8,987		$ 13,594,138	$ 8,725,560		$ 14,464,893	$ 9,284,464		$ 14,464,893	$ 9,284,464		$ 12,350,296	$ 7,927,185		$ 10,411,789	$ 6,682,931		$ 10,411,789	$ 6,682,931
16	8,725		$ 13,594,138	$ 8,471,417		$ 14,464,893	$ 9,014,043		$ 14,464,893	$ 9,014,043		$ 12,350,296	$ 7,696,296		$ 10,411,789	$ 6,488,283		$ 10,411,789	$ 6,488,283
17	8,471		$ 13,594,138	$ 8,224,677		$ 14,464,893	$ 8,751,498		$ 14,464,893	$ 8,751,498		$ 12,350,296	$ 7,472,132		$ 10,411,789	$ 6,299,304		$ 10,411,789	$ 6,299,304
18	8,225		$ 13,594,138	$ 7,985,123		$ 14,464,893	$ 8,496,600		$ 14,464,893	$ 8,496,600		$ 12,350,296	$ 7,254,497		$ 10,411,789	$ 6,115,829		$ 10,411,789	$ 6,115,829
19	7,985		$ 13,594,138	$ 7,752,547		$ 14,464,893	$ 8,249,126		$ 14,464,893	$ 8,249,126		$ 12,350,296	$ 7,043,201		$ 10,411,789	$ 5,937,698		$ 10,411,789	$ 5,937,698
20	7,752		$ 13,594,138	$ 7,526,745		$ 14,464,893	$ 8,008,861		$ 14,464,893	$ 8,008,861		$ 12,350,296	$ 6,838,059		$ 10,411,789	$ 5,764,755		$ 10,411,789	$ 5,764,755
21	7,527		$ 13,594,138	$ 7,307,519		$ 14,464,893	$ 7,775,593		$ 14,464,893	$ 7,775,593		$ 12,350,296	$ 6,638,893		$ 10,411,789	$ 5,596,850		$ 10,411,789	$ 5,596,850
22	7,307		$ 13,594,138	$ 7,094,679		$ 14,464,893	$ 7,549,119		$ 14,464,893	$ 7,549,119		$ 12,350,296	$ 6,445,527		$ 10,411,789	$ 5,433,835		$ 10,411,789	$ 5,433,835
23	7,095		$ 13,594,138	$ 6,888,038		$ 14,464,893	$ 7,329,242		$ 14,464,893	$ 7,329,242		$ 12,350,296	$ 6,257,793		$ 10,411,789	$ 5,275,568		$ 10,411,789	$ 5,275,568
24	6,888		$ 13,594,138	$ 6,687,415		$ 14,464,893	$ 7,115,769		$ 14,464,893	$ 7,115,769		$ 12,350,296	$ 6,075,527		$ 10,411,789	$ 5,121,910		$ 10,411,789	$ 5,121,910
25	6,687		$ 13,594,138	$ 6,492,636		$ 14,464,893	$ 6,908,513		$ 14,464,893	$ 6,908,513		$ 12,350,296	$ 5,898,570		$ 10,411,789	$ 4,972,728		$ 10,411,789	$ 4,972,728
26	6,493		$ 13,594,138	$ 6,303,530		$ 14,464,893	$ 6,707,295		$ 14,464,893	$ 6,707,295		$ 12,350,296	$ 5,726,767		$ 10,411,789	$ 4,827,892		$ 10,411,789	$ 4,827,892
27	6,303		$ 13,594,138	$ 6,119,932		$ 14,464,893	$ 6,511,937		$ 14,464,893	$ 6,511,937		$ 12,350,296	$ 5,559,968		$ 10,411,789	$ 4,687,274		$ 10,411,789	$ 4,687,274
28	6,120		$ 13,594,138	$ 5,941,682		$ 14,464,893	$ 6,322,268		$ 14,464,893	$ 6,322,268		$ 12,350,296	$ 5,398,027		$ 10,411,789	$ 4,550,751		$ 10,411,789	$ 4,550,751
29	5,942		$ 13,594,138	$ 5,768,623		$ 14,464,893	$ 6,138,125		$ 14,464,893	$ 6,138,125		$ 12,350,296	$ 5,240,803		$ 10,411,789	$ 4,418,205		$ 10,411,789	$ 4,418,205
30	5,769		$ 13,594,138	$ 5,600,605		$ 14,464,893	$ 5,959,344		$ 14,464,893	$ 5,959,344		$ 12,350,296	$ 5,088,158		$ 10,411,789	$ 4,289,519		$ 10,411,789	$ 4,289,519
31	5,601		$ 13,594,138	$ 5,437,480		$ 14,464,893	$ 5,785,771		$ 14,464,893	$ 5,785,771		$ 12,350,296	$ 4,939,960		$ 10,411,789	$ 4,164,582		$ 10,411,789	$ 4,164,582
32	5,437		$ 13,594,138	$ 5,279,107		$ 14,464,893	$ 5,617,254		$ 14,464,893	$ 5,617,254		$ 12,350,296	$ 4,796,077		$ 10,411,789	$ 4,043,283		$ 10,411,789	$ 4,043,283
33	5,279		$ 13,594,138	$ 5,125,347		$ 14,464,893	$ 5,453,644		$ 14,464,893	$ 5,453,644		$ 12,350,296	$ 4,656,386		$ 10,411,789	$ 3,925,518		$ 10,411,789	$ 3,925,518
34	5,125		$ 13,594,138	$ 4,976,065		$ 14,464,893	$ 5,294,800		$ 14,464,893	$ 5,294,800		$ 12,350,296	$ 4,520,763		$ 10,411,789	$ 3,811,182		$ 10,411,789	$ 3,811,182
35	4,976		$ 13,594,138	$ 4,831,131		$ 14,464,893	$ 5,140,583		$ 14,464,893	$ 5,140,583		$ 12,350,296	$ 4,389,090		$ 10,411,789	$ 3,700,177		$ 10,411,789	$ 3,700,177
36	4,831		$ 13,594,138	$ 4,690,418		$ 14,464,893	$ 4,990,857		$ 14,464,893	$ 4,990,857		$ 12,350,296	$ 4,261,253		$ 10,411,789	$ 3,592,405		$ 10,411,789	$ 3,592,405
37	4,690		$ 13,594,138	$ 4,553,804		$ 14,464,893	$ 4,845,492		$ 14,464,893	$ 4,845,492		$ 12,350,296	$ 4,137,138		$ 10,411,789	$ 3,487,772		$ 10,411,789	$ 3,487,772
38	4,554		$ 13,594,138	$ 4,421,169		$ 14,464,893	$ 4,704,362		$ 14,464,893	$ 4,704,362		$ 12,350,296	$ 4,016,639		$ 10,411,789	$ 3,386,186		$ 10,411,789	$ 3,386,186
39	4,421		$ 13,594,138	$ 4,292,397		$ 14,464,893	$ 4,567,341		$ 14,464,893	$ 4,567,341		$ 12,350,296	$ 3,899,650		$ 10,411,789	$ 3,287,559		$ 10,411,789	$ 3,287,559
40	4,292		$ 13,594,138	$ 4,167,376		$ 14,464,893	$ 4,434,312		$ 14,464,893	$ 4,434,312		$ 12,350,296	$ 3,786,068		$ 10,411,789	$ 3,191,805		$ 10,411,789	$ 3,191,805
41	4,167		$ 13,594,138	$ 4,045,996		$ 14,464,893	$ 4,305,157		$ 14,464,893	$ 4,305,157		$ 12,350,296	$ 3,675,794		$ 10,411,789	$ 3,098,840		$ 10,411,789	$ 3,098,840
42	4,046		$ 13,594,138	$ 3,928,152		$ 14,464,893	$ 4,179,764		$ 14,464,893	$ 4,179,764		$ 12,350,296	$ 3,568,732		$ 10,411,789	$ 3,008,583		$ 10,411,789	$ 3,008,583
43	3,928		$ 13,594,138	$ 3,813,739		$ 14,464,893	$ 4,058,024		$ 14,464,893	$ 4,058,024		$ 12,350,296	$ 3,464,788		$ 10,411,789	$ 2,920,954		$ 10,411,789	$ 2,920,954
44	3,814		$ 13,594,138	$ 3,702,660		$ 14,464,893	$ 3,939,829		$ 14,464,893	$ 3,939,829		$ 12,350,296	$ 3,363,872		$ 10,411,789	$ 2,835,878		$ 10,411,789	$ 2,835,878
45	3,703		$ 13,594,138	$ 3,594,815		$ 14,464,893	$ 3,825,076		$ 14,464,893	$ 3,825,076		$ 12,350,296	$ 3,265,895		$ 10,411,789	$ 2,753,279		$ 10,411,789	$ 2,753,279
46	3,595		$ 13,594,138	$ 3,490,112		$ 14,464,893	$ 3,713,666		$ 14,464,893	$ 3,713,666		$ 12,350,296	$ 3,170,772		$ 10,411,789	$ 2,673,087		$ 10,411,789	$ 2,673,087
47	3,490		$ 13,594,138	$ 3,388,458		$ 14,464,893	$ 3,605,501		$ 14,464,893	$ 3,605,501		$ 12,350,296	$ 3,078,420		$ 10,411,789	$ 2,595,230		$ 10,411,789	$ 2,595,230
48	3,388		$ 13,594,138	$ 3,289,765		$ 14,464,893	$ 3,500,487		$ 14,464,893	$ 3,500,487		$ 12,350,296	$ 2,988,757		$ 10,411,789	$ 2,519,640		$ 10,411,789	$ 2,519,640
49	3,290		$ 13,594,138	$ 3,193,947		$ 14,464,893	$ 3,398,531		$ 14,464,893	$ 3,398,531		$ 12,350,296	$ 2,901,706		$ 10,411,789	$ 2,446,253		$ 10,411,789	$ 2,446,253
50	3,194		$ 13,594,138	$ 3,100,919		$ 14,464,893	$ 3,299,545		$ 14,464,893	$ 3,299,545		$ 12,350,296	$ 2,817,190		$ 10,411,789	$ 2,375,003		$ 10,411,789	$ 2,375,003
51	3,101		$ 13,594,138	$ 3,010,601		$ 14,464,893	$ 3,203,441		$ 14,464,893	$ 3,203,441		$ 12,350,296	$ 2,735,136		$ 10,411,789	$ 2,305,828		$ 10,411,789	$ 2,305,828
52	3,011	$ 2,880,000		$ 619,237		$ 14,464,893	$ 3,110,137		$ 14,464,893	$ 3,110,137	$ 2,880,000		$ 619,237		$ 10,411,789	$ 2,238,668		$ 10,411,789	$ 2,238,668
53	2,923			$ -		$ 14,464,893	$ 3,019,551	$ 2,880,000		$ 601,201			$ -	$ 2,880,000		$ 601,201	$ 2,880,000		$ 601,201
54	2,838				$ 2,880,000		$ 583,690			$ -						$ -			$ -
Total PV costs				$ 606,413,347			$ 1,045,522,733			$ 998,723,844			$ 592,634,940			$ 848,054,708			$ 898,503,225
Unit cost				$ 1,733.76			$ 3,171			$ 2,941.05			$ 1,694.36			$ 2,497			$ 2,645.92

Table D.1.3 Life cycle cost analysis, 12.5 MGD facility, 3% discount rate, 50-year project life

		Low cost estimate									High cost estimate								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	14,002	$ 196,096,438		$ 196,096,438	$ 213,709,991		$ 213,709,991	$ 256,709,253		$ 256,709,253	$ 208,104,344		$ 208,104,344	$ 254,768,305		$ 254,768,305	$ 255,486,664		$ 255,486,664
1	13,086	$ 72,214,637		$ 67,490,315	$ 209,869,382		$ 196,139,609	$ 252,095,898		$ 235,603,643	$ 77,658,500		$ 72,578,038	$ 250,189,831		$ 233,822,272	$ 250,895,281		$ 234,481,571
2	12,230		$ 13,594,138	$ 11,873,647	$ 206,097,792		$ 180,013,794	$ 154,728,406		$ 135,145,783		$ 12,350,296	$ 10,787,227	$ 103,191,328		$ 90,131,302	$ 155,223,438		$ 135,578,162
3	11,430		$ 13,594,138	$ 11,096,866	$ 101,196,991		$ 82,606,889		$ 14,464,893	$ 11,807,661		$ 12,350,296	$ 10,081,520		$ 10,411,789	$ 8,499,121		$ 10,411,789	$ 8,499,121
4	10,682		$ 13,594,138	$ 10,370,903		$ 14,464,893	$ 11,035,198		$ 14,464,893	$ 11,035,198		$ 12,350,296	$ 9,421,982		$ 10,411,789	$ 7,943,104		$ 10,411,789	$ 7,943,104
5	9,983		$ 13,594,138	$ 9,692,433		$ 14,464,893	$ 10,313,269		$ 14,464,893	$ 10,313,269		$ 12,350,296	$ 8,805,590		$ 10,411,789	$ 7,423,462		$ 10,411,789	$ 7,423,462
6	9,330		$ 13,594,138	$ 9,058,348		$ 14,464,893	$ 9,638,569		$ 14,464,893	$ 9,638,569		$ 12,350,296	$ 8,229,524		$ 10,411,789	$ 6,937,815		$ 10,411,789	$ 6,937,815
7	8,720		$ 13,594,138	$ 8,465,746		$ 14,464,893	$ 9,008,008		$ 14,464,893	$ 9,008,008		$ 12,350,296	$ 7,691,144		$ 10,411,789	$ 6,483,939		$ 10,411,789	$ 6,483,939
8	8,149		$ 13,594,138	$ 7,911,912		$ 14,464,893	$ 8,418,699		$ 14,464,893	$ 8,418,699		$ 12,350,296	$ 7,187,985		$ 10,411,789	$ 6,059,756		$ 10,411,789	$ 6,059,756
9	7,616		$ 13,594,138	$ 7,394,310		$ 14,464,893	$ 7,867,943		$ 14,464,893	$ 7,867,943		$ 12,350,296	$ 6,717,743		$ 10,411,789	$ 5,663,323		$ 10,411,789	$ 5,663,323
10	7,118		$ 13,594,138	$ 6,910,570		$ 14,464,893	$ 7,353,218		$ 14,464,893	$ 7,353,218		$ 12,350,296	$ 6,278,264		$ 10,411,789	$ 5,292,826		$ 10,411,789	$ 5,292,826
11	6,652		$ 13,594,138	$ 6,458,477		$ 14,464,893	$ 6,872,166		$ 14,464,893	$ 6,872,166		$ 12,350,296	$ 5,867,537		$ 10,411,789	$ 4,946,566		$ 10,411,789	$ 4,946,566
12	6,217		$ 13,594,138	$ 6,035,960		$ 14,464,893	$ 6,422,585		$ 14,464,893	$ 6,422,585		$ 12,350,296	$ 5,483,679		$ 10,411,789	$ 4,622,959		$ 10,411,789	$ 4,622,959
13	5,810		$ 13,594,138	$ 5,641,084		$ 14,464,893	$ 6,002,416		$ 14,464,893	$ 6,002,416		$ 12,350,296	$ 5,124,934		$ 10,411,789	$ 4,320,522		$ 10,411,789	$ 4,320,522
14	5,430		$ 13,594,138	$ 5,272,041		$ 14,464,893	$ 5,609,735		$ 14,464,893	$ 5,609,735		$ 12,350,296	$ 4,789,658		$ 10,411,789	$ 4,037,871		$ 10,411,789	$ 4,037,871
15	5,075		$ 13,594,138	$ 4,927,141		$ 14,464,893	$ 5,242,743		$ 14,464,893	$ 5,242,743		$ 12,350,296	$ 4,476,316		$ 10,411,789	$ 3,773,712		$ 10,411,789	$ 3,773,712
16	4,743		$ 13,594,138	$ 4,604,805		$ 14,464,893	$ 4,899,760		$ 14,464,893	$ 4,899,760		$ 12,350,296	$ 4,183,473		$ 10,411,789	$ 3,526,833		$ 10,411,789	$ 3,526,833
17	4,433		$ 13,594,138	$ 4,303,556		$ 14,464,893	$ 4,579,215		$ 14,464,893	$ 4,579,215		$ 12,350,296	$ 3,909,787		$ 10,411,789	$ 3,296,106		$ 10,411,789	$ 3,296,106
18	4,143		$ 13,594,138	$ 4,022,015		$ 14,464,893	$ 4,279,640		$ 14,464,893	$ 4,279,640		$ 12,350,296	$ 3,654,007		$ 10,411,789	$ 3,080,473		$ 10,411,789	$ 3,080,473
19	3,872		$ 13,594,138	$ 3,758,892		$ 14,464,893	$ 3,999,663		$ 14,464,893	$ 3,999,663		$ 12,350,296	$ 3,414,960		$ 10,411,789	$ 2,878,946		$ 10,411,789	$ 2,878,946
20	3,618		$ 13,594,138	$ 3,512,984		$ 14,464,893	$ 3,738,003		$ 14,464,893	$ 3,738,003		$ 12,350,296	$ 3,191,551		$ 10,411,789	$ 2,690,604		$ 10,411,789	$ 2,690,604
21	3,382		$ 13,594,138	$ 3,283,162		$ 14,464,893	$ 3,493,461		$ 14,464,893	$ 3,493,461		$ 12,350,296	$ 2,982,758		$ 10,411,789	$ 2,514,583		$ 10,411,789	$ 2,514,583
22	3,160		$ 13,594,138	$ 3,068,376		$ 14,464,893	$ 3,264,917		$ 14,464,893	$ 3,264,917		$ 12,350,296	$ 2,787,624		$ 10,411,789	$ 2,350,078		$ 10,411,789	$ 2,350,078
23	2,954		$ 13,594,138	$ 2,867,641		$ 14,464,893	$ 3,051,324		$ 14,464,893	$ 3,051,324		$ 12,350,296	$ 2,605,256		$ 10,411,789	$ 2,196,334		$ 10,411,789	$ 2,196,334
24	2,760		$ 13,594,138	$ 2,680,038		$ 14,464,893	$ 2,851,705		$ 14,464,893	$ 2,851,705		$ 12,350,296	$ 2,434,819		$ 10,411,789	$ 2,052,649		$ 10,411,789	$ 2,052,649
25	2,580		$ 13,594,138	$ 2,504,709		$ 14,464,893	$ 2,665,145		$ 14,464,893	$ 2,665,145		$ 12,350,296	$ 2,275,532		$ 10,411,789	$ 1,918,364		$ 10,411,789	$ 1,918,364
26	2,411		$ 13,594,138	$ 2,340,849		$ 14,464,893	$ 2,490,789		$ 14,464,893	$ 2,490,789		$ 12,350,296	$ 2,126,665		$ 10,411,789	$ 1,792,863		$ 10,411,789	$ 1,792,863
27	2,253		$ 13,594,138	$ 2,187,710		$ 14,464,893	$ 2,327,841		$ 14,464,893	$ 2,327,841		$ 12,350,296	$ 1,987,538		$ 10,411,789	$ 1,675,573		$ 10,411,789	$ 1,675,573
28	2,106		$ 13,594,138	$ 2,044,588		$ 14,464,893	$ 2,175,552		$ 14,464,893	$ 2,175,552		$ 12,350,296	$ 1,857,512		$ 10,411,789	$ 1,565,956		$ 10,411,789	$ 1,565,956
29	1,968		$ 13,594,138	$ 1,910,830		$ 14,464,893	$ 2,033,226		$ 14,464,893	$ 2,033,226		$ 12,350,296	$ 1,735,992		$ 10,411,789	$ 1,463,510		$ 10,411,789	$ 1,463,510
30	1,839		$ 13,594,138	$ 1,785,823		$ 14,464,893	$ 1,900,211		$ 14,464,893	$ 1,900,211		$ 12,350,296	$ 1,622,423		$ 10,411,789	$ 1,367,767		$ 10,411,789	$ 1,367,767
31	1,719		$ 13,594,138	$ 1,668,993		$ 14,464,893	$ 1,775,898		$ 14,464,893	$ 1,775,898		$ 12,350,296	$ 1,516,283		$ 10,411,789	$ 1,278,287		$ 10,411,789	$ 1,278,287
32	1,607		$ 13,594,138	$ 1,559,807		$ 14,464,893	$ 1,659,718		$ 14,464,893	$ 1,659,718		$ 12,350,296	$ 1,417,087		$ 10,411,789	$ 1,194,660		$ 10,411,789	$ 1,194,660
33	1,501		$ 13,594,138	$ 1,457,763		$ 14,464,893	$ 1,551,138		$ 14,464,893	$ 1,551,138		$ 12,350,296	$ 1,324,380		$ 10,411,789	$ 1,116,505		$ 10,411,789	$ 1,116,505
34	1,403		$ 13,594,138	$ 1,362,396		$ 14,464,893	$ 1,449,662		$ 14,464,893	$ 1,449,662		$ 12,350,296	$ 1,237,739		$ 10,411,789	$ 1,043,463		$ 10,411,789	$ 1,043,463
35	1,311		$ 13,594,138	$ 1,273,267		$ 14,464,893	$ 1,354,824		$ 14,464,893	$ 1,354,824		$ 12,350,296	$ 1,156,765		$ 10,411,789	$ 975,199		$ 10,411,789	$ 975,199
36	1,226		$ 13,594,138	$ 1,189,969		$ 14,464,893	$ 1,266,191		$ 14,464,893	$ 1,266,191		$ 12,350,296	$ 1,081,089		$ 10,411,789	$ 911,401		$ 10,411,789	$ 911,401
37	1,145		$ 13,594,138	$ 1,112,121		$ 14,464,893	$ 1,183,356		$ 14,464,893	$ 1,183,356		$ 12,350,296	$ 1,010,363		$ 10,411,789	$ 851,776		$ 10,411,789	$ 851,776
38	1,071		$ 13,594,138	$ 1,039,365		$ 14,464,893	$ 1,105,940		$ 14,464,893	$ 1,105,940		$ 12,350,296	$ 944,265		$ 10,411,789	$ 796,053		$ 10,411,789	$ 796,053
39	1,000		$ 13,594,138	$ 971,369		$ 14,464,893	$ 1,033,589		$ 14,464,893	$ 1,033,589		$ 12,350,296	$ 882,490		$ 10,411,789	$ 743,974		$ 10,411,789	$ 743,974
40	935		$ 13,594,138	$ 907,822		$ 14,464,893	$ 965,971		$ 14,464,893	$ 965,971		$ 12,350,296	$ 824,757		$ 10,411,789	$ 695,303		$ 10,411,789	$ 695,303
41	874		$ 13,594,138	$ 848,432		$ 14,464,893	$ 902,777		$ 14,464,893	$ 902,777		$ 12,350,296	$ 770,801		$ 10,411,789	$ 649,816		$ 10,411,789	$ 649,816
42	817		$ 13,594,138	$ 792,927		$ 14,464,893	$ 843,717		$ 14,464,893	$ 843,717		$ 12,350,296	$ 720,375		$ 10,411,789	$ 607,305		$ 10,411,789	$ 607,305
43	763		$ 13,594,138	$ 741,053		$ 14,464,893	$ 788,520		$ 14,464,893	$ 788,520		$ 12,350,296	$ 673,248		$ 10,411,789	$ 567,575		$ 10,411,789	$ 567,575
44	713		$ 13,594,138	$ 692,573		$ 14,464,893	$ 736,935		$ 14,464,893	$ 736,935		$ 12,350,296	$ 629,204		$ 10,411,789	$ 530,444		$ 10,411,789	$ 530,444
45	667		$ 13,594,138	$ 647,264		$ 14,464,893	$ 688,724		$ 14,464,893	$ 688,724		$ 12,350,296	$ 588,041		$ 10,411,789	$ 495,742		$ 10,411,789	$ 495,742
46	623		$ 13,594,138	$ 604,920		$ 14,464,893	$ 643,667		$ 14,464,893	$ 643,667		$ 12,350,296	$ 549,571		$ 10,411,789	$ 463,310		$ 10,411,789	$ 463,310
47	582		$ 13,594,138	$ 565,346		$ 14,464,893	$ 601,558		$ 14,464,893	$ 601,558		$ 12,350,296	$ 513,617		$ 10,411,789	$ 433,000		$ 10,411,789	$ 433,000
48	544		$ 13,594,138	$ 528,361		$ 14,464,893	$ 562,204		$ 14,464,893	$ 562,204		$ 12,350,296	$ 480,016		$ 10,411,789	$ 404,673		$ 10,411,789	$ 404,673
49	509		$ 13,594,138	$ 493,795		$ 14,464,893	$ 525,424		$ 14,464,893	$ 525,424		$ 12,350,296	$ 448,613		$ 10,411,789	$ 378,199		$ 10,411,789	$ 378,199
50	475		$ 13,594,138	$ 461,491		$ 14,464,893	$ 491,051		$ 14,464,893	$ 491,051		$ 12,350,296	$ 419,265		$ 10,411,789	$ 353,457		$ 10,411,789	$ 353,457
51	444		$ 13,594,138	$ 431,300		$ 14,464,893	$ 458,926		$ 14,464,893	$ 458,926		$ 12,350,296	$ 391,836		$ 10,411,789	$ 330,334		$ 10,411,789	$ 330,334
52	415	$ 2,880,000		$ 85,396		$ 14,464,893	$ 428,903		$ 14,464,893	$ 428,903	$ 2,880,000		$ 85,396		$ 10,411,789	$ 308,723		$ 10,411,789	$ 308,723
53	388			$ -		$ 14,464,893	$ 400,844	$ 2,880,000		$ 79,809			$ -	$ 2,880,000		$ 79,809	$ 2,880,000		$ 79,809
54	363				$ 2,880,000		$ 74,588			$ -						$ -			$ -
Total PV costs				$ 439,007,897			$ 835,499,411			$ 801,899,846			$ 440,060,582			$ 704,306,501			$ 751,131,020
Unit cost				$ 2,430.92			$ 5,297			$ 4,751.19			$ 2,436.75			$ 4,173			$ 4,450.39

Table D.1.4 Life cycle cost analysis, 12.5 MGD facility, 7% discount rate, 50-year project life

		Low cost estimate									High cost estimate								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	28,004	$ 228,779,178		$ 228,779,178	$ 249,355,203		$ 249,355,203	$ 299,521,008		$ 299,521,008	$ 243,966,986		$ 243,966,986	$ 298,077,664		$ 298,077,664	$ 298,472,897		$ 298,472,897
1	27,188	$ 224,667,758		$ 218,124,037	$ 244,874,009		$ 237,741,756	$ 294,138,278		$ 285,571,144	$ 239,582,624		$ 232,604,489	$ 292,720,872		$ 284,195,021	$ 293,109,002		$ 284,571,846
2	26,396	$ 13,789,389		$ 12,997,822	$ 240,473,347		$ 226,669,193	$ 288,852,281		$ 272,270,979	$ 14,116,623		$ 13,306,271	$ 287,460,348		$ 270,958,948	$ 287,841,502		$ 271,318,223
3	25,627		$ 27,188,276	$ 24,881,124	$ 236,151,769		$ 216,112,322	$ 265,932,450		$ 243,365,863		$ 24,700,592	$ 22,604,541	$ 175,022,504		$ 160,170,384	$ 265,708,546		$ 243,160,959
4	24,881		$ 27,188,276	$ 24,156,431	$ 231,907,856		$ 206,047,126		$ 28,929,786	$ 25,703,740		$ 24,700,592	$ 21,946,156		$ 20,823,578	$ 18,501,480		$ 20,823,578	$ 18,501,480
5	24,156		$ 27,188,276	$ 23,452,846	$ 56,935,052		$ 49,112,676		$ 28,929,786	$ 24,955,088		$ 24,700,592	$ 21,306,947		$ 20,823,578	$ 17,962,602		$ 20,823,578	$ 17,962,602
6	23,452		$ 27,188,276	$ 22,769,753		$ 28,929,786	$ 24,228,240		$ 28,929,786	$ 24,228,240		$ 24,700,592	$ 20,686,357		$ 20,823,578	$ 17,439,419		$ 20,823,578	$ 17,439,419
7	22,769		$ 27,188,276	$ 22,106,557		$ 28,929,786	$ 23,522,563		$ 28,929,786	$ 23,522,563		$ 24,700,592	$ 20,083,842		$ 20,823,578	$ 16,931,475		$ 20,823,578	$ 16,931,475
8	22,106		$ 27,188,276	$ 21,462,676		$ 28,929,786	$ 22,837,440		$ 28,929,786	$ 22,837,440		$ 24,700,592	$ 19,498,875		$ 20,823,578	$ 16,438,325		$ 20,823,578	$ 16,438,325
9	21,462		$ 27,188,276	$ 20,837,550		$ 28,929,786	$ 22,172,272		$ 28,929,786	$ 22,172,272		$ 24,700,592	$ 18,930,947		$ 20,823,578	$ 15,959,539		$ 20,823,578	$ 15,959,539
10	20,837		$ 27,188,276	$ 20,230,631		$ 28,929,786	$ 21,526,478		$ 28,929,786	$ 21,526,478		$ 24,700,592	$ 18,379,560		$ 20,823,578	$ 15,494,698		$ 20,823,578	$ 15,494,698
11	20,230		$ 27,188,276	$ 19,641,389		$ 28,929,786	$ 20,899,493		$ 28,929,786	$ 20,899,493		$ 24,700,592	$ 17,844,233		$ 20,823,578	$ 15,043,396		$ 20,823,578	$ 15,043,396
12	19,641		$ 27,188,276	$ 19,069,310		$ 28,929,786	$ 20,290,770		$ 28,929,786	$ 20,290,770		$ 24,700,592	$ 17,324,498		$ 20,823,578	$ 14,605,239		$ 20,823,578	$ 14,605,239
13	19,069		$ 27,188,276	$ 18,513,893		$ 28,929,786	$ 19,699,777		$ 28,929,786	$ 19,699,777		$ 24,700,592	$ 16,819,901		$ 20,823,578	$ 14,179,844		$ 20,823,578	$ 14,179,844
14	18,514		$ 27,188,276	$ 17,974,653		$ 28,929,786	$ 19,125,997		$ 28,929,786	$ 19,125,997		$ 24,700,592	$ 16,330,001		$ 20,823,578	$ 13,766,838		$ 20,823,578	$ 13,766,838
15	17,974		$ 27,188,276	$ 17,451,120		$ 28,929,786	$ 18,568,929		$ 28,929,786	$ 18,568,929		$ 24,700,592	$ 15,854,370		$ 20,823,578	$ 13,365,863		$ 20,823,578	$ 13,365,863
16	17,451		$ 27,188,276	$ 16,942,835		$ 28,929,786	$ 18,028,086		$ 28,929,786	$ 18,028,086		$ 24,700,592	$ 15,392,592		$ 20,823,578	$ 12,976,566		$ 20,823,578	$ 12,976,566
17	16,943		$ 27,188,276	$ 16,449,354		$ 28,929,786	$ 17,502,996		$ 28,929,786	$ 17,502,996		$ 24,700,592	$ 14,944,264		$ 20,823,578	$ 12,598,607		$ 20,823,578	$ 12,598,607
18	16,449		$ 27,188,276	$ 15,970,247		$ 28,929,786	$ 16,993,200		$ 28,929,786	$ 16,993,200		$ 24,700,592	$ 14,508,994		$ 20,823,578	$ 12,231,658		$ 20,823,578	$ 12,231,658
19	15,970		$ 27,188,276	$ 15,505,094		$ 28,929,786	$ 16,498,253		$ 28,929,786	$ 16,498,253		$ 24,700,592	$ 14,086,402		$ 20,823,578	$ 11,875,396		$ 20,823,578	$ 11,875,396
20	15,505		$ 27,188,276	$ 15,053,489		$ 28,929,786	$ 16,017,721		$ 28,929,786	$ 16,017,721		$ 24,700,592	$ 13,676,119		$ 20,823,578	$ 11,529,510		$ 20,823,578	$ 11,529,510
21	15,053		$ 27,188,276	$ 14,615,038		$ 28,929,786	$ 15,551,186		$ 28,929,786	$ 15,551,186		$ 24,700,592	$ 13,277,785		$ 20,823,578	$ 11,193,699		$ 20,823,578	$ 11,193,699
22	14,615		$ 27,188,276	$ 14,189,357		$ 28,929,786	$ 15,098,238		$ 28,929,786	$ 15,098,238		$ 24,700,592	$ 12,891,054		$ 20,823,578	$ 10,867,669		$ 20,823,578	$ 10,867,669
23	14,189		$ 27,188,276	$ 13,776,075		$ 28,929,786	$ 14,658,484		$ 28,929,786	$ 14,658,484		$ 24,700,592	$ 12,515,586		$ 20,823,578	$ 10,551,135		$ 20,823,578	$ 10,551,135
24	13,776		$ 27,188,276	$ 13,374,830		$ 28,929,786	$ 14,231,538		$ 28,929,786	$ 14,231,538		$ 24,700,592	$ 12,151,054		$ 20,823,578	$ 10,243,821		$ 20,823,578	$ 10,243,821
25	13,375		$ 27,188,276	$ 12,985,272		$ 28,929,786	$ 13,817,027		$ 28,929,786	$ 13,817,027		$ 24,700,592	$ 11,797,140		$ 20,823,578	$ 9,945,457		$ 20,823,578	$ 9,945,457
26	12,985		$ 27,188,276	$ 12,607,060		$ 28,929,786	$ 13,414,589		$ 28,929,786	$ 13,414,589		$ 24,700,592	$ 11,453,534		$ 20,823,578	$ 9,655,783		$ 20,823,578	$ 9,655,783
27	12,607		$ 27,188,276	$ 12,239,864		$ 28,929,786	$ 13,023,873		$ 28,929,786	$ 13,023,873		$ 24,700,592	$ 11,119,936		$ 20,823,578	$ 9,374,547		$ 20,823,578	$ 9,374,547
28	12,240		$ 27,188,276	$ 11,883,363		$ 28,929,786	$ 12,644,537		$ 28,929,786	$ 12,644,537		$ 24,700,592	$ 10,796,054		$ 20,823,578	$ 9,101,502		$ 20,823,578	$ 9,101,502
29	11,883		$ 27,188,276	$ 11,537,246		$ 28,929,786	$ 12,276,249		$ 28,929,786	$ 12,276,249		$ 24,700,592	$ 10,481,606		$ 20,823,578	$ 8,836,410		$ 20,823,578	$ 8,836,410
30	11,537		$ 27,188,276	$ 11,201,210		$ 28,929,786	$ 11,918,689		$ 28,929,786	$ 11,918,689		$ 24,700,592	$ 10,176,317		$ 20,823,578	$ 8,579,039		$ 20,823,578	$ 8,579,039
31	11,201		$ 27,188,276	$ 10,874,961		$ 28,929,786	$ 11,571,543		$ 28,929,786	$ 11,571,543		$ 24,700,592	$ 9,879,919		$ 20,823,578	$ 8,329,164		$ 20,823,578	$ 8,329,164
32	10,875		$ 27,188,276	$ 10,558,215		$ 28,929,786	$ 11,234,507		$ 28,929,786	$ 11,234,507		$ 24,700,592	$ 9,592,155		$ 20,823,578	$ 8,086,567		$ 20,823,578	$ 8,086,567
33	10,558	$ 5,040,000		$ 1,900,212		$ 28,929,786	$ 10,907,289		$ 28,929,786	$ 10,907,289	$ 5,040,000		$ 1,900,212		$ 20,823,578	$ 7,851,036		$ 20,823,578	$ 7,851,036
34	10,251					$ 28,929,786	$ 10,589,601	$ 5,040,000		$ 1,844,866			$ -	$ 5,040,000		$ 1,844,866	$ 5,040,000		$ 1,844,866
35	9,952					$ 28,929,786	$ 10,281,166			$ -			$ -			$ -			$ -
36	9,662				$ 5,040,000		$ 1,738,963			$ -			$ -			$ -			$ -
Total PV costs				$ 964,112,695			$ 1,675,907,971			$ 1,621,492,652			$ 948,128,700			$ 1,388,763,165			$ 1,472,885,073
Unit cost				$ 1,863			$ 3,540			$ 3,228			$ 1,833			$ 2,765			$ 2,932

Table D.2.1 Life cycle cost analysis, 25 MGD facility, 3% discount rate, 30-year project life

		Low cost estimate									**High cost estimate**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	28003.5	$ 228,779,178		$ 228,779,178	$ 249,355,203		$ 249,355,203	$ 299,521,008		$ 299,521,008	$ 243,966,986		$ 243,966,986	$ 298,077,664		$ 298,077,664	$ 298,472,897		$ 298,472,897
1	26171.4953	$ 224,667,758		$ 209,969,868	$ 244,874,009		$ 228,854,214	$ 294,138,278		$ 274,895,587	$ 239,582,624		$ 223,908,994	$ 292,720,872		$ 273,570,908	$ 293,109,002		$ 273,933,647
2	24459.3414	$ 13,789,389		$ 12,044,186	$ 240,473,347		$ 210,038,734	$ 288,852,281		$ 252,294,769	$ 14,116,623		$ 12,330,005	$ 287,460,348		$ 251,079,000	$ 287,841,502		$ 251,411,916
3	22859.1976		$ 27,188,276	$ 22,193,732	$ 236,151,769		$ 192,770,188	$ 265,932,450		$ 217,080,094		$ 24,700,592	$ 20,163,041	$ 175,022,504		$ 142,870,498	$ 265,708,546		$ 216,897,322
4	21363.7361		$ 27,188,276	$ 20,741,806	$ 231,907,856		$ 176,921,393		$ 28,929,786	$ 22,070,395		$ 24,700,592	$ 18,843,963		$ 20,823,578	$ 15,886,208		$ 20,823,578	$ 15,886,208
5	19966.1085		$ 27,188,276	$ 19,384,865	$ 56,935,052		$ 40,593,906		$ 28,929,786	$ 20,626,538		$ 24,700,592	$ 17,611,181		$ 20,823,578	$ 14,846,924		$ 20,823,578	$ 14,846,924
6	18659.9145		$ 27,188,276	$ 18,116,696		$ 28,929,786	$ 19,277,138		$ 28,929,786	$ 19,277,138		$ 24,700,592	$ 16,459,047		$ 20,823,578	$ 13,875,629		$ 20,823,578	$ 13,875,629
7	17439.1724		$ 27,188,276	$ 16,931,492		$ 28,929,786	$ 18,016,017		$ 28,929,786	$ 18,016,017		$ 24,700,592	$ 15,382,287		$ 20,823,578	$ 12,967,878		$ 20,823,578	$ 12,967,878
8	16298.292		$ 27,188,276	$ 15,823,824		$ 28,929,786	$ 16,837,399		$ 28,929,786	$ 16,837,399		$ 24,700,592	$ 14,375,969		$ 20,823,578	$ 12,119,512		$ 20,823,578	$ 12,119,512
9	15232.0486		$ 27,188,276	$ 14,788,621		$ 28,929,786	$ 15,735,887		$ 28,929,786	$ 15,735,887		$ 24,700,592	$ 13,435,485		$ 20,823,578	$ 11,326,647		$ 20,823,578	$ 11,326,647
10	14235.5594		$ 27,188,276	$ 13,821,141		$ 28,929,786	$ 14,706,436		$ 28,929,786	$ 14,706,436		$ 24,700,592	$ 12,556,528		$ 20,823,578	$ 10,585,651		$ 20,823,578	$ 10,585,651
11	13304.2611		$ 27,188,276	$ 12,916,954		$ 28,929,786	$ 13,744,333		$ 28,929,786	$ 13,744,333		$ 24,700,592	$ 11,735,073		$ 20,823,578	$ 9,893,132		$ 20,823,578	$ 9,893,132
12	12433.8889		$ 27,188,276	$ 12,071,920		$ 28,929,786	$ 12,845,171		$ 28,929,786	$ 12,845,171		$ 24,700,592	$ 10,967,358		$ 20,823,578	$ 9,245,918		$ 20,823,578	$ 9,245,918
13	11620.4569		$ 27,188,276	$ 11,282,168		$ 28,929,786	$ 12,004,833		$ 28,929,786	$ 12,004,833		$ 24,700,592	$ 10,249,867		$ 20,823,578	$ 8,641,045		$ 20,823,578	$ 8,641,045
14	10860.2401		$ 27,188,276	$ 10,544,082		$ 28,929,786	$ 11,219,470		$ 28,929,786	$ 11,219,470		$ 24,700,592	$ 9,579,315		$ 20,823,578	$ 8,075,743		$ 20,823,578	$ 8,075,743
15	10149.7571		$ 27,188,276	$ 9,854,282		$ 28,929,786	$ 10,485,486		$ 28,929,786	$ 10,485,486		$ 24,700,592	$ 8,952,631		$ 20,823,578	$ 7,547,423		$ 20,823,578	$ 7,547,423
16	9485.75431		$ 27,188,276	$ 9,209,610		$ 28,929,786	$ 9,799,519		$ 28,929,786	$ 9,799,519		$ 24,700,592	$ 8,366,945		$ 20,823,578	$ 7,053,666		$ 20,823,578	$ 7,053,666
17	8865.19094		$ 27,188,276	$ 8,607,112		$ 28,929,786	$ 9,158,429		$ 28,929,786	$ 9,158,429		$ 24,700,592	$ 7,819,575		$ 20,823,578	$ 6,592,212		$ 20,823,578	$ 6,592,212
18	8285.22518		$ 27,188,276	$ 8,044,030		$ 28,929,786	$ 8,559,280		$ 28,929,786	$ 8,559,280		$ 24,700,592	$ 7,308,014		$ 20,823,578	$ 6,160,945		$ 20,823,578	$ 6,160,945
19	7743.2011		$ 27,188,276	$ 7,517,785		$ 28,929,786	$ 7,999,327		$ 28,929,786	$ 7,999,327		$ 24,700,592	$ 6,829,919		$ 20,823,578	$ 5,757,893		$ 20,823,578	$ 5,757,893
20	7236.63655		$ 27,188,276	$ 7,025,967		$ 28,929,786	$ 7,476,006		$ 28,929,786	$ 7,476,006		$ 24,700,592	$ 6,383,102		$ 20,823,578	$ 5,381,208		$ 20,823,578	$ 5,381,208
21	6763.21172		$ 27,188,276	$ 6,566,325		$ 28,929,786	$ 6,986,922		$ 28,929,786	$ 6,986,922		$ 24,700,592	$ 5,965,516		$ 20,823,578	$ 5,029,167		$ 20,823,578	$ 5,029,167
22	6320.75862		$ 27,188,276	$ 6,136,752		$ 28,929,786	$ 6,529,834		$ 28,929,786	$ 6,529,834		$ 24,700,592	$ 5,575,249		$ 20,823,578	$ 4,700,156		$ 20,823,578	$ 4,700,156
23	5907.25105		$ 27,188,276	$ 5,735,282		$ 28,929,786	$ 6,102,648		$ 28,929,786	$ 6,102,648		$ 24,700,592	$ 5,210,513		$ 20,823,578	$ 4,392,669		$ 20,823,578	$ 4,392,669
24	5520.79537		$ 27,188,276	$ 5,360,077		$ 28,929,786	$ 5,703,410		$ 28,929,786	$ 5,703,410		$ 24,700,592	$ 4,869,638		$ 20,823,578	$ 4,105,298		$ 20,823,578	$ 4,105,298
25	5159.62184		$ 27,188,276	$ 5,009,418		$ 28,929,786	$ 5,330,289		$ 28,929,786	$ 5,330,289		$ 24,700,592	$ 4,551,064		$ 20,823,578	$ 3,836,727		$ 20,823,578	$ 3,836,727
26	4822.07649		$ 27,188,276	$ 4,681,699		$ 28,929,786	$ 4,981,579		$ 28,929,786	$ 4,981,579		$ 24,700,592	$ 4,253,331		$ 20,823,578	$ 3,585,726		$ 20,823,578	$ 3,585,726
27	4506.61354		$ 27,188,276	$ 4,375,419		$ 28,929,786	$ 4,655,681		$ 28,929,786	$ 4,655,681		$ 24,700,592	$ 3,975,075		$ 20,823,578	$ 3,351,146		$ 20,823,578	$ 3,351,146
28	4211.78836		$ 27,188,276	$ 4,089,177		$ 28,929,786	$ 4,351,104		$ 28,929,786	$ 4,351,104		$ 24,700,592	$ 3,715,024		$ 20,823,578	$ 3,131,912		$ 20,823,578	$ 3,131,912
29	3936.2508		$ 27,188,276	$ 3,821,661		$ 28,929,786	$ 4,066,452		$ 28,929,786	$ 4,066,452		$ 24,700,592	$ 3,471,985		$ 20,823,578	$ 2,927,021		$ 20,823,578	$ 2,927,021
30	3678.73907		$ 27,188,276	$ 3,571,645		$ 28,929,786	$ 3,800,423		$ 28,929,786	$ 3,800,423		$ 24,700,592	$ 3,244,846		$ 20,823,578	$ 2,735,533		$ 20,823,578	$ 2,735,533
31	3438.07389		$ 27,188,276	$ 3,337,986		$ 28,929,786	$ 3,551,797		$ 28,929,786	$ 3,551,797		$ 24,700,592	$ 3,032,566		$ 20,823,578	$ 2,556,573		$ 20,823,578	$ 2,556,573
32	3213.15317		$ 27,188,276	$ 3,119,613		$ 28,929,786	$ 3,319,436		$ 28,929,786	$ 3,319,436		$ 24,700,592	$ 2,834,174		$ 20,823,578	$ 2,389,321		$ 20,823,578	$ 2,389,321
33	3002.94689	$ 5,040,000		$ 540,463		$ 28,929,786	$ 3,102,277		$ 28,929,786	$ 3,102,277	$ 5,040,000		$ 540,463		$ 20,823,578	$ 2,233,010		$ 20,823,578	$ 2,233,010
34	2806.49242					$ 28,929,786	$ 2,899,324	$ 5,040,000		$ 505,105			$ -	$ 5,040,000		$ 505,105	$ 5,040,000		$ 505,105
35	2622.89011					$ 28,929,786	$ 2,709,649			$ -			$ -			$ -			$ -
36	2451.29917				$ 5,040,000		$ 441,179			$ -			$ -			$ -			$ -
Total PV costs				$ 746,014,836			$ 1,354,930,371			$ 1,337,340,079			$ 748,464,731			$ 1,177,035,071			$ 1,252,152,781
Unit cost				$ 2,458			$ 5,469			$ 4,715			$ 2,466			$ 4,149			$ 4,414

Table D.2.2 Life cycle cost analysis, 25 MGD facility, 7% discount rate, 30-year project life

		Low cost estimate									**High cost estimate**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	28,004	$ 228,779,178		$ 228,779,178	$ 249,355,203		$ 249,355,203	$ 299,521,008		$ 299,521,008	$ 243,966,986		$ 243,966,986	$ 298,077,664		$ 298,077,664	$ 298,472,897		$ 298,472,897
1	27,188	$ 224,667,758		$ 218,124,037	$ 244,874,009		$ 237,741,756	$ 294,138,278		$ 285,571,144	$ 239,582,624		$ 232,604,489	$ 292,720,872		$ 284,195,021	$ 293,109,002		$ 284,571,846
2	26,396	$ 13,789,389		$ 12,997,822	$ 240,473,347		$ 226,669,193	$ 288,852,281		$ 272,270,979	$ 14,116,623		$ 13,306,271	$ 287,460,348		$ 270,958,948	$ 287,841,502		$ 271,318,223
3	25,627		$ 27,188,276	$ 24,881,124	$ 236,151,769		$ 216,112,322	$ 265,932,450		$ 243,365,863		$ 24,700,592	$ 22,604,541	$ 175,022,504		$ 160,170,384	$ 265,708,546		$ 243,160,959
4	24,881		$ 27,188,276	$ 24,156,431	$ 231,907,856		$ 206,047,126		$ 28,929,786	$ 25,703,740		$ 24,700,592	$ 21,946,156		$ 20,823,578	$ 18,501,480		$ 20,823,578	$ 18,501,480
5	24,156		$ 27,188,276	$ 23,452,846	$ 56,935,052		$ 49,112,676		$ 28,929,786	$ 24,955,088		$ 24,700,592	$ 21,306,947		$ 20,823,578	$ 17,962,602		$ 20,823,578	$ 17,962,602
6	23,452		$ 27,188,276	$ 22,769,753		$ 28,929,786	$ 24,228,240		$ 28,929,786	$ 24,228,240		$ 24,700,592	$ 20,686,357		$ 20,823,578	$ 17,439,419		$ 20,823,578	$ 17,439,419
7	22,769		$ 27,188,276	$ 22,106,557		$ 28,929,786	$ 23,522,563		$ 28,929,786	$ 23,522,563		$ 24,700,592	$ 20,083,842		$ 20,823,578	$ 16,931,475		$ 20,823,578	$ 16,931,475
8	22,106		$ 27,188,276	$ 21,462,676		$ 28,929,786	$ 22,837,440		$ 28,929,786	$ 22,837,440		$ 24,700,592	$ 19,498,875		$ 20,823,578	$ 16,438,325		$ 20,823,578	$ 16,438,325
9	21,462		$ 27,188,276	$ 20,837,550		$ 28,929,786	$ 22,172,272		$ 28,929,786	$ 22,172,272		$ 24,700,592	$ 18,930,947		$ 20,823,578	$ 15,959,539		$ 20,823,578	$ 15,959,539
10	20,837		$ 27,188,276	$ 20,230,631		$ 28,929,786	$ 21,526,478		$ 28,929,786	$ 21,526,478		$ 24,700,592	$ 18,379,560		$ 20,823,578	$ 15,494,698		$ 20,823,578	$ 15,494,698
11	20,230		$ 27,188,276	$ 19,641,389		$ 28,929,786	$ 20,899,493		$ 28,929,786	$ 20,899,493		$ 24,700,592	$ 17,844,233		$ 20,823,578	$ 15,043,396		$ 20,823,578	$ 15,043,396
12	19,641		$ 27,188,276	$ 19,069,310		$ 28,929,786	$ 20,290,770		$ 28,929,786	$ 20,290,770		$ 24,700,592	$ 17,324,498		$ 20,823,578	$ 14,605,239		$ 20,823,578	$ 14,605,239
13	19,069		$ 27,188,276	$ 18,513,893		$ 28,929,786	$ 19,699,777		$ 28,929,786	$ 19,699,777		$ 24,700,592	$ 16,819,901		$ 20,823,578	$ 14,179,844		$ 20,823,578	$ 14,179,844
14	18,514		$ 27,188,276	$ 17,974,653		$ 28,929,786	$ 19,125,997		$ 28,929,786	$ 19,125,997		$ 24,700,592	$ 16,330,001		$ 20,823,578	$ 13,766,838		$ 20,823,578	$ 13,766,838
15	17,974		$ 27,188,276	$ 17,451,120		$ 28,929,786	$ 18,568,929		$ 28,929,786	$ 18,568,929		$ 24,700,592	$ 15,854,370		$ 20,823,578	$ 13,365,863		$ 20,823,578	$ 13,365,863
16	17,451		$ 27,188,276	$ 16,942,835		$ 28,929,786	$ 18,028,086		$ 28,929,786	$ 18,028,086		$ 24,700,592	$ 15,392,592		$ 20,823,578	$ 12,976,566		$ 20,823,578	$ 12,976,566
17	16,943		$ 27,188,276	$ 16,449,354		$ 28,929,786	$ 17,502,996		$ 28,929,786	$ 17,502,996		$ 24,700,592	$ 14,944,264		$ 20,823,578	$ 12,598,607		$ 20,823,578	$ 12,598,607
18	16,449		$ 27,188,276	$ 15,970,247		$ 28,929,786	$ 16,993,200		$ 28,929,786	$ 16,993,200		$ 24,700,592	$ 14,508,994		$ 20,823,578	$ 12,231,658		$ 20,823,578	$ 12,231,658
19	15,970		$ 27,188,276	$ 15,505,094		$ 28,929,786	$ 16,498,253		$ 28,929,786	$ 16,498,253		$ 24,700,592	$ 14,086,402		$ 20,823,578	$ 11,875,396		$ 20,823,578	$ 11,875,396
20	15,505		$ 27,188,276	$ 15,053,489		$ 28,929,786	$ 16,017,721		$ 28,929,786	$ 16,017,721		$ 24,700,592	$ 13,676,119		$ 20,823,578	$ 11,529,510		$ 20,823,578	$ 11,529,510
21	15,053		$ 27,188,276	$ 14,615,038		$ 28,929,786	$ 15,551,186		$ 28,929,786	$ 15,551,186		$ 24,700,592	$ 13,277,785		$ 20,823,578	$ 11,193,699		$ 20,823,578	$ 11,193,699
22	14,615		$ 27,188,276	$ 14,189,357		$ 28,929,786	$ 15,098,238		$ 28,929,786	$ 15,098,238		$ 24,700,592	$ 12,891,054		$ 20,823,578	$ 10,867,669		$ 20,823,578	$ 10,867,669
23	14,189		$ 27,188,276	$ 13,776,075		$ 28,929,786	$ 14,658,484		$ 28,929,786	$ 14,658,484		$ 24,700,592	$ 12,515,586		$ 20,823,578	$ 10,551,135		$ 20,823,578	$ 10,551,135
24	13,776		$ 27,188,276	$ 13,374,830		$ 28,929,786	$ 14,231,538		$ 28,929,786	$ 14,231,538		$ 24,700,592	$ 12,151,054		$ 20,823,578	$ 10,243,821		$ 20,823,578	$ 10,243,821
25	13,375		$ 27,188,276	$ 12,985,272		$ 28,929,786	$ 13,817,027		$ 28,929,786	$ 13,817,027		$ 24,700,592	$ 11,797,140		$ 20,823,578	$ 9,945,457		$ 20,823,578	$ 9,945,457
26	12,985		$ 27,188,276	$ 12,607,060		$ 28,929,786	$ 13,414,589		$ 28,929,786	$ 13,414,589		$ 24,700,592	$ 11,453,534		$ 20,823,578	$ 9,655,783		$ 20,823,578	$ 9,655,783
27	12,607		$ 27,188,276	$ 12,239,864		$ 28,929,786	$ 13,023,873		$ 28,929,786	$ 13,023,873		$ 24,700,592	$ 11,119,936		$ 20,823,578	$ 9,374,547		$ 20,823,578	$ 9,374,547
28	12,240		$ 27,188,276	$ 11,883,363		$ 28,929,786	$ 12,644,537		$ 28,929,786	$ 12,644,537		$ 24,700,592	$ 10,796,054		$ 20,823,578	$ 9,101,502		$ 20,823,578	$ 9,101,502
29	11,883		$ 27,188,276	$ 11,537,246		$ 28,929,786	$ 12,276,249		$ 28,929,786	$ 12,276,249		$ 24,700,592	$ 10,481,606		$ 20,823,578	$ 8,836,410		$ 20,823,578	$ 8,836,410
30	11,537		$ 27,188,276	$ 11,201,210		$ 28,929,786	$ 11,918,689		$ 28,929,786	$ 11,918,689		$ 24,700,592	$ 10,176,317		$ 20,823,578	$ 8,579,039		$ 20,823,578	$ 8,579,039
31	11,201		$ 27,188,276	$ 10,874,961		$ 28,929,786	$ 11,571,543		$ 28,929,786	$ 11,571,543		$ 24,700,592	$ 9,879,919		$ 20,823,578	$ 8,329,164		$ 20,823,578	$ 8,329,164
32	10,875		$ 27,188,276	$ 10,558,215		$ 28,929,786	$ 11,234,507		$ 28,929,786	$ 11,234,507		$ 24,700,592	$ 9,592,155		$ 20,823,578	$ 8,086,567		$ 20,823,578	$ 8,086,567
33	10,558		$ 27,188,276	$ 10,250,694		$ 28,929,786	$ 10,907,289		$ 28,929,786	$ 10,907,289		$ 24,700,592	$ 9,312,771		$ 20,823,578	$ 7,851,036		$ 20,823,578	$ 7,851,036
34	10,251		$ 27,188,276	$ 9,952,130		$ 28,929,786	$ 10,589,601		$ 28,929,786	$ 10,589,601		$ 24,700,592	$ 9,041,526		$ 20,823,578	$ 7,622,365		$ 20,823,578	$ 7,622,365
35	9,952		$ 27,188,276	$ 9,662,262		$ 28,929,786	$ 10,281,166		$ 28,929,786	$ 10,281,166		$ 24,700,592	$ 8,778,180		$ 20,823,578	$ 7,400,354		$ 20,823,578	$ 7,400,354
36	9,662		$ 27,188,276	$ 9,380,837		$ 28,929,786	$ 9,981,714		$ 28,929,786	$ 9,981,714		$ 24,700,592	$ 8,522,505		$ 20,823,578	$ 7,184,810		$ 20,823,578	$ 7,184,810
37	9,381		$ 27,188,276	$ 9,107,609		$ 28,929,786	$ 9,690,985		$ 28,929,786	$ 9,690,985		$ 24,700,592	$ 8,274,277		$ 20,823,578	$ 6,975,543		$ 20,823,578	$ 6,975,543
38	9,107		$ 27,188,276	$ 8,842,338		$ 28,929,786	$ 9,408,723		$ 28,929,786	$ 9,408,723		$ 24,700,592	$ 8,033,278		$ 20,823,578	$ 6,772,372		$ 20,823,578	$ 6,772,372
39	8,842		$ 27,188,276	$ 8,584,795		$ 28,929,786	$ 9,134,683		$ 28,929,786	$ 9,134,683		$ 24,700,592	$ 7,799,299		$ 20,823,578	$ 6,575,119		$ 20,823,578	$ 6,575,119
40	8,585		$ 27,188,276	$ 8,334,752		$ 28,929,786	$ 8,868,624		$ 28,929,786	$ 8,868,624		$ 24,700,592	$ 7,572,135		$ 20,823,578	$ 6,383,610		$ 20,823,578	$ 6,383,610
41	8,335		$ 27,188,276	$ 8,091,992		$ 28,929,786	$ 8,610,314		$ 28,929,786	$ 8,610,314		$ 24,700,592	$ 7,351,588		$ 20,823,578	$ 6,197,680		$ 20,823,578	$ 6,197,680
42	8,092		$ 27,188,276	$ 7,856,303		$ 28,929,786	$ 8,359,529		$ 28,929,786	$ 8,359,529		$ 24,700,592	$ 7,137,464		$ 20,823,578	$ 6,017,165		$ 20,823,578	$ 6,017,165
43	7,856		$ 27,188,276	$ 7,627,479		$ 28,929,786	$ 8,116,047		$ 28,929,786	$ 8,116,047		$ 24,700,592	$ 6,929,577		$ 20,823,578	$ 5,841,908		$ 20,823,578	$ 5,841,908
44	7,627		$ 27,188,276	$ 7,405,319		$ 28,929,786	$ 7,879,657		$ 28,929,786	$ 7,879,657		$ 24,700,592	$ 6,727,744		$ 20,823,578	$ 5,671,755		$ 20,823,578	$ 5,671,755
45	7,405		$ 27,188,276	$ 7,189,630		$ 28,929,786	$ 7,650,153		$ 28,929,786	$ 7,650,153		$ 24,700,592	$ 6,531,791		$ 20,823,578	$ 5,506,558		$ 20,823,578	$ 5,506,558
46	7,190		$ 27,188,276	$ 6,980,224		$ 28,929,786	$ 7,427,333		$ 28,929,786	$ 7,427,333		$ 24,700,592	$ 6,341,544		$ 20,823,578	$ 5,346,173		$ 20,823,578	$ 5,346,173
47	6,980		$ 27,188,276	$ 6,776,916		$ 28,929,786	$ 7,211,003		$ 28,929,786	$ 7,211,003		$ 24,700,592	$ 6,156,839		$ 20,823,578	$ 5,190,459		$ 20,823,578	$ 5,190,459
48	6,777		$ 27,188,276	$ 6,579,530		$ 28,929,786	$ 7,000,974		$ 28,929,786	$ 7,000,974		$ 24,700,592	$ 5,977,514		$ 20,823,578	$ 5,039,281		$ 20,823,578	$ 5,039,281
49	6,579		$ 27,188,276	$ 6,387,893		$ 28,929,786	$ 6,797,062		$ 28,929,786	$ 6,797,062		$ 24,700,592	$ 5,803,411		$ 20,823,578	$ 4,892,506		$ 20,823,578	$ 4,892,506
50	6,388		$ 27,188,276	$ 6,201,838		$ 28,929,786	$ 6,599,089		$ 28,929,786	$ 6,599,089		$ 24,700,592	$ 5,634,380		$ 20,823,578	$ 4,750,006		$ 20,823,578	$ 4,750,006
51	6,202		$ 27,188,276	$ 6,021,202		$ 28,929,786	$ 6,406,883		$ 28,929,786	$ 6,406,883		$ 24,700,592	$ 5,470,272		$ 20,823,578	$ 4,611,656		$ 20,823,578	$ 4,611,656
52	6,021		$ 27,188,276	$ 5,845,827		$ 28,929,786	$ 6,220,274		$ 28,929,786	$ 6,220,274		$ 24,700,592	$ 5,310,943		$ 20,823,578	$ 4,477,336		$ 20,823,578	$ 4,477,336
53	5,846	$ 5,040,000		$ 1,052,101		$ 28,929,786	$ 6,039,101		$ 28,929,786	$ 6,039,101	$ 5,040,000		$ 1,052,101		$ 20,823,578	$ 4,346,928		$ 20,823,578	$ 4,346,928
54	5,675					$ 28,929,786	$ 5,863,205	$ 5,040,000		$ 1,021,458				$ 5,040,000		$ 1,021,458	$ 5,040,000		$ 1,021,458
55	5,510					$ 28,929,786	$ 5,692,432			$ -						$ -			$ -
56	5,350				$ 5,040,000		$ 962,822			$ -									
Total PV costs				$ 1,120,344,155			$ 1,828,089,613			$ 1,782,942,156			$ 1,089,987,628			$ 1,504,743,341			$ 1,588,865,249
Unit cost				$ 1,649.60			$ 2,941			$ 2,703.96			$ 1,604.90			$ 2,282			$ 2,409.63

Table D.2.3 Life cycle cost analysis, 25 MGD facility, 3% discount rate, 50-year project life

		Low cost estimate									**High cost estimate**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	28,004	$ 228,779,178		$ 228,779,178	$ 249,355,203		$ 249,355,203	$ 299,521,008		$ 299,521,008	$ 243,966,986		$ 243,966,986	$ 298,077,664		$ 298,077,664	$ 298,472,897		$ 298,472,897
1	26,171	$ 224,667,758		$ 209,969,868	$ 244,874,009		$ 228,854,214	$ 294,138,278		$ 274,895,587	$ 239,582,624		$ 223,908,994	$ 292,720,872		$ 273,570,908	$ 293,109,002		$ 273,933,647
2	24,459	$ 13,789,389		$ 12,044,186	$ 240,473,347		$ 210,038,734	$ 288,852,281		$ 252,294,769	$ 14,116,623		$ 12,330,005	$ 287,460,348		$ 251,079,000	$ 287,841,502		$ 251,411,916
3	22,859		$ 27,188,276	$ 22,193,732	$ 236,151,769		$ 192,770,188	$ 265,932,450		$ 217,080,094		$ 24,700,592	$ 20,163,041	$ 175,022,504		$ 142,870,498	$ 265,708,546		$ 216,897,322
4	21,364		$ 27,188,276	$ 20,741,806	$ 231,907,856		$ 176,921,393		$ 28,929,786	$ 22,070,395		$ 24,700,592	$ 18,843,963		$ 20,823,578	$ 15,886,208		$ 20,823,578	$ 15,886,208
5	19,966		$ 27,188,276	$ 19,384,865	$ 56,935,052		$ 40,593,906		$ 28,929,786	$ 20,626,538		$ 24,700,592	$ 17,611,181		$ 20,823,578	$ 14,846,924		$ 20,823,578	$ 14,846,924
6	18,660		$ 27,188,276	$ 18,116,696		$ 28,929,786	$ 19,277,138		$ 28,929,786	$ 19,277,138		$ 24,700,592	$ 16,459,047		$ 20,823,578	$ 13,875,629		$ 20,823,578	$ 13,875,629
7	17,439		$ 27,188,276	$ 16,931,492		$ 28,929,786	$ 18,016,017		$ 28,929,786	$ 18,016,017		$ 24,700,592	$ 15,382,287		$ 20,823,578	$ 12,967,878		$ 20,823,578	$ 12,967,878
8	16,298		$ 27,188,276	$ 15,823,824		$ 28,929,786	$ 16,837,399		$ 28,929,786	$ 16,837,399		$ 24,700,592	$ 14,375,969		$ 20,823,578	$ 12,119,512		$ 20,823,578	$ 12,119,512
9	15,232		$ 27,188,276	$ 14,788,621		$ 28,929,786	$ 15,735,887		$ 28,929,786	$ 15,735,887		$ 24,700,592	$ 13,435,485		$ 20,823,578	$ 11,326,647		$ 20,823,578	$ 11,326,647
10	14,236		$ 27,188,276	$ 13,821,141		$ 28,929,786	$ 14,706,436		$ 28,929,786	$ 14,706,436		$ 24,700,592	$ 12,556,528		$ 20,823,578	$ 10,585,651		$ 20,823,578	$ 10,585,651
11	13,304		$ 27,188,276	$ 12,916,954		$ 28,929,786	$ 13,744,333		$ 28,929,786	$ 13,744,333		$ 24,700,592	$ 11,735,073		$ 20,823,578	$ 9,893,132		$ 20,823,578	$ 9,893,132
12	12,434		$ 27,188,276	$ 12,071,920		$ 28,929,786	$ 12,845,171		$ 28,929,786	$ 12,845,171		$ 24,700,592	$ 10,967,358		$ 20,823,578	$ 9,245,918		$ 20,823,578	$ 9,245,918
13	11,620		$ 27,188,276	$ 11,282,168		$ 28,929,786	$ 12,004,833		$ 28,929,786	$ 12,004,833		$ 24,700,592	$ 10,249,867		$ 20,823,578	$ 8,641,045		$ 20,823,578	$ 8,641,045
14	10,860		$ 27,188,276	$ 10,544,082		$ 28,929,786	$ 11,219,470		$ 28,929,786	$ 11,219,470		$ 24,700,592	$ 9,579,315		$ 20,823,578	$ 8,075,743		$ 20,823,578	$ 8,075,743
15	10,150		$ 27,188,276	$ 9,854,282		$ 28,929,786	$ 10,485,486		$ 28,929,786	$ 10,485,486		$ 24,700,592	$ 8,952,631		$ 20,823,578	$ 7,547,423		$ 20,823,578	$ 7,547,423
16	9,486		$ 27,188,276	$ 9,209,610		$ 28,929,786	$ 9,799,519		$ 28,929,786	$ 9,799,519		$ 24,700,592	$ 8,366,945		$ 20,823,578	$ 7,053,666		$ 20,823,578	$ 7,053,666
17	8,865		$ 27,188,276	$ 8,607,112		$ 28,929,786	$ 9,158,429		$ 28,929,786	$ 9,158,429		$ 24,700,592	$ 7,819,575		$ 20,823,578	$ 6,592,212		$ 20,823,578	$ 6,592,212
18	8,285		$ 27,188,276	$ 8,044,030		$ 28,929,786	$ 8,559,280		$ 28,929,786	$ 8,559,280		$ 24,700,592	$ 7,308,014		$ 20,823,578	$ 6,160,945		$ 20,823,578	$ 6,160,945
19	7,743		$ 27,188,276	$ 7,517,785		$ 28,929,786	$ 7,999,327		$ 28,929,786	$ 7,999,327		$ 24,700,592	$ 6,829,919		$ 20,823,578	$ 5,757,893		$ 20,823,578	$ 5,757,893
20	7,237		$ 27,188,276	$ 7,025,967		$ 28,929,786	$ 7,476,006		$ 28,929,786	$ 7,476,006		$ 24,700,592	$ 6,383,102		$ 20,823,578	$ 5,381,208		$ 20,823,578	$ 5,381,208
21	6,763		$ 27,188,276	$ 6,566,325		$ 28,929,786	$ 6,986,922		$ 28,929,786	$ 6,986,922		$ 24,700,592	$ 5,965,516		$ 20,823,578	$ 5,029,167		$ 20,823,578	$ 5,029,167
22	6,321		$ 27,188,276	$ 6,136,752		$ 28,929,786	$ 6,529,834		$ 28,929,786	$ 6,529,834		$ 24,700,592	$ 5,575,249		$ 20,823,578	$ 4,700,156		$ 20,823,578	$ 4,700,156
23	5,907		$ 27,188,276	$ 5,735,282		$ 28,929,786	$ 6,102,648		$ 28,929,786	$ 6,102,648		$ 24,700,592	$ 5,210,513		$ 20,823,578	$ 4,392,669		$ 20,823,578	$ 4,392,669
24	5,521		$ 27,188,276	$ 5,360,077		$ 28,929,786	$ 5,703,410		$ 28,929,786	$ 5,703,410		$ 24,700,592	$ 4,869,638		$ 20,823,578	$ 4,105,298		$ 20,823,578	$ 4,105,298
25	5,160		$ 27,188,276	$ 5,009,418		$ 28,929,786	$ 5,330,289		$ 28,929,786	$ 5,330,289		$ 24,700,592	$ 4,551,064		$ 20,823,578	$ 3,836,727		$ 20,823,578	$ 3,836,727
26	4,822		$ 27,188,276	$ 4,681,699		$ 28,929,786	$ 4,981,579		$ 28,929,786	$ 4,981,579		$ 24,700,592	$ 4,253,331		$ 20,823,578	$ 3,585,726		$ 20,823,578	$ 3,585,726
27	4,507		$ 27,188,276	$ 4,375,419		$ 28,929,786	$ 4,655,681		$ 28,929,786	$ 4,655,681		$ 24,700,592	$ 3,975,075		$ 20,823,578	$ 3,351,146		$ 20,823,578	$ 3,351,146
28	4,212		$ 27,188,276	$ 4,089,177		$ 28,929,786	$ 4,351,104		$ 28,929,786	$ 4,351,104		$ 24,700,592	$ 3,715,024		$ 20,823,578	$ 3,131,912		$ 20,823,578	$ 3,131,912
29	3,936		$ 27,188,276	$ 3,821,661		$ 28,929,786	$ 4,066,452		$ 28,929,786	$ 4,066,452		$ 24,700,592	$ 3,471,985		$ 20,823,578	$ 2,927,021		$ 20,823,578	$ 2,927,021
30	3,679		$ 27,188,276	$ 3,571,645		$ 28,929,786	$ 3,800,423		$ 28,929,786	$ 3,800,423		$ 24,700,592	$ 3,244,846		$ 20,823,578	$ 2,735,533		$ 20,823,578	$ 2,735,533
31	3,438		$ 27,188,276	$ 3,337,986		$ 28,929,786	$ 3,551,797		$ 28,929,786	$ 3,551,797		$ 24,700,592	$ 3,032,566		$ 20,823,578	$ 2,556,573		$ 20,823,578	$ 2,556,573
32	3,213		$ 27,188,276	$ 3,119,613		$ 28,929,786	$ 3,319,436		$ 28,929,786	$ 3,319,436		$ 24,700,592	$ 2,834,174		$ 20,823,578	$ 2,389,321		$ 20,823,578	$ 2,389,321
33	3,003		$ 27,188,276	$ 2,915,527		$ 28,929,786	$ 3,102,277		$ 28,929,786	$ 3,102,277		$ 24,700,592	$ 2,648,761		$ 20,823,578	$ 2,233,010		$ 20,823,578	$ 2,233,010
34	2,806		$ 27,188,276	$ 2,724,791		$ 28,929,786	$ 2,899,324		$ 28,929,786	$ 2,899,324		$ 24,700,592	$ 2,475,477		$ 20,823,578	$ 2,086,925		$ 20,823,578	$ 2,086,925
35	2,623		$ 27,188,276	$ 2,546,534		$ 28,929,786	$ 2,709,649		$ 28,929,786	$ 2,709,649		$ 24,700,592	$ 2,313,530		$ 20,823,578	$ 1,950,398		$ 20,823,578	$ 1,950,398
36	2,451		$ 27,188,276	$ 2,379,938		$ 28,929,786	$ 2,532,382		$ 28,929,786	$ 2,532,382		$ 24,700,592	$ 2,162,178		$ 20,823,578	$ 1,822,801		$ 20,823,578	$ 1,822,801
37	2,291		$ 27,188,276	$ 2,224,241		$ 28,929,786	$ 2,366,712		$ 28,929,786	$ 2,366,712		$ 24,700,592	$ 2,020,727		$ 20,823,578	$ 1,703,553		$ 20,823,578	$ 1,703,553
38	2,141		$ 27,188,276	$ 2,078,730		$ 28,929,786	$ 2,211,881		$ 28,929,786	$ 2,211,881		$ 24,700,592	$ 1,888,530		$ 20,823,578	$ 1,592,105		$ 20,823,578	$ 1,592,105
39	2,001		$ 27,188,276	$ 1,942,738		$ 28,929,786	$ 2,067,178		$ 28,929,786	$ 2,067,178		$ 24,700,592	$ 1,764,981		$ 20,823,578	$ 1,487,949		$ 20,823,578	$ 1,487,949
40	1,870		$ 27,188,276	$ 1,815,643		$ 28,929,786	$ 1,931,942		$ 28,929,786	$ 1,931,942		$ 24,700,592	$ 1,649,515		$ 20,823,578	$ 1,390,606		$ 20,823,578	$ 1,390,606
41	1,748		$ 27,188,276	$ 1,696,863		$ 28,929,786	$ 1,805,553		$ 28,929,786	$ 1,805,553		$ 24,700,592	$ 1,541,603		$ 20,823,578	$ 1,299,632		$ 20,823,578	$ 1,299,632
42	1,633		$ 27,188,276	$ 1,585,853		$ 28,929,786	$ 1,687,433		$ 28,929,786	$ 1,687,433		$ 24,700,592	$ 1,440,750		$ 20,823,578	$ 1,214,610		$ 20,823,578	$ 1,214,610
43	1,527		$ 27,188,276	$ 1,482,106		$ 28,929,786	$ 1,577,040		$ 28,929,786	$ 1,577,040		$ 24,700,592	$ 1,346,496		$ 20,823,578	$ 1,135,149		$ 20,823,578	$ 1,135,149
44	1,427		$ 27,188,276	$ 1,385,146		$ 28,929,786	$ 1,473,869		$ 28,929,786	$ 1,473,869		$ 24,700,592	$ 1,258,407		$ 20,823,578	$ 1,060,887		$ 20,823,578	$ 1,060,887
45	1,333		$ 27,188,276	$ 1,294,529		$ 28,929,786	$ 1,377,448		$ 28,929,786	$ 1,377,448		$ 24,700,592	$ 1,176,081		$ 20,823,578	$ 991,483		$ 20,823,578	$ 991,483
46	1,246		$ 27,188,276	$ 1,209,840		$ 28,929,786	$ 1,287,335		$ 28,929,786	$ 1,287,335		$ 24,700,592	$ 1,099,141		$ 20,823,578	$ 926,620		$ 20,823,578	$ 926,620
47	1,165		$ 27,188,276	$ 1,130,691		$ 28,929,786	$ 1,203,116		$ 28,929,786	$ 1,203,116		$ 24,700,592	$ 1,027,235		$ 20,823,578	$ 866,000		$ 20,823,578	$ 866,000
48	1,088		$ 27,188,276	$ 1,056,721		$ 28,929,786	$ 1,124,408		$ 28,929,786	$ 1,124,408		$ 24,700,592	$ 960,033		$ 20,823,578	$ 809,346		$ 20,823,578	$ 809,346
49	1,017		$ 27,188,276	$ 987,590		$ 28,929,786	$ 1,050,849		$ 28,929,786	$ 1,050,849		$ 24,700,592	$ 897,227		$ 20,823,578	$ 756,398		$ 20,823,578	$ 756,398
50	951		$ 27,188,276	$ 922,981		$ 28,929,786	$ 982,101		$ 28,929,786	$ 982,101		$ 24,700,592	$ 838,530		$ 20,823,578	$ 706,914		$ 20,823,578	$ 706,914
51	888		$ 27,188,276	$ 862,599		$ 28,929,786	$ 917,852		$ 28,929,786	$ 917,852		$ 24,700,592	$ 783,673		$ 20,823,578	$ 660,667		$ 20,823,578	$ 660,667
52	830		$ 27,188,276	$ 806,167		$ 28,929,786	$ 857,805		$ 28,929,786	$ 857,805		$ 24,700,592	$ 732,404		$ 20,823,578	$ 617,446		$ 20,823,578	$ 617,446
53	776	$ 5,040,000		$ 139,666		$ 28,929,786	$ 801,687		$ 28,929,786	$ 801,687	$ 5,040,000		$ 139,666		$ 20,823,578	$ 577,052		$ 20,823,578	$ 577,052
54	725					$ 28,929,786	$ 749,240	$ 5,040,000		$ 130,529				$ 5,040,000		$ 130,529	$ 5,040,000		$ 130,529
55	678					$ 28,929,786	$ 700,225			$ -						$ -			$ -
56	633				$ 5,040,000		$ 114,009			$ -									
Total PV costs				$ 778,663,269			$ 1,383,309,260			$1,369,831,068			$ 778,089,211			$ 1,200,317,036			$1,275,434,746
Unit cost				$ 2,306.76			$ 5,020			$ 4,342.14			$ 2,305.06			$ 3,805			$ 4,042.92

Table D.2.4 Life cycle cost analysis, 25 MGD facility, 7% discount rate, 50-year project life

		Low cost estimate									**High cost estimate**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	56007	$ 306,400,685		$ 306,400,685	$ 333,993,862		$ 333,993,862	$ 401,180,208		$ 401,180,208	$ 326,345,449		$ 326,345,449	$ 398,971,649		$ 398,971,649	$ 400,030,290		$ 400,030,290
1	54375.7282	$ 300,894,319		$ 292,130,407	$ 327,991,615		$ 318,438,461	$ 393,970,547		$ 382,495,677	$ 320,480,653		$ 311,146,265	$ 391,801,678		$ 380,389,979	$ 392,841,294		$ 381,399,315
2	52791.9691	$ 221,615,181		$ 208,893,563	$ 322,097,236		$ 303,607,537	$ 386,890,452		$ 364,681,357	$ 236,040,940		$ 222,491,225	$ 384,760,560		$ 362,673,730	$ 385,781,493		$ 363,636,057
3	51254.3389		$ 54,376,552	$ 49,762,248	$ 316,308,785		$ 289,467,346	$ 379,937,594		$ 347,696,720		$ 49,401,184	$ 45,209,081	$ 377,845,978		$ 345,782,596	$ 378,848,564		$ 346,700,104
4	49761.4941		$ 54,376,552	$ 48,312,862	$ 310,624,359		$ 275,985,720	$ 373,109,686		$ 331,503,124		$ 49,401,184	$ 43,892,312	$ 307,976,198		$ 273,632,863	$ 372,040,228		$ 330,552,924
5	48312.1302		$ 54,376,552	$ 46,905,692	$ 305,042,089		$ 263,131,986	$ 91,601,121		$ 79,015,932		$ 49,401,184	$ 42,613,895		$ 41,647,157	$ 35,925,203	$ 100,007,572		$ 86,267,411
6	46904.9808		$ 54,376,552	$ 45,539,507	$ 299,560,138		$ 250,876,900		$ 57,859,572	$ 48,456,481		$ 49,401,184	$ 41,372,714		$ 41,647,157	$ 34,878,838		$ 41,647,157	$ 34,878,838
7	45538.8163		$ 54,376,552	$ 44,213,113		$ 57,859,572	$ 47,045,127		$ 57,859,572	$ 47,045,127		$ 49,401,184	$ 40,167,683		$ 41,647,157	$ 33,862,950		$ 41,647,157	$ 33,862,950
8	44212.443		$ 54,376,552	$ 42,925,353		$ 57,859,572	$ 45,674,880		$ 57,859,572	$ 45,674,880		$ 49,401,184	$ 38,997,751		$ 41,647,157	$ 32,876,650		$ 41,647,157	$ 32,876,650
9	42924.7019		$ 54,376,552	$ 41,675,100		$ 57,859,572	$ 44,344,544		$ 57,859,572	$ 44,344,544		$ 49,401,184	$ 37,861,894		$ 41,647,157	$ 31,919,078		$ 41,647,157	$ 31,919,078
10	41674.4679		$ 54,376,552	$ 40,461,262		$ 57,859,572	$ 43,052,955		$ 57,859,572	$ 43,052,955		$ 49,401,184	$ 36,759,120		$ 41,647,157	$ 30,989,396		$ 41,647,157	$ 30,989,396
11	40460.6484		$ 54,376,552	$ 39,282,778		$ 57,859,572	$ 41,798,986		$ 57,859,572	$ 41,798,986		$ 49,401,184	$ 35,688,466		$ 41,647,157	$ 30,086,792		$ 41,647,157	$ 30,086,792
12	39282.1829		$ 54,376,552	$ 38,138,620		$ 57,859,572	$ 40,581,540		$ 57,859,572	$ 40,581,540		$ 49,401,184	$ 34,648,996		$ 41,647,157	$ 29,210,478		$ 41,647,157	$ 29,210,478
13	38138.0417		$ 54,376,552	$ 37,027,786		$ 57,859,572	$ 39,399,553		$ 57,859,572	$ 39,399,553		$ 49,401,184	$ 33,639,802		$ 41,647,157	$ 28,359,687		$ 41,647,157	$ 28,359,687
14	37027.225		$ 54,376,552	$ 35,949,307		$ 57,859,572	$ 38,251,993		$ 57,859,572	$ 38,251,993		$ 49,401,184	$ 32,660,002		$ 41,647,157	$ 27,533,677		$ 41,647,157	$ 27,533,677
15	35948.7621		$ 54,376,552	$ 34,902,240		$ 57,859,572	$ 37,137,858		$ 57,859,572	$ 37,137,858		$ 49,401,184	$ 31,708,740		$ 41,647,157	$ 26,731,725		$ 41,647,157	$ 26,731,725
16	34901.7108		$ 54,376,552	$ 33,885,670		$ 57,859,572	$ 36,056,172		$ 57,859,572	$ 36,056,172		$ 49,401,184	$ 30,785,184		$ 41,647,157	$ 25,953,131		$ 41,647,157	$ 25,953,131
17	33885.1561		$ 54,376,552	$ 32,898,708		$ 57,859,572	$ 35,005,993		$ 57,859,572	$ 35,005,993		$ 49,401,184	$ 29,888,529		$ 41,647,157	$ 25,197,215		$ 41,647,157	$ 25,197,215
18	32898.2098		$ 54,376,552	$ 31,940,494		$ 57,859,572	$ 33,986,401		$ 57,859,572	$ 33,986,401		$ 49,401,184	$ 29,017,989		$ 41,647,157	$ 24,463,315		$ 41,647,157	$ 24,463,315
19	31940.0095		$ 54,376,552	$ 31,010,188		$ 57,859,572	$ 32,996,505		$ 57,859,572	$ 32,996,505		$ 49,401,184	$ 28,172,805		$ 41,647,157	$ 23,750,792		$ 41,647,157	$ 23,750,792
20	31009.718		$ 54,376,552	$ 30,106,979		$ 57,859,572	$ 32,035,442		$ 57,859,572	$ 32,035,442		$ 49,401,184	$ 27,352,238		$ 41,647,157	$ 23,059,021		$ 41,647,157	$ 23,059,021
21	30106.5223		$ 54,376,552	$ 29,230,076		$ 57,859,572	$ 31,102,371		$ 57,859,572	$ 31,102,371		$ 49,401,184	$ 26,555,571		$ 41,647,157	$ 22,387,399		$ 41,647,157	$ 22,387,399
22	29229.6333		$ 54,376,552	$ 28,378,715		$ 57,859,572	$ 30,196,477		$ 57,859,572	$ 30,196,477		$ 49,401,184	$ 25,782,107		$ 41,647,157	$ 21,735,339		$ 41,647,157	$ 21,735,339
23	28378.2848		$ 54,376,552	$ 27,552,150		$ 57,859,572	$ 29,316,968		$ 57,859,572	$ 29,316,968		$ 49,401,184	$ 25,031,172		$ 41,647,157	$ 21,102,271		$ 41,647,157	$ 21,102,271
24	27551.7328		$ 54,376,552	$ 26,749,661		$ 57,859,572	$ 28,463,075		$ 57,859,572	$ 28,463,075		$ 49,401,184	$ 24,302,109		$ 41,647,157	$ 20,487,641		$ 41,647,157	$ 20,487,641
25	26749.2551		$ 54,376,552	$ 25,970,544		$ 57,859,572	$ 27,634,054		$ 57,859,572	$ 27,634,054		$ 49,401,184	$ 23,594,280		$ 41,647,157	$ 19,890,914		$ 41,647,157	$ 19,890,914
26	25970.1506		$ 54,376,552	$ 25,214,121		$ 57,859,572	$ 26,829,179		$ 57,859,572	$ 26,829,179		$ 49,401,184	$ 22,907,068		$ 41,647,157	$ 19,311,567		$ 41,647,157	$ 19,311,567
27	25213.7384		$ 54,376,552	$ 24,479,729		$ 57,859,572	$ 26,047,746		$ 57,859,572	$ 26,047,746		$ 49,401,184	$ 22,239,872		$ 41,647,157	$ 18,749,094		$ 41,647,157	$ 18,749,094
28	24479.3577		$ 54,376,552	$ 23,766,727		$ 57,859,572	$ 25,289,074		$ 57,859,572	$ 25,289,074		$ 49,401,184	$ 21,592,109		$ 41,647,157	$ 18,203,004		$ 41,647,157	$ 18,203,004
29	23766.3667		$ 54,376,552	$ 23,074,492		$ 57,859,572	$ 24,552,499		$ 57,859,572	$ 24,552,499		$ 49,401,184	$ 20,963,213		$ 41,647,157	$ 17,672,819		$ 41,647,157	$ 17,672,819
30	23074.1424		$ 54,376,552	$ 22,402,420		$ 57,859,572	$ 23,837,378		$ 57,859,572	$ 23,837,378		$ 49,401,184	$ 20,352,634		$ 41,647,157	$ 17,158,077		$ 41,647,157	$ 17,158,077
31	22402.08		$ 54,376,552	$ 21,749,922		$ 57,859,572	$ 23,143,085		$ 57,859,572	$ 23,143,085		$ 49,401,184	$ 19,759,838		$ 41,647,157	$ 16,658,327		$ 41,647,157	$ 16,658,327
32	21749.5923		$ 54,376,552	$ 21,116,429		$ 57,859,572	$ 22,469,015		$ 57,859,572	$ 22,469,015		$ 49,401,184	$ 19,184,309		$ 41,647,157	$ 16,173,133		$ 41,647,157	$ 16,173,133
33	21116.109	$ 9,000,000		$ 3,393,236		$ 57,859,572	$ 21,814,577		$ 57,859,572	$ 21,814,577	$ 9,000,000		$ 3,393,236		$ 41,647,157	$ 15,702,071		$ 41,647,157	$ 15,702,071
34	20501.0767					$ 57,859,572	$ 21,179,201		$ 57,859,572	$ 21,179,201			$ -		$ 41,647,157	$ 15,244,729		$ 41,647,157	$ 15,244,729
35	19903.958					$ 57,859,572	$ 20,562,331		$ 57,859,572	$ 20,562,331			$ -	$ 9,000,000		$ 3,198,451		$ 41,647,157	$ 14,800,708
36	19324.231					$ 57,859,572	$ 19,963,428	$ 9,000,000		$ 3,105,292			$ -			$ -	$ 9,000,000		$ 3,105,292
37	18761.3893				$ 9,000,000		$ 3,014,846			$ -			$ -			$ -			$ -
Total PV costs				$ 1,815,440,782			$ 2,988,285,066			$ 2,887,939,769			$ 1,776,077,657			$ 2,489,923,600			$ 2,615,841,230
Unit cost				$ 1,754			$ 3,250			$ 3,050			$ 1,716			$ 2,553			$ 2,762

Table D.3.1 Life cycle cost analysis, 50 MGD facility, 3% discount rate, 30-year project life

		Low cost estimate									**High cost estimate**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	56007	$ 306,400,685		$ 306,400,685	$ 333,993,862		$ 333,993,862	$ 401,180,208		$ 401,180,208	$ 326,345,449		$ 326,345,449	$ 398,971,649		$ 398,971,649	$400,030,290		$ 400,030,290
1	52342.991	$ 300,894,319		$ 281,209,644	$ 327,991,615		$ 306,534,220	$ 393,970,547		$ 368,196,773	$ 320,480,653		$ 299,514,629	$ 391,801,678		$ 366,169,793	$392,841,294		$ 367,141,396
2	48918.683	$ 221,615,181		$ 193,567,282	$ 322,097,236		$ 281,332,200	$ 386,890,452		$ 337,925,104	$ 236,040,940		$ 206,167,299	$ 384,760,560		$ 336,064,774	$385,781,493		$ 336,956,497
3	45718.395		$ 54,376,552	$ 44,387,464	$ 316,308,785		$ 258,202,190	$ 379,937,594		$ 310,142,251		$ 49,401,184	$ 40,326,081	$ 377,845,978		$ 308,434,870	$378,848,564		$ 309,253,279
4	42727.472		$ 54,376,552	$ 41,483,611	$ 310,624,359		$ 236,973,836	$ 373,109,686		$ 284,643,593		$ 49,401,184	$ 37,687,926	$ 307,976,198		$ 234,953,567	$372,040,228		$ 283,827,709
5	39932.217		$ 54,376,552	$ 38,769,730	$ 305,042,089		$ 217,490,794	$ 91,601,121		$ 65,310,333		$ 49,401,184	$ 35,222,361		$ 41,647,157	$ 29,693,847	$100,007,572		$ 71,304,017
6	37319.829		$ 54,376,552	$ 36,233,393	$ 299,560,138		$ 199,609,569		$ 57,859,572	$ 38,554,276		$ 49,401,184	$ 32,918,095		$ 41,647,157	$ 27,751,259		$ 41,647,157	$ 27,751,259
7	34878.345		$ 54,376,552	$ 33,862,984		$ 57,859,572	$ 36,032,034		$ 57,859,572	$ 36,032,034		$ 49,401,184	$ 30,764,574		$ 41,647,157	$ 25,935,756		$ 41,647,157	$ 25,935,756
8	32596.584		$ 54,376,552	$ 31,647,649		$ 57,859,572	$ 33,674,798		$ 57,859,572	$ 33,674,798		$ 49,401,184	$ 28,751,939		$ 41,647,157	$ 24,239,024		$ 41,647,157	$ 24,239,024
9	30464.097		$ 54,376,552	$ 29,577,242		$ 57,859,572	$ 31,471,774		$ 57,859,572	$ 31,471,774		$ 49,401,184	$ 26,870,971		$ 41,647,157	$ 22,653,294		$ 41,647,157	$ 22,653,294
10	28471.119		$ 54,376,552	$ 27,642,282		$ 57,859,572	$ 29,412,873		$ 57,859,572	$ 29,412,873		$ 49,401,184	$ 25,113,057		$ 41,647,157	$ 21,171,303		$ 41,647,157	$ 21,171,303
11	26608.522		$ 54,376,552	$ 25,833,908		$ 57,859,572	$ 27,488,666		$ 57,859,572	$ 27,488,666		$ 49,401,184	$ 23,470,146		$ 41,647,157	$ 19,786,264		$ 41,647,157	$ 19,786,264
12	24867.778		$ 54,376,552	$ 24,143,840		$ 57,859,572	$ 25,690,342		$ 57,859,572	$ 25,690,342		$ 49,401,184	$ 21,934,716		$ 41,647,157	$ 18,491,836		$ 41,647,157	$ 18,491,836
13	23240.914		$ 54,376,552	$ 22,564,336		$ 57,859,572	$ 24,009,665		$ 57,859,572	$ 24,009,665		$ 49,401,184	$ 20,499,735		$ 41,647,157	$ 17,282,089		$ 41,647,157	$ 17,282,089
14	21720.48		$ 54,376,552	$ 21,088,165		$ 57,859,572	$ 22,438,940		$ 57,859,572	$ 22,438,940		$ 49,401,184	$ 19,158,631		$ 41,647,157	$ 16,151,485		$ 41,647,157	$ 16,151,485
15	20299.514		$ 54,376,552	$ 19,708,565		$ 57,859,572	$ 20,970,972		$ 57,859,572	$ 20,970,972		$ 49,401,184	$ 17,905,262		$ 41,647,157	$ 15,094,846		$ 41,647,157	$ 15,094,846
16	18971.509		$ 54,376,552	$ 18,419,220		$ 57,859,572	$ 19,599,039		$ 57,859,572	$ 19,599,039		$ 49,401,184	$ 16,733,890		$ 41,647,157	$ 14,107,333		$ 41,647,157	$ 14,107,333
17	17730.382		$ 54,376,552	$ 17,214,224		$ 57,859,572	$ 18,316,859		$ 57,859,572	$ 18,316,859		$ 49,401,184	$ 15,639,150		$ 41,647,157	$ 13,184,423		$ 41,647,157	$ 13,184,423
18	16570.45		$ 54,376,552	$ 16,088,060		$ 57,859,572	$ 17,118,560		$ 57,859,572	$ 17,118,560		$ 49,401,184	$ 14,616,028		$ 41,647,157	$ 12,321,891		$ 41,647,157	$ 12,321,891
19	15486.402		$ 54,376,552	$ 15,035,570		$ 57,859,572	$ 15,998,654		$ 57,859,572	$ 15,998,654		$ 49,401,184	$ 13,659,839		$ 41,647,157	$ 11,515,786		$ 41,647,157	$ 11,515,786
20	14473.273		$ 54,376,552	$ 14,051,934		$ 57,859,572	$ 14,952,013		$ 57,859,572	$ 14,952,013		$ 49,401,184	$ 12,766,205		$ 41,647,157	$ 10,762,417		$ 41,647,157	$ 10,762,417
21	13526.423		$ 54,376,552	$ 13,132,649		$ 57,859,572	$ 13,973,844		$ 57,859,572	$ 13,973,844		$ 49,401,184	$ 11,931,032		$ 41,647,157	$ 10,058,333		$ 41,647,157	$ 10,058,333
22	12641.517		$ 54,376,552	$ 12,273,504		$ 57,859,572	$ 13,059,667		$ 57,859,572	$ 13,059,667		$ 49,401,184	$ 11,150,498		$ 41,647,157	$ 9,400,312		$ 41,647,157	$ 9,400,312
23	11814.502		$ 54,376,552	$ 11,470,564		$ 57,859,572	$ 12,205,296		$ 57,859,572	$ 12,205,296		$ 49,401,184	$ 10,421,026		$ 41,647,157	$ 8,785,338		$ 41,647,157	$ 8,785,338
24	11041.591		$ 54,376,552	$ 10,720,153		$ 57,859,572	$ 11,406,819		$ 57,859,572	$ 11,406,819		$ 49,401,184	$ 9,739,276		$ 41,647,157	$ 8,210,596		$ 41,647,157	$ 8,210,596
25	10319.244		$ 54,376,552	$ 10,018,835		$ 57,859,572	$ 10,660,579		$ 57,859,572	$ 10,660,579		$ 49,401,184	$ 9,102,127		$ 41,647,157	$ 7,673,454		$ 41,647,157	$ 7,673,454
26	9644.153		$ 54,376,552	$ 9,363,397		$ 57,859,572	$ 9,963,158		$ 57,859,572	$ 9,963,158		$ 49,401,184	$ 8,506,661		$ 41,647,157	$ 7,171,453		$ 41,647,157	$ 7,171,453
27	9013.2271		$ 54,376,552	$ 8,750,839		$ 57,859,572	$ 9,311,362		$ 57,859,572	$ 9,311,362		$ 49,401,184	$ 7,950,151		$ 41,647,157	$ 6,702,292		$ 41,647,157	$ 6,702,292
28	8423.5767		$ 54,376,552	$ 8,178,354		$ 57,859,572	$ 8,702,208		$ 57,859,572	$ 8,702,208		$ 49,401,184	$ 7,430,047		$ 41,647,157	$ 6,263,825		$ 41,647,157	$ 6,263,825
29	7872.5016		$ 54,376,552	$ 7,643,321		$ 57,859,572	$ 8,132,904		$ 57,859,572	$ 8,132,904		$ 49,401,184	$ 6,943,969		$ 41,647,157	$ 5,854,042		$ 41,647,157	$ 5,854,042
30	7357.4781		$ 54,376,552	$ 7,143,291		$ 57,859,572	$ 7,600,845		$ 57,859,572	$ 7,600,845		$ 49,401,184	$ 6,489,691		$ 41,647,157	$ 5,471,067		$ 41,647,157	$ 5,471,067
31	6876.1478		$ 54,376,552	$ 6,675,973		$ 57,859,572	$ 7,103,594		$ 57,859,572	$ 7,103,594		$ 49,401,184	$ 6,065,132		$ 41,647,157	$ 5,113,147		$ 41,647,157	$ 5,113,147
32	6426.3063		$ 54,376,552	$ 6,239,227		$ 57,859,572	$ 6,638,873		$ 57,859,572	$ 6,638,873		$ 49,401,184	$ 5,668,348		$ 41,647,157	$ 4,778,642		$ 41,647,157	$ 4,778,642
33	6005.8938	$ 9,000,000		$ 965,112		$ 57,859,572	$ 6,204,554		$ 57,859,572	$ 6,204,554	$ 9,000,000		$ 965,112		$ 41,647,157	$ 4,466,020		$ 41,647,157	$ 4,466,020
34	5612.9848					$ 57,859,572	$ 5,798,648		$ 57,859,572	$ 5,798,648			$ -		$ 41,647,157	$ 4,173,851		$ 41,647,157	$ 4,173,851
35	5245.7802					$ 57,859,572	$ 5,419,298		$ 57,859,572	$ 5,419,298			$ -	$ 9,000,000		$ 842,966		$ 41,647,157	$ 3,900,795
36	4902.5983					$ 57,859,572	$ 5,064,764	$ 9,000,000		$ 787,819			$ -			$ -	$ 9,000,000		$ 787,819
37	4581.8676				$ 9,000,000		$ 736,280			$ -			$ -			$ -			$ -
38	4282.1193						$ -			$ -			$ -			$ -			$ -
39	4001.9806						$ -			$ -			$ -			$ -			$ -
Total PV costs				$1,371,505,006			$ 2,313,294,547			$ 2,280,097,191			$ 1,368,429,053			$ 2,039,702,843			$ 2,137,773,178
Unit cost				$ 2,259			$ 4,995			$ 4,601			$ 2,254			$ 3,847			$ 4,314

Table D.3.2 Life cycle cost analysis, 50 MGD facility, 7% discount rate, 30-year project life

		Low cost estimate									**High cost estimate**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	56,007	$ 306,400,685		$ 306,400,685	$ 333,993,862		$ 333,993,862	$ 401,180,208		$ 401,180,208	$ 326,345,449		$ 326,345,449	$ 398,971,649		$ 398,971,649	$ 400,030,290		$ 400,030,290
1	54,376	$ 300,894,319		$ 292,130,407	$ 327,991,615		$ 318,438,461	$ 393,970,547		$ 382,495,677	$ 320,480,653		$ 311,146,265	$ 391,801,678		$ 380,389,979	$ 392,841,294		$ 381,399,315
2	52,792	$ 221,615,181		$ 208,893,563	$ 322,097,236		$ 303,607,537	$ 386,890,452		$ 364,681,357	$ 236,040,940		$ 222,491,225	$ 384,760,560		$ 362,673,730	$ 385,781,493		$ 363,636,057
3	51,254		$ 54,376,552	$ 49,762,248	$ 316,308,785		$ 289,467,346	$ 379,937,594		$ 347,696,720		$ 49,401,184	$ 45,209,081	$ 377,845,978		$ 345,782,596	$ 378,848,564		$ 346,700,104
4	49,761		$ 54,376,552	$ 48,312,862	$ 310,624,359		$ 275,985,720	$ 373,109,686		$ 331,503,124		$ 49,401,184	$ 43,892,312	$ 307,976,198		$ 273,632,863	$ 372,040,228		$ 330,552,924
5	48,312		$ 54,376,552	$ 46,905,692	$ 305,042,089		$ 263,131,986	$ 91,601,121		$ 79,015,932		$ 49,401,184	$ 42,613,895		$ 41,647,157	$ 35,925,203	$ 100,007,572		$ 86,267,411
6	46,905		$ 54,376,552	$ 45,539,507	$ 299,560,138		$ 250,876,900		$ 57,859,572	$ 48,456,481		$ 49,401,184	$ 41,372,714		$ 41,647,157	$ 34,878,838		$ 41,647,157	$ 34,878,838
7	45,539		$ 54,376,552	$ 44,213,113		$ 57,859,572	$ 47,045,127		$ 57,859,572	$ 47,045,127		$ 49,401,184	$ 40,167,683		$ 41,647,157	$ 33,862,950		$ 41,647,157	$ 33,862,950
8	44,212		$ 54,376,552	$ 42,925,353		$ 57,859,572	$ 45,674,880		$ 57,859,572	$ 45,674,880		$ 49,401,184	$ 38,997,751		$ 41,647,157	$ 32,876,650		$ 41,647,157	$ 32,876,650
9	42,925		$ 54,376,552	$ 41,675,100		$ 57,859,572	$ 44,344,544		$ 57,859,572	$ 44,344,544		$ 49,401,184	$ 37,861,894		$ 41,647,157	$ 31,919,078		$ 41,647,157	$ 31,919,078
10	41,674		$ 54,376,552	$ 40,461,262		$ 57,859,572	$ 43,052,955		$ 57,859,572	$ 43,052,955		$ 49,401,184	$ 36,759,120		$ 41,647,157	$ 30,989,396		$ 41,647,157	$ 30,989,396
11	40,461		$ 54,376,552	$ 39,282,778		$ 57,859,572	$ 41,798,986		$ 57,859,572	$ 41,798,986		$ 49,401,184	$ 35,688,466		$ 41,647,157	$ 30,086,792		$ 41,647,157	$ 30,086,792
12	39,282		$ 54,376,552	$ 38,138,620		$ 57,859,572	$ 40,581,540		$ 57,859,572	$ 40,581,540		$ 49,401,184	$ 34,648,996		$ 41,647,157	$ 29,210,478		$ 41,647,157	$ 29,210,478
13	38,138		$ 54,376,552	$ 37,027,786		$ 57,859,572	$ 39,399,553		$ 57,859,572	$ 39,399,553		$ 49,401,184	$ 33,639,802		$ 41,647,157	$ 28,359,687		$ 41,647,157	$ 28,359,687
14	37,027		$ 54,376,552	$ 35,949,307		$ 57,859,572	$ 38,251,993		$ 57,859,572	$ 38,251,993		$ 49,401,184	$ 32,660,002		$ 41,647,157	$ 27,533,677		$ 41,647,157	$ 27,533,677
15	35,949		$ 54,376,552	$ 34,902,240		$ 57,859,572	$ 37,137,858		$ 57,859,572	$ 37,137,858		$ 49,401,184	$ 31,708,740		$ 41,647,157	$ 26,731,725		$ 41,647,157	$ 26,731,725
16	34,902		$ 54,376,552	$ 33,885,670		$ 57,859,572	$ 36,056,172		$ 57,859,572	$ 36,056,172		$ 49,401,184	$ 30,785,184		$ 41,647,157	$ 25,953,131		$ 41,647,157	$ 25,953,131
17	33,885		$ 54,376,552	$ 32,898,708		$ 57,859,572	$ 35,005,993		$ 57,859,572	$ 35,005,993		$ 49,401,184	$ 29,888,529		$ 41,647,157	$ 25,197,215		$ 41,647,157	$ 25,197,215
18	32,898		$ 54,376,552	$ 31,940,494		$ 57,859,572	$ 33,986,401		$ 57,859,572	$ 33,986,401		$ 49,401,184	$ 29,017,989		$ 41,647,157	$ 24,463,315		$ 41,647,157	$ 24,463,315
19	31,940		$ 54,376,552	$ 31,010,188		$ 57,859,572	$ 32,996,505		$ 57,859,572	$ 32,996,505		$ 49,401,184	$ 28,172,805		$ 41,647,157	$ 23,750,792		$ 41,647,157	$ 23,750,792
20	31,010		$ 54,376,552	$ 30,106,979		$ 57,859,572	$ 32,035,442		$ 57,859,572	$ 32,035,442		$ 49,401,184	$ 27,352,238		$ 41,647,157	$ 23,059,021		$ 41,647,157	$ 23,059,021
21	30,107		$ 54,376,552	$ 29,230,076		$ 57,859,572	$ 31,102,371		$ 57,859,572	$ 31,102,371		$ 49,401,184	$ 26,555,571		$ 41,647,157	$ 22,387,399		$ 41,647,157	$ 22,387,399
22	29,230		$ 54,376,552	$ 28,378,715		$ 57,859,572	$ 30,196,477		$ 57,859,572	$ 30,196,477		$ 49,401,184	$ 25,782,107		$ 41,647,157	$ 21,735,339		$ 41,647,157	$ 21,735,339
23	28,378		$ 54,376,552	$ 27,552,150		$ 57,859,572	$ 29,316,968		$ 57,859,572	$ 29,316,968		$ 49,401,184	$ 25,031,172		$ 41,647,157	$ 21,102,271		$ 41,647,157	$ 21,102,271
24	27,552		$ 54,376,552	$ 26,749,661		$ 57,859,572	$ 28,463,075		$ 57,859,572	$ 28,463,075		$ 49,401,184	$ 24,302,109		$ 41,647,157	$ 20,487,641		$ 41,647,157	$ 20,487,641
25	26,749		$ 54,376,552	$ 25,970,544		$ 57,859,572	$ 27,634,054		$ 57,859,572	$ 27,634,054		$ 49,401,184	$ 23,594,280		$ 41,647,157	$ 19,890,914		$ 41,647,157	$ 19,890,914
26	25,970		$ 54,376,552	$ 25,214,121		$ 57,859,572	$ 26,829,179		$ 57,859,572	$ 26,829,179		$ 49,401,184	$ 22,907,068		$ 41,647,157	$ 19,311,567		$ 41,647,157	$ 19,311,567
27	25,214		$ 54,376,552	$ 24,479,729		$ 57,859,572	$ 26,047,746		$ 57,859,572	$ 26,047,746		$ 49,401,184	$ 22,239,872		$ 41,647,157	$ 18,749,094		$ 41,647,157	$ 18,749,094
28	24,479		$ 54,376,552	$ 23,766,727		$ 57,859,572	$ 25,289,074		$ 57,859,572	$ 25,289,074		$ 49,401,184	$ 21,592,109		$ 41,647,157	$ 18,203,004		$ 41,647,157	$ 18,203,004
29	23,766		$ 54,376,552	$ 23,074,492		$ 57,859,572	$ 24,552,499		$ 57,859,572	$ 24,552,499		$ 49,401,184	$ 20,963,213		$ 41,647,157	$ 17,672,819		$ 41,647,157	$ 17,672,819
30	23,074		$ 54,376,552	$ 22,402,420		$ 57,859,572	$ 23,837,378		$ 57,859,572	$ 23,837,378		$ 49,401,184	$ 20,352,634		$ 41,647,157	$ 17,158,077		$ 41,647,157	$ 17,158,077
31	22,402		$ 54,376,552	$ 21,749,922		$ 57,859,572	$ 23,143,085		$ 57,859,572	$ 23,143,085		$ 49,401,184	$ 19,759,838		$ 41,647,157	$ 16,658,327		$ 41,647,157	$ 16,658,327
32	21,750		$ 54,376,552	$ 21,116,429		$ 57,859,572	$ 22,469,015		$ 57,859,572	$ 22,469,015		$ 49,401,184	$ 19,184,309		$ 41,647,157	$ 16,173,133		$ 41,647,157	$ 16,173,133
33	21,116		$ 54,376,552	$ 20,501,387		$ 57,859,572	$ 21,814,577		$ 57,859,572	$ 21,814,577		$ 49,401,184	$ 18,625,543		$ 41,647,157	$ 15,702,071		$ 41,647,157	$ 15,702,071
34	20,501		$ 54,376,552	$ 19,904,260		$ 57,859,572	$ 21,179,201		$ 57,859,572	$ 21,179,201		$ 49,401,184	$ 18,083,051		$ 41,647,157	$ 15,244,729		$ 41,647,157	$ 15,244,729
35	19,904		$ 54,376,552	$ 19,324,524		$ 57,859,572	$ 20,562,331		$ 57,859,572	$ 20,562,331		$ 49,401,184	$ 17,556,361		$ 41,647,157	$ 14,800,708		$ 41,647,157	$ 14,800,708
36	19,324		$ 54,376,552	$ 18,761,674		$ 57,859,572	$ 19,963,428		$ 57,859,572	$ 19,963,428		$ 49,401,184	$ 17,045,010		$ 41,647,157	$ 14,369,619		$ 41,647,157	$ 14,369,619
37	18,761		$ 54,376,552	$ 18,215,217		$ 57,859,572	$ 19,381,969		$ 57,859,572	$ 19,381,969		$ 49,401,184	$ 16,548,554		$ 41,647,157	$ 13,951,087		$ 41,647,157	$ 13,951,087
38	18,215		$ 54,376,552	$ 17,684,677		$ 57,859,572	$ 18,817,446		$ 57,859,572	$ 18,817,446		$ 49,401,184	$ 16,066,557		$ 41,647,157	$ 13,544,745		$ 41,647,157	$ 13,544,745
39	17,684		$ 54,376,552	$ 17,169,589		$ 57,859,572	$ 18,269,365		$ 57,859,572	$ 18,269,365		$ 49,401,184	$ 15,598,599		$ 41,647,157	$ 13,150,237		$ 41,647,157	$ 13,150,237
40	17,169		$ 54,376,552	$ 16,669,504		$ 57,859,572	$ 17,737,248		$ 57,859,572	$ 17,737,248		$ 49,401,184	$ 15,144,271		$ 41,647,157	$ 12,767,221		$ 41,647,157	$ 12,767,221
41	16,669		$ 54,376,552	$ 16,183,985		$ 57,859,572	$ 17,220,629		$ 57,859,572	$ 17,220,629		$ 49,401,184	$ 14,703,176		$ 41,647,157	$ 12,395,360		$ 41,647,157	$ 12,395,360
42	16,184		$ 54,376,552	$ 15,712,606		$ 57,859,572	$ 16,719,057		$ 57,859,572	$ 16,719,057		$ 49,401,184	$ 14,274,928		$ 41,647,157	$ 12,034,330		$ 41,647,157	$ 12,034,330
43	15,712		$ 54,376,552	$ 15,254,958		$ 57,859,572	$ 16,232,094		$ 57,859,572	$ 16,232,094		$ 49,401,184	$ 13,859,153		$ 41,647,157	$ 11,683,816		$ 41,647,157	$ 11,683,816
44	15,255		$ 54,376,552	$ 14,810,638		$ 57,859,572	$ 15,759,315		$ 57,859,572	$ 15,759,315		$ 49,401,184	$ 13,455,488		$ 41,647,157	$ 11,343,510		$ 41,647,157	$ 11,343,510
45	14,810		$ 54,376,552	$ 14,379,261		$ 57,859,572	$ 15,300,306		$ 57,859,572	$ 15,300,306		$ 49,401,184	$ 13,063,581		$ 41,647,157	$ 11,013,117		$ 41,647,157	$ 11,013,117
46	14,379		$ 54,376,552	$ 13,960,447		$ 57,859,572	$ 14,854,666		$ 57,859,572	$ 14,854,666		$ 49,401,184	$ 12,683,088		$ 41,647,157	$ 10,692,346		$ 41,647,157	$ 10,692,346
47	13,960		$ 54,376,552	$ 13,553,832		$ 57,859,572	$ 14,422,005		$ 57,859,572	$ 14,422,005		$ 49,401,184	$ 12,313,678		$ 41,647,157	$ 10,380,919		$ 41,647,157	$ 10,380,919
48	13,554		$ 54,376,552	$ 13,159,060		$ 57,859,572	$ 14,001,947		$ 57,859,572	$ 14,001,947		$ 49,401,184	$ 11,955,027		$ 41,647,157	$ 10,078,562		$ 41,647,157	$ 10,078,562
49	13,159		$ 54,376,552	$ 12,775,787		$ 57,859,572	$ 13,594,123		$ 57,859,572	$ 13,594,123		$ 49,401,184	$ 11,606,823		$ 41,647,157	$ 9,785,012		$ 41,647,157	$ 9,785,012
50	12,776		$ 54,376,552	$ 12,403,677		$ 57,859,572	$ 13,198,178		$ 57,859,572	$ 13,198,178		$ 49,401,184	$ 11,268,760		$ 41,647,157	$ 9,500,011		$ 41,647,157	$ 9,500,011
51	12,403		$ 54,376,552	$ 12,042,404		$ 57,859,572	$ 12,813,765		$ 57,859,572	$ 12,813,765		$ 49,401,184	$ 10,940,543		$ 41,647,157	$ 9,223,312		$ 41,647,157	$ 9,223,312
52	12,042		$ 54,376,552	$ 11,691,655		$ 57,859,572	$ 12,440,549		$ 57,859,572	$ 12,440,549		$ 49,401,184	$ 10,621,887		$ 41,647,157	$ 8,954,672		$ 41,647,157	$ 8,954,672
53	11,691	$ 9,000,000		$ 1,878,753		$ 57,859,572	$ 12,078,203		$ 57,859,572	$ 12,078,203	$ 9,000,000		$ 1,878,753		$ 41,647,157	$ 8,693,856		$ 41,647,157	$ 8,693,856
54	11,351					$ 57,859,572	$ 11,726,410		$ 57,859,572	$ 11,726,410					$ 41,647,157	$ 8,440,637		$ 41,647,157	$ 8,440,637
55	11,020					$ 57,859,572	$ 11,384,864		$ 57,859,572	$ 11,384,864				$ 9,000,000		$ 1,770,905		$ 41,647,157	$ 8,194,793
56	10,699					$ 57,859,572	$ 11,053,266	$ 9,000,000		$ 1,719,325							$ 9,000,000		
57	10,388				$ 9,000,000		$ 1,669,247			$ -									
Total PV costs				$ 2,128,085,441			$ 3,283,944,872			$ 3,192,469,369			$ 2,059,977,251			$ 2,715,299,130			$ 2,832,933,100
Unit cost				$ 1,567			$ 2,721			$ 2,568			$ 1,517			$ 2,121			$ 2,279

Table D.3.3 Life cycle cost analysis, 50 MGD facility, 3% discount rate, 50-year project life

		Low cost estimate									High cost estimate								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	56,007	$ 306,400,685		$ 306,400,685	$ 333,993,862		$ 333,993,862	$ 401,180,208		$ 401,180,208	$ 326,345,449		$ 326,345,449	$ 398,971,649		$ 398,971,649	$ 400,030,290		$ 400,030,290
1	52,343	$ 300,894,319		$ 281,209,644	$ 327,991,615		$ 306,534,220	$ 393,970,547		$ 368,196,773	$ 320,480,653		$ 299,514,629	$ 391,801,678		$ 366,169,793	$ 392,841,294		$ 367,141,396
2	48,919	$ 221,615,181		$ 193,567,282	$ 322,097,236		$ 281,332,200	$ 386,890,452		$ 337,925,104	$ 236,040,940		$ 206,167,299	$ 384,760,560		$ 336,064,774	$ 385,781,493		$ 336,956,497
3	45,718		$ 54,376,552	$ 44,387,464	$ 316,308,785		$ 258,202,190	$ 379,937,594		$ 310,142,251		$ 49,401,184	$ 40,326,081	$ 377,845,978		$ 308,434,870	$ 378,848,564		$ 309,253,279
4	42,727		$ 54,376,552	$ 41,483,611	$ 310,624,359		$ 236,973,836	$ 373,109,686		$ 284,643,593		$ 49,401,184	$ 37,687,926	$ 307,976,198		$ 234,953,567	$ 372,040,228		$ 283,827,709
5	39,932		$ 54,376,552	$ 38,769,730	$ 305,042,089		$ 217,490,794	$ 91,601,121		$ 65,310,333		$ 49,401,184	$ 35,222,361		$ 41,647,157	$ 29,693,847	$ 100,007,572		$ 71,304,017
6	37,320		$ 54,376,552	$ 36,233,393	$ 299,560,138		$ 199,609,569		$ 57,859,572	$ 38,554,276		$ 49,401,184	$ 32,918,095		$ 41,647,157	$ 27,751,259		$ 41,647,157	$ 27,751,259
7	34,878		$ 54,376,552	$ 33,862,984		$ 57,859,572	$ 36,032,034		$ 57,859,572	$ 36,032,034		$ 49,401,184	$ 30,764,574		$ 41,647,157	$ 25,935,756		$ 41,647,157	$ 25,935,756
8	32,597		$ 54,376,552	$ 31,647,649		$ 57,859,572	$ 33,674,798		$ 57,859,572	$ 33,674,798		$ 49,401,184	$ 28,751,939		$ 41,647,157	$ 24,239,024		$ 41,647,157	$ 24,239,024
9	30,464		$ 54,376,552	$ 29,577,242		$ 57,859,572	$ 31,471,774		$ 57,859,572	$ 31,471,774		$ 49,401,184	$ 26,870,971		$ 41,647,157	$ 22,653,294		$ 41,647,157	$ 22,653,294
10	28,471		$ 54,376,552	$ 27,642,282		$ 57,859,572	$ 29,412,873		$ 57,859,572	$ 29,412,873		$ 49,401,184	$ 25,113,057		$ 41,647,157	$ 21,171,303		$ 41,647,157	$ 21,171,303
11	26,609		$ 54,376,552	$ 25,833,908		$ 57,859,572	$ 27,488,666		$ 57,859,572	$ 27,488,666		$ 49,401,184	$ 23,470,146		$ 41,647,157	$ 19,786,264		$ 41,647,157	$ 19,786,264
12	24,868		$ 54,376,552	$ 24,143,840		$ 57,859,572	$ 25,690,342		$ 57,859,572	$ 25,690,342		$ 49,401,184	$ 21,934,716		$ 41,647,157	$ 18,491,836		$ 41,647,157	$ 18,491,836
13	23,241		$ 54,376,552	$ 22,564,336		$ 57,859,572	$ 24,009,665		$ 57,859,572	$ 24,009,665		$ 49,401,184	$ 20,499,735		$ 41,647,157	$ 17,282,089		$ 41,647,157	$ 17,282,089
14	21,720		$ 54,376,552	$ 21,088,165		$ 57,859,572	$ 22,438,940		$ 57,859,572	$ 22,438,940		$ 49,401,184	$ 19,158,631		$ 41,647,157	$ 16,151,485		$ 41,647,157	$ 16,151,485
15	20,300		$ 54,376,552	$ 19,708,565		$ 57,859,572	$ 20,970,972		$ 57,859,572	$ 20,970,972		$ 49,401,184	$ 17,905,262		$ 41,647,157	$ 15,094,846		$ 41,647,157	$ 15,094,846
16	18,972		$ 54,376,552	$ 18,419,220		$ 57,859,572	$ 19,599,039		$ 57,859,572	$ 19,599,039		$ 49,401,184	$ 16,733,890		$ 41,647,157	$ 14,107,333		$ 41,647,157	$ 14,107,333
17	17,730		$ 54,376,552	$ 17,214,224		$ 57,859,572	$ 18,316,859		$ 57,859,572	$ 18,316,859		$ 49,401,184	$ 15,639,150		$ 41,647,157	$ 13,184,423		$ 41,647,157	$ 13,184,423
18	16,570		$ 54,376,552	$ 16,088,060		$ 57,859,572	$ 17,118,560		$ 57,859,572	$ 17,118,560		$ 49,401,184	$ 14,616,028		$ 41,647,157	$ 12,321,891		$ 41,647,157	$ 12,321,891
19	15,486		$ 54,376,552	$ 15,035,570		$ 57,859,572	$ 15,998,654		$ 57,859,572	$ 15,998,654		$ 49,401,184	$ 13,659,839		$ 41,647,157	$ 11,515,786		$ 41,647,157	$ 11,515,786
20	14,473		$ 54,376,552	$ 14,051,934		$ 57,859,572	$ 14,952,013		$ 57,859,572	$ 14,952,013		$ 49,401,184	$ 12,766,205		$ 41,647,157	$ 10,762,417		$ 41,647,157	$ 10,762,417
21	13,526		$ 54,376,552	$ 13,132,649		$ 57,859,572	$ 13,973,844		$ 57,859,572	$ 13,973,844		$ 49,401,184	$ 11,931,032		$ 41,647,157	$ 10,058,333		$ 41,647,157	$ 10,058,333
22	12,642		$ 54,376,552	$ 12,273,504		$ 57,859,572	$ 13,059,667		$ 57,859,572	$ 13,059,667		$ 49,401,184	$ 11,150,498		$ 41,647,157	$ 9,400,312		$ 41,647,157	$ 9,400,312
23	11,815		$ 54,376,552	$ 11,470,564		$ 57,859,572	$ 12,205,296		$ 57,859,572	$ 12,205,296		$ 49,401,184	$ 10,421,026		$ 41,647,157	$ 8,785,338		$ 41,647,157	$ 8,785,338
24	11,042		$ 54,376,552	$ 10,720,153		$ 57,859,572	$ 11,406,819		$ 57,859,572	$ 11,406,819		$ 49,401,184	$ 9,739,276		$ 41,647,157	$ 8,210,596		$ 41,647,157	$ 8,210,596
25	10,319		$ 54,376,552	$ 10,018,835		$ 57,859,572	$ 10,660,579		$ 57,859,572	$ 10,660,579		$ 49,401,184	$ 9,102,127		$ 41,647,157	$ 7,673,454		$ 41,647,157	$ 7,673,454
26	9,644		$ 54,376,552	$ 9,363,397		$ 57,859,572	$ 9,963,158		$ 57,859,572	$ 9,963,158		$ 49,401,184	$ 8,506,661		$ 41,647,157	$ 7,171,453		$ 41,647,157	$ 7,171,453
27	9,013		$ 54,376,552	$ 8,750,839		$ 57,859,572	$ 9,311,362		$ 57,859,572	$ 9,311,362		$ 49,401,184	$ 7,950,151		$ 41,647,157	$ 6,702,292		$ 41,647,157	$ 6,702,292
28	8,424		$ 54,376,552	$ 8,178,354		$ 57,859,572	$ 8,702,208		$ 57,859,572	$ 8,702,208		$ 49,401,184	$ 7,430,047		$ 41,647,157	$ 6,263,825		$ 41,647,157	$ 6,263,825
29	7,873		$ 54,376,552	$ 7,643,321		$ 57,859,572	$ 8,132,904		$ 57,859,572	$ 8,132,904		$ 49,401,184	$ 6,943,969		$ 41,647,157	$ 5,854,042		$ 41,647,157	$ 5,854,042
30	7,357		$ 54,376,552	$ 7,143,291		$ 57,859,572	$ 7,600,845		$ 57,859,572	$ 7,600,845		$ 49,401,184	$ 6,489,691		$ 41,647,157	$ 5,471,067		$ 41,647,157	$ 5,471,067
31	6,876		$ 54,376,552	$ 6,675,973		$ 57,859,572	$ 7,103,594		$ 57,859,572	$ 7,103,594		$ 49,401,184	$ 6,065,132		$ 41,647,157	$ 5,113,147		$ 41,647,157	$ 5,113,147
32	6,426		$ 54,376,552	$ 6,239,227		$ 57,859,572	$ 6,638,873		$ 57,859,572	$ 6,638,873		$ 49,401,184	$ 5,668,348		$ 41,647,157	$ 4,778,642		$ 41,647,157	$ 4,778,642
33	6,006		$ 54,376,552	$ 5,831,053		$ 57,859,572	$ 6,204,554		$ 57,859,572	$ 6,204,554		$ 49,401,184	$ 5,297,521		$ 41,647,157	$ 4,466,020		$ 41,647,157	$ 4,466,020
34	5,613		$ 54,376,552	$ 5,449,582		$ 57,859,572	$ 5,798,648		$ 57,859,572	$ 5,798,648		$ 49,401,184	$ 4,950,954		$ 41,647,157	$ 4,173,851		$ 41,647,157	$ 4,173,851
35	5,246		$ 54,376,552	$ 5,093,068		$ 57,859,572	$ 5,419,298		$ 57,859,572	$ 5,419,298		$ 49,401,184	$ 4,627,060		$ 41,647,157	$ 3,900,795		$ 41,647,157	$ 3,900,795
36	4,903		$ 54,376,552	$ 4,759,876		$ 57,859,572	$ 5,064,764		$ 57,859,572	$ 5,064,764		$ 49,401,184	$ 4,324,355		$ 41,647,157	$ 3,645,603		$ 41,647,157	$ 3,645,603
37	4,582		$ 54,376,552	$ 4,448,483		$ 57,859,572	$ 4,733,424		$ 57,859,572	$ 4,733,424		$ 49,401,184	$ 4,041,453		$ 41,647,157	$ 3,407,106		$ 41,647,157	$ 3,407,106
38	4,282		$ 54,376,552	$ 4,157,460		$ 57,859,572	$ 4,423,761		$ 57,859,572	$ 4,423,761		$ 49,401,184	$ 3,777,059		$ 41,647,157	$ 3,184,211		$ 41,647,157	$ 3,184,211
39	4,002		$ 54,376,552	$ 3,885,477		$ 57,859,572	$ 4,134,356		$ 57,859,572	$ 4,134,356		$ 49,401,184	$ 3,529,962		$ 41,647,157	$ 2,975,898		$ 41,647,157	$ 2,975,898
40	3,740		$ 54,376,552	$ 3,631,287		$ 57,859,572	$ 3,863,884		$ 57,859,572	$ 3,863,884		$ 49,401,184	$ 3,299,030		$ 41,647,157	$ 2,781,213		$ 41,647,157	$ 2,781,213
41	3,495		$ 54,376,552	$ 3,393,726		$ 57,859,572	$ 3,611,107		$ 57,859,572	$ 3,611,107		$ 49,401,184	$ 3,083,205		$ 41,647,157	$ 2,599,264		$ 41,647,157	$ 2,599,264
42	3,267		$ 54,376,552	$ 3,171,707		$ 57,859,572	$ 3,374,866		$ 57,859,572	$ 3,374,866		$ 49,401,184	$ 2,881,500		$ 41,647,157	$ 2,429,219		$ 41,647,157	$ 2,429,219
43	3,053		$ 54,376,552	$ 2,964,212		$ 57,859,572	$ 3,154,081		$ 57,859,572	$ 3,154,081		$ 49,401,184	$ 2,692,991		$ 41,647,157	$ 2,270,298		$ 41,647,157	$ 2,270,298
44	2,853		$ 54,376,552	$ 2,770,291		$ 57,859,572	$ 2,947,739		$ 57,859,572	$ 2,947,739		$ 49,401,184	$ 2,516,814		$ 41,647,157	$ 2,121,774		$ 41,647,157	$ 2,121,774
45	2,667		$ 54,376,552	$ 2,589,057		$ 57,859,572	$ 2,754,896		$ 57,859,572	$ 2,754,896		$ 49,401,184	$ 2,352,163		$ 41,647,157	$ 1,982,966		$ 41,647,157	$ 1,982,966
46	2,492		$ 54,376,552	$ 2,419,680		$ 57,859,572	$ 2,574,669		$ 57,859,572	$ 2,574,669		$ 49,401,184	$ 2,198,283		$ 41,647,157	$ 1,853,240		$ 41,647,157	$ 1,853,240
47	2,329		$ 54,376,552	$ 2,261,383		$ 57,859,572	$ 2,406,233		$ 57,859,572	$ 2,406,233		$ 49,401,184	$ 2,054,470		$ 41,647,157	$ 1,732,000		$ 41,647,157	$ 1,732,000
48	2,177		$ 54,376,552	$ 2,113,442		$ 57,859,572	$ 2,248,816		$ 57,859,572	$ 2,248,816		$ 49,401,184	$ 1,920,065		$ 41,647,157	$ 1,618,691		$ 41,647,157	$ 1,618,691
49	2,034		$ 54,376,552	$ 1,975,179		$ 57,859,572	$ 2,101,697		$ 57,859,572	$ 2,101,697		$ 49,401,184	$ 1,794,454		$ 41,647,157	$ 1,512,796		$ 41,647,157	$ 1,512,796
50	1,901		$ 54,376,552	$ 1,845,962		$ 57,859,572	$ 1,964,203		$ 57,859,572	$ 1,964,203		$ 49,401,184	$ 1,677,059		$ 41,647,157	$ 1,413,828		$ 41,647,157	$ 1,413,828
51	1,777		$ 54,376,552	$ 1,725,198		$ 57,859,572	$ 1,835,704		$ 57,859,572	$ 1,835,704		$ 49,401,184	$ 1,567,345		$ 41,647,157	$ 1,321,334		$ 41,647,157	$ 1,321,334
52	1,661		$ 54,376,552	$ 1,612,335		$ 57,859,572	$ 1,715,611		$ 57,859,572	$ 1,715,611		$ 49,401,184	$ 1,464,809		$ 41,647,157	$ 1,234,892		$ 41,647,157	$ 1,234,892
53	1,552	$ 9,000,000		$ 249,403		$ 57,859,572	$ 1,603,375		$ 57,859,572	$ 1,603,375	$ 9,000,000		$ 249,403		$ 41,647,157	$ 1,154,105		$ 41,647,157	$ 1,154,105
54	1,451					$ 57,859,572	$ 1,498,481		$ 57,859,572	$ 1,498,481					$ 41,647,157	$ 1,078,602		$ 41,647,157	$ 1,078,602
55	1,356					$ 57,859,572	$ 1,400,449		$ 57,859,572	$ 1,400,449				$ 9,000,000		$ 217,839		$ 41,647,157	$ 1,008,040
56	1,267					$ 57,859,572	$ 1,308,831	$ 9,000,000		$ 203,587							$ 9,000,000		
57	1,184				$ 9,000,000		$ 190,269			$ -									
Total PV costs				$1,436,887,756			$2,366,404,719			$2,336,925,075			$1,427,763,899			$2,083,295,549			$ 2,178,310,438
Unit cost				$ 2,128			$ 4,595			$ 4,241			$ 2,115			$ 3,533			$ 3,953

Table D.3.4 Life cycle cost analysis, 50 MGD facility, 7% discount rate, 50-year project life

		Low cost estimate									High cost estimate								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	112014	$ 563,777,261		$ 563,777,261	$ 506,145,692		$ 506,145,692	$ 553,694,927		$ 553,694,927	$ 600,475,626		$ 600,475,626	$ 734,107,834		$ 734,107,834	$ 736,055,733		$ 736,055,733
1	108751.456	$ 553,645,547		$ 537,519,949	$ 497,049,682		$ 482,572,507	$ 543,744,404		$ 527,907,189	$ 589,684,401		$ 572,509,127	$ 720,915,088		$ 699,917,561	$ 722,827,981		$ 701,774,739
2	105583.938	$ 407,771,934		$ 384,364,157	$ 488,117,139		$ 460,097,218	$ 533,972,704		$ 503,320,486	$ 434,315,330		$ 409,383,854	$ 707,959,430		$ 667,319,663	$ 709,837,947		$ 669,090,345
3	102508.678		$ 108,753,105	$ 99,524,497	$ 479,345,123		$ 438,668,691	$ 524,376,612		$ 479,878,883		$ 98,802,367	$ 90,418,162	$ 695,236,600		$ 636,239,976	$ 697,081,358		$ 637,928,191
4	99522.9882		$ 108,753,105	$ 96,625,725	$ 470,730,750		$ 418,238,175	$ 514,952,972		$ 457,529,046		$ 98,802,367	$ 87,784,624	$ 566,676,204		$ 503,484,467	$ 684,554,020		$ 608,217,380
5	96624.2604		$ 108,753,105	$ 93,811,383	$ 462,271,188		$ 398,759,187	$ 505,698,686		$ 436,220,129		$ 98,802,367	$ 85,227,790		$ 83,294,313	$ 71,850,406	$ 184,013,933		$ 158,732,035
6	93809.9615		$ 108,753,105	$ 91,079,013	$ 453,963,653		$ 380,187,412	$ 496,610,710		$ 415,903,652		$ 98,802,367	$ 82,745,427		$ 83,294,313	$ 69,757,676		$ 83,294,313	$ 69,757,676
7	91077.6326		$ 108,753,105	$ 88,426,226	$ 445,805,414		$ 362,480,598		$ 115,719,144	$ 94,090,254		$ 98,802,367	$ 80,335,366		$ 83,294,313	$ 67,725,899		$ 83,294,313	$ 67,725,899
8	88424.886		$ 108,753,105	$ 85,850,705	$ 218,896,894		$ 172,799,229		$ 115,719,144	$ 91,349,761		$ 98,802,367	$ 77,995,501		$ 83,294,313	$ 65,753,300		$ 83,294,313	$ 65,753,300
9	85849.4039		$ 108,753,105	$ 83,350,199		$115,719,144	$ 88,689,088		$ 115,719,144	$ 88,689,088		$ 98,802,367	$ 75,723,788		$ 83,294,313	$ 63,838,155		$ 83,294,313	$ 63,838,155
10	83348.9358		$ 108,753,105	$ 80,922,523		$115,719,144	$ 86,105,911		$ 115,719,144	$ 86,105,911		$ 98,802,367	$ 73,518,240		$ 83,294,313	$ 61,978,792		$ 83,294,313	$ 61,978,792
11	80921.2969		$ 108,753,105	$ 78,565,557		$115,719,144	$ 83,597,972		$ 115,719,144	$ 83,597,972		$ 98,802,367	$ 71,376,932		$ 83,294,313	$ 60,173,584		$ 83,294,313	$ 60,173,584
12	78564.3659		$ 108,753,105	$ 76,277,240		$115,719,144	$ 81,163,079		$ 115,719,144	$ 81,163,079		$ 98,802,367	$ 69,297,993		$ 83,294,313	$ 58,420,956		$ 83,294,313	$ 58,420,956
13	76276.0834		$ 108,753,105	$ 74,055,572		$115,719,144	$ 78,799,106		$ 115,719,144	$ 78,799,106		$ 98,802,367	$ 67,279,604		$ 83,294,313	$ 56,719,374		$ 83,294,313	$ 56,719,374
14	74054.4499		$ 108,753,105	$ 71,898,614		$115,719,144	$ 76,503,987		$ 115,719,144	$ 76,503,987		$ 98,802,367	$ 65,320,004		$ 83,294,313	$ 55,067,354		$ 83,294,313	$ 55,067,354
15	71897.5242		$ 108,753,105	$ 69,804,480		$115,719,144	$ 74,275,715		$ 115,719,144	$ 74,275,715		$ 98,802,367	$ 63,417,480		$ 83,294,313	$ 53,463,450		$ 83,294,313	$ 53,463,450
16	69803.4215		$ 108,753,105	$ 67,771,339		$115,719,144	$ 72,112,345		$ 115,719,144	$ 72,112,345		$ 98,802,367	$ 61,570,369		$ 83,294,313	$ 51,906,262		$ 83,294,313	$ 51,906,262
17	67770.3122		$ 108,753,105	$ 65,797,417		$115,719,144	$ 70,011,985		$ 115,719,144	$ 70,011,985		$ 98,802,367	$ 59,777,057		$ 83,294,313	$ 50,394,429		$ 83,294,313	$ 50,394,429
18	65796.4196		$ 108,753,105	$ 63,880,987		$115,719,144	$ 67,972,801		$ 115,719,144	$ 67,972,801		$ 98,802,367	$ 58,035,978		$ 83,294,313	$ 48,926,630		$ 83,294,313	$ 48,926,630
19	63880.019		$ 108,753,105	$ 62,020,376		$115,719,144	$ 65,993,011		$ 115,719,144	$ 65,993,011		$ 98,802,367	$ 56,345,610		$ 83,294,313	$ 47,501,583		$ 83,294,313	$ 47,501,583
20	62019.4359		$ 108,753,105	$ 60,213,957		$115,719,144	$ 64,070,884		$ 115,719,144	$ 64,070,884		$ 98,802,367	$ 54,704,475		$ 83,294,313	$ 46,118,042		$ 83,294,313	$ 46,118,042
21	60213.0446		$ 108,753,105	$ 58,460,153		$115,719,144	$ 62,204,742		$ 115,719,144	$ 62,204,742		$ 98,802,367	$ 53,111,141		$ 83,294,313	$ 44,774,798		$ 83,294,313	$ 44,774,798
22	58459.2666		$ 108,753,105	$ 56,757,430		$115,719,144	$ 60,392,954		$ 115,719,144	$ 60,392,954		$ 98,802,367	$ 51,564,215		$ 83,294,313	$ 43,470,677		$ 83,294,313	$ 43,470,677
23	56756.5695		$ 108,753,105	$ 55,104,301		$115,719,144	$ 58,633,935		$ 115,719,144	$ 58,633,935		$ 98,802,367	$ 50,062,344		$ 83,294,313	$ 42,204,541		$ 83,294,313	$ 42,204,541
24	55103.4655		$ 108,753,105	$ 53,499,321		$115,719,144	$ 56,926,151		$ 115,719,144	$ 56,926,151		$ 98,802,367	$ 48,604,218		$ 83,294,313	$ 40,975,283		$ 83,294,313	$ 40,975,283
25	53498.5102		$ 108,753,105	$ 51,941,088		$115,719,144	$ 55,268,108		$ 115,719,144	$ 55,268,108		$ 98,802,367	$ 47,188,561		$ 83,294,313	$ 39,781,828		$ 83,294,313	$ 39,781,828
26	51940.3012		$ 108,753,105	$ 50,428,241		$115,719,144	$ 53,658,357		$ 115,719,144	$ 53,658,357		$ 98,802,367	$ 45,814,137		$ 83,294,313	$ 38,623,134		$ 83,294,313	$ 38,623,134
27	50427.4769		$ 108,753,105	$ 48,959,458		$115,719,144	$ 52,095,492		$ 115,719,144	$ 52,095,492		$ 98,802,367	$ 44,479,744		$ 83,294,313	$ 37,498,188		$ 83,294,313	$ 37,498,188
28	48958.7154		$ 108,753,105	$ 47,533,454		$115,719,144	$ 50,578,148		$ 115,719,144	$ 50,578,148		$ 98,802,367	$ 43,184,218		$ 83,294,313	$ 36,406,008		$ 83,294,313	$ 36,406,008
29	47532.7334		$ 108,753,105	$ 46,148,984		$115,719,144	$ 49,104,998		$ 115,719,144	$ 49,104,998		$ 98,802,367	$ 41,926,425		$ 83,294,313	$ 35,345,639		$ 83,294,313	$ 35,345,639
30	46148.2849		$ 108,753,105	$ 44,804,839		$115,719,144	$ 47,674,755		$ 115,719,144	$ 47,674,755		$ 98,802,367	$ 40,705,267		$ 83,294,313	$ 34,316,154		$ 83,294,313	$ 34,316,154
31	44804.1601		$ 108,753,105	$ 43,499,844		$115,719,144	$ 46,286,170		$ 115,719,144	$ 46,286,170		$ 98,802,367	$ 39,519,677		$ 83,294,313	$ 33,316,655		$ 83,294,313	$ 33,316,655
32	43499.1845		$ 108,753,105	$ 42,232,858		$115,719,144	$ 44,938,029		$ 115,719,144	$ 44,938,029		$ 98,802,367	$ 38,368,618		$ 83,294,313	$ 32,346,267		$ 83,294,313	$ 32,346,267
33	42232.218	$ 16,560,000		$ 6,243,555		$115,719,144	$ 43,629,155		$ 115,719,144	$ 43,629,155	$ 16,560,000		$ 6,243,555		$ 83,294,313	$ 31,404,142		$ 83,294,313	$ 31,404,142
34	41002.1534					$115,719,144	$ 42,358,403		$ 115,719,144	$ 42,358,403			$ -		$ 83,294,313	$ 30,489,459		$ 83,294,313	$ 30,489,459
35	39807.9159					$115,719,144	$ 41,124,663		$ 115,719,144	$ 41,124,663			$ -	$ 16,560,000		$ 5,885,149		$ 83,294,313	$ 29,601,416
36	38648.4621					$115,719,144	$ 39,926,857		$ 115,719,144	$ 39,926,857			$ -			$ -	$ 16,560,000		$ 5,713,737
37	37522.7787					$115,719,144	$ 38,763,939	$ 16,560,000		$ 5,547,317			$ -			$ -			$ -
38	36429.8822					$115,719,144	$ 37,634,892			$ -			$ -			$ -			$ -
39	35368.8177				$ 16,560,000		$ 5,228,879			$ -			$ -			$ -			$ -
Total PV costs				$ 3,501,150,702			$ 5,415,673,220			$ 5,279,538,445			$ 3,414,015,127			$ 4,697,503,317			$ 4,925,811,837
Unit cost				$ 1,692			$ 3,125			$ 2,871			$ 1,650			$ 2,408			$ 2,601

Table D.4.1 Life cycle cost analysis, 100 MGD facility, 3% discount rate, 30-year project life

		Low cost estimate									**High cost estiamte**								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	112014	$ 563,777,261		$ 563,777,261	$ 506,145,692		$ 506,145,692	$ 553,694,927		$ 553,694,927	$ 600,475,626		$ 600,475,626	$ 734,107,834		$ 734,107,834	$ 736,055,733		$ 736,055,733
1	104686	$ 553,645,547		$ 517,425,745	$ 497,049,682		$ 464,532,413	$ 543,744,404		$ 508,172,340	$ 589,684,401		$ 551,106,917	$ 720,915,088		$ 673,752,419	$ 722,827,981		$ 675,540,170
2	97837.37	$ 407,771,934		$ 356,163,799	$ 488,117,139		$ 426,340,413	$ 533,972,704		$ 466,392,439	$ 434,315,330		$ 379,347,830	$ 707,959,430		$ 618,359,184	$ 709,837,947		$ 619,999,954
3	91436.79		$ 108,753,105	$ 88,774,928	$ 479,345,123		$ 391,288,406	$ 524,376,612		$ 428,047,515		$ 98,802,367	$ 80,652,163	$ 695,236,600		$ 567,520,161	$ 697,081,358		$ 569,026,033
4	85454.94		$ 108,753,105	$ 82,967,223	$ 470,730,750		$ 359,118,236	$ 514,952,972		$ 392,855,157		$ 98,802,367	$ 75,375,853	$ 566,676,204		$ 432,314,563	$ 684,554,020		$ 522,242,984
5	79864.43		$ 108,753,105	$ 77,539,461	$ 462,271,188		$ 329,592,968	$ 505,698,686		$ 360,556,174		$ 98,802,367	$ 70,444,722		$ 83,294,313	$ 59,387,694	$ 184,013,933		$ 131,199,391
6	74639.66		$ 108,753,105	$ 72,466,786	$ 453,963,653		$ 302,495,150	$ 496,610,710		$ 330,912,685		$ 98,802,367	$ 65,836,189		$ 83,294,313	$ 55,502,518		$ 83,294,313	$ 55,502,518
7	69756.69		$ 108,753,105	$ 67,725,968	$ 445,805,414		$ 277,625,206		$ 115,719,144	$ 72,064,067		$ 98,802,367	$ 61,529,149		$ 83,294,313	$ 51,871,512		$ 83,294,313	$ 51,871,512
8	65193.17		$ 108,753,105	$ 63,295,297	$ 218,896,894		$ 127,399,985		$ 115,719,144	$ 67,349,595		$ 98,802,367	$ 57,503,877		$ 83,294,313	$ 48,478,049		$ 83,294,313	$ 48,478,049
9	60928.19		$ 108,753,105	$ 59,154,483		$ 115,719,144	$ 62,943,547		$ 115,719,144	$ 62,943,547		$ 98,802,367	$ 53,741,941		$ 83,294,313	$ 45,306,588		$ 83,294,313	$ 45,306,588
10	56942.24		$ 108,753,105	$ 55,284,564		$ 115,719,144	$ 58,825,745		$ 115,719,144	$ 58,825,745		$ 98,802,367	$ 50,226,113		$ 83,294,313	$ 42,342,605		$ 83,294,313	$ 42,342,605
11	53217.04		$ 108,753,105	$ 51,667,817		$ 115,719,144	$ 54,977,332		$ 115,719,144	$ 54,977,332		$ 98,802,367	$ 46,940,293		$ 83,294,313	$ 39,572,528		$ 83,294,313	$ 39,572,528
12	49735.56		$ 108,753,105	$ 48,287,679		$ 115,719,144	$ 51,380,684		$ 115,719,144	$ 51,380,684		$ 98,802,367	$ 43,869,433		$ 83,294,313	$ 36,983,671		$ 83,294,313	$ 36,983,671
13	46481.83		$ 108,753,105	$ 45,128,672		$ 115,719,144	$ 48,019,331		$ 115,719,144	$ 48,019,331		$ 98,802,367	$ 40,999,470		$ 83,294,313	$ 34,564,179		$ 83,294,313	$ 34,564,179
14	43440.96		$ 108,753,105	$ 42,176,329		$ 115,719,144	$ 44,877,879		$ 115,719,144	$ 44,877,879		$ 98,802,367	$ 38,317,262		$ 83,294,313	$ 32,302,971		$ 83,294,313	$ 32,302,971
15	40599.03		$ 108,753,105	$ 39,417,130		$ 115,719,144	$ 41,941,943		$ 115,719,144	$ 41,941,943		$ 98,802,367	$ 35,810,525		$ 83,294,313	$ 30,189,692		$ 83,294,313	$ 30,189,692
16	37943.02		$ 108,753,105	$ 36,838,439		$ 115,719,144	$ 39,198,078		$ 115,719,144	$ 39,198,078		$ 98,802,367	$ 33,467,780		$ 83,294,313	$ 28,214,666		$ 83,294,313	$ 28,214,666
17	35460.76		$ 108,753,105	$ 34,428,448		$ 115,719,144	$ 36,633,718		$ 115,719,144	$ 36,633,718		$ 98,802,367	$ 31,278,299		$ 83,294,313	$ 26,368,846		$ 83,294,313	$ 26,368,846
18	33140.9		$ 108,753,105	$ 32,176,119		$ 115,719,144	$ 34,237,119		$ 115,719,144	$ 34,237,119		$ 98,802,367	$ 29,232,055		$ 83,294,313	$ 24,643,782		$ 83,294,313	$ 24,643,782
19	30972.8		$ 108,753,105	$ 30,071,140		$ 115,719,144	$ 31,997,308		$ 115,719,144	$ 31,997,308		$ 98,802,367	$ 27,319,678		$ 83,294,313	$ 23,031,572		$ 83,294,313	$ 23,031,572
20	28946.55		$ 108,753,105	$ 28,103,869		$ 115,719,144	$ 29,904,026		$ 115,719,144	$ 29,904,026		$ 98,802,367	$ 25,532,409		$ 83,294,313	$ 21,524,833		$ 83,294,313	$ 21,524,833
21	27052.85		$ 108,753,105	$ 26,265,298		$ 115,719,144	$ 27,947,688		$ 115,719,144	$ 27,947,688		$ 98,802,367	$ 23,862,065		$ 83,294,313	$ 20,116,667		$ 83,294,313	$ 20,116,667
22	25283.03		$ 108,753,105	$ 24,547,007		$ 115,719,144	$ 26,119,334		$ 115,719,144	$ 26,119,334		$ 98,802,367	$ 22,300,995		$ 83,294,313	$ 18,800,623		$ 83,294,313	$ 18,800,623
23	23629		$ 108,753,105	$ 22,941,128		$ 115,719,144	$ 24,410,593		$ 115,719,144	$ 24,410,593		$ 98,802,367	$ 20,842,051		$ 83,294,313	$ 17,570,676		$ 83,294,313	$ 17,570,676
24	22083.18		$ 108,753,105	$ 21,440,307		$ 115,719,144	$ 22,813,638		$ 115,719,144	$ 22,813,638		$ 98,802,367	$ 19,478,553		$ 83,294,313	$ 16,421,192		$ 83,294,313	$ 16,421,192
25	20638.49		$ 108,753,105	$ 20,037,670		$ 115,719,144	$ 21,321,157		$ 115,719,144	$ 21,321,157		$ 98,802,367	$ 18,204,255		$ 83,294,313	$ 15,346,909		$ 83,294,313	$ 15,346,909
26	19288.31		$ 108,753,105	$ 18,726,794		$ 115,719,144	$ 19,926,315		$ 115,719,144	$ 19,926,315		$ 98,802,367	$ 17,013,322		$ 83,294,313	$ 14,342,905		$ 83,294,313	$ 14,342,905
27	18026.45		$ 108,753,105	$ 17,501,677		$ 115,719,144	$ 18,622,724		$ 115,719,144	$ 18,622,724		$ 98,802,367	$ 15,900,301		$ 83,294,313	$ 13,404,584		$ 83,294,313	$ 13,404,584
28	16847.15		$ 108,753,105	$ 16,356,708		$ 115,719,144	$ 17,404,415		$ 115,719,144	$ 17,404,415		$ 98,802,367	$ 14,860,095		$ 83,294,313	$ 12,527,649		$ 83,294,313	$ 12,527,649
29	15745		$ 108,753,105	$ 15,286,643		$ 115,719,144	$ 16,265,809		$ 115,719,144	$ 16,265,809		$ 98,802,367	$ 13,887,939		$ 83,294,313	$ 11,708,083		$ 83,294,313	$ 11,708,083
30	14714.96		$ 108,753,105	$ 14,286,582		$ 115,719,144	$ 15,201,690		$ 115,719,144	$ 15,201,690		$ 98,802,367	$ 12,979,382		$ 83,294,313	$ 10,942,134		$ 83,294,313	$ 10,942,134
31	13752.3		$ 108,753,105	$ 13,351,946		$ 115,719,144	$ 14,207,187		$ 115,719,144	$ 14,207,187		$ 98,802,367	$ 12,130,264		$ 83,294,313	$ 10,226,293		$ 83,294,313	$ 10,226,293
32	12852.61		$ 108,753,105	$ 12,478,454		$ 115,719,144	$ 13,277,745		$ 115,719,144	$ 13,277,745		$ 98,802,367	$ 11,336,695		$ 83,294,313	$ 9,557,283		$ 83,294,313	$ 9,557,283
33	12011.79	$ 16,560,000		$ 1,775,807		$ 115,719,144	$ 12,409,108		$ 115,719,144	$ 12,409,108	$ 16,560,000		$ 1,775,807		$ 83,294,313	$ 8,932,041		$ 83,294,313	$ 8,932,041
34	11225.97					$ 115,719,144	$ 11,597,297		$ 115,719,144	$ 11,597,297			$ -		$ 83,294,313	$ 8,347,701		$ 83,294,313	$ 8,347,701
35	10491.56					$ 115,719,144	$ 10,838,595		$ 115,719,144	$ 10,838,595			$ -	$ 16,560,000		$ 1,551,058		$ 83,294,313	$ 7,801,590
36	9805.197					$ 115,719,144	$ 10,129,528		$ 115,719,144	$ 10,129,528			$ -			$ -	$ 16,560,000		$ 1,449,587
37	9163.735					$ 115,719,144	$ 9,466,849	$ 16,560,000		$ 1,354,754			$ -			$ -			$ -
38	8564.239					$ 115,719,144	$ 8,847,522			$ -			$ -			$ -			$ -
39	8003.961				$ 16,560,000		$ 1,183,295			$ -			$ -			$ -			$ -
Total PV costs				$ 2,617,867,177			$ 4,021,465,668			$ 3,998,829,188			$ 2,603,579,308			$ 3,816,135,666			$ 3,992,458,195
Unit cost				$ 2,156			$ 4,971			$ 4,317			$ 2,145			$ 3,599			$ 4,029

Table D.4.2 Life cycle cost analysis, 100 MGD facility, 7% discount rate, 30-year project life

		Low cost estimate									High cost estimate								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	112,014	$ 563,777,261		$ 563,777,261	$ 506,145,692		$ 506,145,692	$ 553,694,927		$ 553,694,927	$ 600,475,626		$ 600,475,626	$ 734,107,834		$ 734,107,834	$ 736,055,733		$ 736,055,733
1	108,751	$ 553,645,547		$ 537,519,949	$ 497,049,682		$ 482,572,507	$ 543,744,404		$ 527,907,189	$ 589,684,401		$ 572,509,127	$ 720,915,088		$ 699,917,561	$ 722,827,981		$ 701,774,739
2	105,584	$ 407,771,934		$ 384,364,157	$ 488,117,139		$ 460,097,218	$ 533,972,704		$ 503,320,486	$ 434,315,330		$ 409,383,854	$ 707,959,430		$ 667,319,663	$ 709,837,947		$ 669,090,345
3	102,509		$ 108,753,105	$ 99,524,497	$ 479,345,123		$ 438,668,691	$ 524,376,612		$ 479,878,883		$ 98,802,367	$ 90,418,162	$ 695,236,600		$ 636,239,976	$ 697,081,358		$ 637,928,191
4	99,523		$ 108,753,105	$ 96,625,725	$ 470,730,750		$ 418,238,175	$ 514,952,972		$ 457,529,046		$ 98,802,367	$ 87,784,624	$ 566,676,204		$ 503,484,467	$ 684,554,020		$ 608,217,380
5	96,624		$ 108,753,105	$ 93,811,383	$ 462,271,188		$ 398,759,187	$ 505,698,686		$ 436,220,129		$ 98,802,367	$ 85,227,790		$ 83,294,313	$ 71,850,406	$ 184,013,933		$ 158,732,035
6	93,810		$ 108,753,105	$ 91,079,013	$ 453,963,653		$ 380,187,412	$ 496,610,710		$ 415,903,652		$ 98,802,367	$ 82,745,427		$ 83,294,313	$ 69,757,676		$ 83,294,313	$ 69,757,676
7	91,078		$ 108,753,105	$ 88,426,226	$ 445,805,414		$ 362,480,598		$ 115,719,144	$ 94,090,254		$ 98,802,367	$ 80,335,366		$ 83,294,313	$ 67,725,899		$ 83,294,313	$ 67,725,899
8	88,425		$ 108,753,105	$ 85,850,705	$ 218,896,894		$ 172,799,229		$ 115,719,144	$ 91,349,761		$ 98,802,367	$ 77,995,501		$ 83,294,313	$ 65,753,300		$ 83,294,313	$ 65,753,300
9	85,849		$ 108,753,105	$ 83,350,199		$ 115,719,144	$ 88,689,088		$ 115,719,144	$ 88,689,088		$ 98,802,367	$ 75,723,788		$ 83,294,313	$ 63,838,155		$ 83,294,313	$ 63,838,155
10	83,349		$ 108,753,105	$ 80,922,523		$ 115,719,144	$ 86,105,911		$ 115,719,144	$ 86,105,911		$ 98,802,367	$ 73,518,240		$ 83,294,313	$ 61,978,792		$ 83,294,313	$ 61,978,792
11	80,921		$ 108,753,105	$ 78,565,557		$ 115,719,144	$ 83,597,972		$ 115,719,144	$ 83,597,972		$ 98,802,367	$ 71,376,932		$ 83,294,313	$ 60,173,584		$ 83,294,313	$ 60,173,584
12	78,564		$ 108,753,105	$ 76,277,240		$ 115,719,144	$ 81,163,079		$ 115,719,144	$ 81,163,079		$ 98,802,367	$ 69,297,993		$ 83,294,313	$ 58,420,956		$ 83,294,313	$ 58,420,956
13	76,276		$ 108,753,105	$ 74,055,572		$ 115,719,144	$ 78,799,106		$ 115,719,144	$ 78,799,106		$ 98,802,367	$ 67,279,604		$ 83,294,313	$ 56,719,374		$ 83,294,313	$ 56,719,374
14	74,054		$ 108,753,105	$ 71,898,614		$ 115,719,144	$ 76,503,987		$ 115,719,144	$ 76,503,987		$ 98,802,367	$ 65,320,004		$ 83,294,313	$ 55,067,354		$ 83,294,313	$ 55,067,354
15	71,898		$ 108,753,105	$ 69,804,480		$ 115,719,144	$ 74,275,715		$ 115,719,144	$ 74,275,715		$ 98,802,367	$ 63,417,480		$ 83,294,313	$ 53,463,450		$ 83,294,313	$ 53,463,450
16	69,803		$ 108,753,105	$ 67,771,339		$ 115,719,144	$ 72,112,345		$ 115,719,144	$ 72,112,345		$ 98,802,367	$ 61,570,369		$ 83,294,313	$ 51,906,262		$ 83,294,313	$ 51,906,262
17	67,770		$ 108,753,105	$ 65,797,417		$ 115,719,144	$ 70,011,985		$ 115,719,144	$ 70,011,985		$ 98,802,367	$ 59,777,057		$ 83,294,313	$ 50,394,429		$ 83,294,313	$ 50,394,429
18	65,796		$ 108,753,105	$ 63,880,987		$ 115,719,144	$ 67,972,801		$ 115,719,144	$ 67,972,801		$ 98,802,367	$ 58,035,978		$ 83,294,313	$ 48,926,630		$ 83,294,313	$ 48,926,630
19	63,880		$ 108,753,105	$ 62,020,376		$ 115,719,144	$ 65,993,011		$ 115,719,144	$ 65,993,011		$ 98,802,367	$ 56,345,610		$ 83,294,313	$ 47,501,583		$ 83,294,313	$ 47,501,583
20	62,019		$ 108,753,105	$ 60,213,957		$ 115,719,144	$ 64,070,884		$ 115,719,144	$ 64,070,884		$ 98,802,367	$ 54,704,475		$ 83,294,313	$ 46,118,042		$ 83,294,313	$ 46,118,042
21	60,213		$ 108,753,105	$ 58,460,153		$ 115,719,144	$ 62,204,742		$ 115,719,144	$ 62,204,742		$ 98,802,367	$ 53,111,141		$ 83,294,313	$ 44,774,798		$ 83,294,313	$ 44,774,798
22	58,459		$ 108,753,105	$ 56,757,430		$ 115,719,144	$ 60,392,954		$ 115,719,144	$ 60,392,954		$ 98,802,367	$ 51,564,215		$ 83,294,313	$ 43,470,677		$ 83,294,313	$ 43,470,677
23	56,757		$ 108,753,105	$ 55,104,301		$ 115,719,144	$ 58,633,935		$ 115,719,144	$ 58,633,935		$ 98,802,367	$ 50,062,344		$ 83,294,313	$ 42,204,541		$ 83,294,313	$ 42,204,541
24	55,103		$ 108,753,105	$ 53,499,321		$ 115,719,144	$ 56,926,151		$ 115,719,144	$ 56,926,151		$ 98,802,367	$ 48,604,218		$ 83,294,313	$ 40,975,283		$ 83,294,313	$ 40,975,283
25	53,499		$ 108,753,105	$ 51,941,088		$ 115,719,144	$ 55,268,108		$ 115,719,144	$ 55,268,108		$ 98,802,367	$ 47,188,561		$ 83,294,313	$ 39,781,828		$ 83,294,313	$ 39,781,828
26	51,940		$ 108,753,105	$ 50,428,241		$ 115,719,144	$ 53,658,357		$ 115,719,144	$ 53,658,357		$ 98,802,367	$ 45,814,137		$ 83,294,313	$ 38,623,134		$ 83,294,313	$ 38,623,134
27	50,427		$ 108,753,105	$ 48,959,458		$ 115,719,144	$ 52,095,492		$ 115,719,144	$ 52,095,492		$ 98,802,367	$ 44,479,744		$ 83,294,313	$ 37,498,188		$ 83,294,313	$ 37,498,188
28	48,959		$ 108,753,105	$ 47,533,454		$ 115,719,144	$ 50,578,148		$ 115,719,144	$ 50,578,148		$ 98,802,367	$ 43,184,218		$ 83,294,313	$ 36,406,008		$ 83,294,313	$ 36,406,008
29	47,533		$ 108,753,105	$ 46,148,984		$ 115,719,144	$ 49,104,998		$ 115,719,144	$ 49,104,998		$ 98,802,367	$ 41,926,425		$ 83,294,313	$ 35,345,639		$ 83,294,313	$ 35,345,639
30	46,148		$ 108,753,105	$ 44,804,839		$ 115,719,144	$ 47,674,755		$ 115,719,144	$ 47,674,755		$ 98,802,367	$ 40,705,267		$ 83,294,313	$ 34,316,154		$ 83,294,313	$ 34,316,154
31	44,804		$ 108,753,105	$ 43,499,844		$ 115,719,144	$ 46,286,170		$ 115,719,144	$ 46,286,170		$ 98,802,367	$ 39,519,677		$ 83,294,313	$ 33,316,655		$ 83,294,313	$ 33,316,655
32	43,499		$ 108,753,105	$ 42,232,858		$ 115,719,144	$ 44,938,029		$ 115,719,144	$ 44,938,029		$ 98,802,367	$ 38,368,618		$ 83,294,313	$ 32,346,267		$ 83,294,313	$ 32,346,267
33	42,232		$ 108,753,105	$ 41,002,775		$ 115,719,144	$ 43,629,155		$ 115,719,144	$ 43,629,155		$ 98,802,367	$ 37,251,086		$ 83,294,313	$ 31,404,142		$ 83,294,313	$ 31,404,142
34	41,002		$ 108,753,105	$ 39,808,519		$ 115,719,144	$ 42,358,403		$ 115,719,144	$ 42,358,403		$ 98,802,367	$ 36,166,103		$ 83,294,313	$ 30,489,459		$ 83,294,313	$ 30,489,459
35	39,808		$ 108,753,105	$ 38,649,048		$ 115,719,144	$ 41,124,663		$ 115,719,144	$ 41,124,663		$ 98,802,367	$ 35,112,721		$ 83,294,313	$ 29,601,416		$ 83,294,313	$ 29,601,416
36	38,648		$ 108,753,105	$ 37,523,347		$ 115,719,144	$ 39,926,857		$ 115,719,144	$ 39,926,857		$ 98,802,367	$ 34,090,020		$ 83,294,313	$ 28,739,239		$ 83,294,313	$ 28,739,239
37	37,523		$ 108,753,105	$ 36,430,434		$ 115,719,144	$ 38,763,939		$ 115,719,144	$ 38,763,939		$ 98,802,367	$ 33,097,107		$ 83,294,313	$ 27,902,174		$ 83,294,313	$ 27,902,174
38	36,430		$ 108,753,105	$ 35,369,354		$ 115,719,144	$ 37,634,892		$ 115,719,144	$ 37,634,892		$ 98,802,367	$ 32,133,114		$ 83,294,313	$ 27,089,489		$ 83,294,313	$ 27,089,489
39	35,369		$ 108,753,105	$ 34,339,178		$ 115,719,144	$ 36,538,730		$ 115,719,144	$ 36,538,730		$ 98,802,367	$ 31,197,198		$ 83,294,313	$ 26,300,475		$ 83,294,313	$ 26,300,475
40	34,339		$ 108,753,105	$ 33,339,008		$ 115,719,144	$ 35,474,495		$ 115,719,144	$ 35,474,495		$ 98,802,367	$ 30,288,542		$ 83,294,313	$ 25,534,442		$ 83,294,313	$ 25,534,442
41	33,339		$ 108,753,105	$ 32,367,969		$ 115,719,144	$ 34,441,258		$ 115,719,144	$ 34,441,258		$ 98,802,367	$ 29,406,351		$ 83,294,313	$ 24,790,720		$ 83,294,313	$ 24,790,720
42	32,367		$ 108,753,105	$ 31,425,213		$ 115,719,144	$ 33,438,114		$ 115,719,144	$ 33,438,114		$ 98,802,367	$ 28,549,855		$ 83,294,313	$ 24,068,660		$ 83,294,313	$ 24,068,660
43	31,425		$ 108,753,105	$ 30,509,915		$ 115,719,144	$ 32,464,188		$ 115,719,144	$ 32,464,188		$ 98,802,367	$ 27,718,306		$ 83,294,313	$ 23,367,631		$ 83,294,313	$ 23,367,631
44	30,509		$ 108,753,105	$ 29,621,277		$ 115,719,144	$ 31,518,630		$ 115,719,144	$ 31,518,630		$ 98,802,367	$ 26,910,977		$ 83,294,313	$ 22,687,021		$ 83,294,313	$ 22,687,021
45	29,621		$ 108,753,105	$ 28,758,521		$ 115,719,144	$ 30,600,611		$ 115,719,144	$ 30,600,611		$ 98,802,367	$ 26,127,162		$ 83,294,313	$ 22,026,234		$ 83,294,313	$ 22,026,234
46	28,758		$ 108,753,105	$ 27,920,894		$ 115,719,144	$ 29,709,331		$ 115,719,144	$ 29,709,331		$ 98,802,367	$ 25,366,177		$ 83,294,313	$ 21,384,693		$ 83,294,313	$ 21,384,693
47	27,920		$ 108,753,105	$ 27,107,665		$ 115,719,144	$ 28,844,011		$ 115,719,144	$ 28,844,011		$ 98,802,367	$ 24,627,356		$ 83,294,313	$ 20,761,838		$ 83,294,313	$ 20,761,838
48	27,107		$ 108,753,105	$ 26,318,121		$ 115,719,144	$ 28,003,894		$ 115,719,144	$ 28,003,894		$ 98,802,367	$ 23,910,054		$ 83,294,313	$ 20,157,124		$ 83,294,313	$ 20,157,124
49	26,318		$ 108,753,105	$ 25,551,574		$ 115,719,144	$ 27,188,247		$ 115,719,144	$ 27,188,247		$ 98,802,367	$ 23,213,645		$ 83,294,313	$ 19,570,023		$ 83,294,313	$ 19,570,023
50	25,551		$ 108,753,105	$ 24,807,353		$ 115,719,144	$ 26,396,356		$ 115,719,144	$ 26,396,356		$ 98,802,367	$ 22,537,519		$ 83,294,313	$ 19,000,023		$ 83,294,313	$ 19,000,023
51	24,807		$ 108,753,105	$ 24,084,809		$ 115,719,144	$ 25,627,530		$ 115,719,144	$ 25,627,530		$ 98,802,367	$ 21,881,087		$ 83,294,313	$ 18,446,624		$ 83,294,313	$ 18,446,624
52	24,084		$ 108,753,105	$ 23,383,310		$ 115,719,144	$ 24,881,097		$ 115,719,144	$ 24,881,097		$ 98,802,367	$ 21,243,774		$ 83,294,313	$ 17,909,344		$ 83,294,313	$ 17,909,344
53	23,383	$ 16,560,000		$ 3,456,905		$ 115,719,144	$ 24,156,405		$ 115,719,144	$ 24,156,405	$ 16,560,000		$ 3,456,905		$ 83,294,313	$ 17,387,712		$ 83,294,313	$ 17,387,712
54	22,702					$ 115,719,144	$ 23,452,820		$ 115,719,144	$ 23,452,820					$ 83,294,313	$ 16,881,274		$ 83,294,313	$ 16,881,274
55	22,041					$ 115,719,144	$ 22,769,729		$ 115,719,144	$ 22,769,729				$ 16,560,000		$ 3,258,464		$ 83,294,313	$ 16,389,586
56	21,399					$ 115,719,144	$ 22,106,533		$ 115,719,144	$ 22,106,533							$ 16,560,000		
57	20,775					$ 115,719,144	$ 21,462,653	$ 16,560,000		$ 3,071,415									
58	20,170					$ 115,719,144	$ 20,837,527												
59	19,583				$ 16,560,000														
Total PV costs				$4,126,682,337			$ 5,970,356,501			$ 5,871,073,353			$3,982,056,631			$ 5,148,482,785			$5,360,492,423
Unit cost				$ 1,519			$ 2,624			$ 2,432			$ 1,466			$ 2,011			$ 2,156

Table D.4.3 Life cycle cost analysis, 100 MGD facility, 3% discount rate, 50-year project life

		Low cost estimate									High cost estimate								
		Open Ocean			SIG Trestle			SIG Float-in			Open Ocean			SIG Trestle			SIG Float-in		
Year	PV water production	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total	Capital	O&M	PV total
0	112,014	$ 563,777,261		$ 563,777,261	$ 506,145,692		$ 506,145,692	$ 553,694,927		$ 553,694,927	$ 600,475,626		$ 600,475,626	$ 734,107,834		$ 734,107,834	$ 736,055,733		$ 736,055,733
1	104,686	$ 553,645,547		$ 517,425,745	$ 497,049,682		$ 464,532,413	$ 543,744,404		$ 508,172,340	$ 589,684,401		$ 551,106,917	$ 720,915,088		$ 673,752,419	$ 722,827,981		$ 675,540,170
2	97,837	$ 407,771,934		$ 356,163,799	$ 488,117,139		$ 426,340,413	$ 533,972,704		$ 466,392,439	$ 434,315,330		$ 379,347,830	$ 707,959,430		$ 618,359,184	$ 709,837,947		$ 619,999,954
3	91,437		$ 108,753,105	$ 88,774,928	$ 479,345,123		$ 391,288,406	$ 524,376,612		$ 428,047,515		$ 98,802,367	$ 80,652,163	$ 695,236,600		$ 567,520,161	$ 697,081,358		$ 569,026,033
4	85,455		$ 108,753,105	$ 82,967,223	$ 470,730,750		$ 359,118,236	$ 514,952,972		$ 392,855,157		$ 98,802,367	$ 75,375,853	$ 566,676,204		$ 432,314,563	$ 684,554,020		$ 522,242,984
5	79,864		$ 108,753,105	$ 77,539,461	$ 462,271,188		$ 329,592,968	$ 505,698,686		$ 360,556,174		$ 98,802,367	$ 70,444,722		$ 83,294,313	$ 59,387,694	$ 184,013,933		$ 131,199,391
6	74,640		$ 108,753,105	$ 72,466,786	$ 453,963,653		$ 302,495,150	$ 496,610,710		$ 330,912,685		$ 98,802,367	$ 65,836,189		$ 83,294,313	$ 55,502,518		$ 83,294,313	$ 55,502,518
7	69,757		$ 108,753,105	$ 67,725,968	$ 445,805,414		$ 277,625,206		$ 115,719,144	$ 72,064,067		$ 98,802,367	$ 61,529,149		$ 83,294,313	$ 51,871,512		$ 83,294,313	$ 51,871,512
8	65,193		$ 108,753,105	$ 63,295,297	$ 218,896,894		$ 127,399,985		$ 115,719,144	$ 67,349,595		$ 98,802,367	$ 57,503,877		$ 83,294,313	$ 48,478,049		$ 83,294,313	$ 48,478,049
9	60,928		$ 108,753,105	$ 59,154,483		$ 115,719,144	$ 62,943,547		$ 115,719,144	$ 62,943,547		$ 98,802,367	$ 53,741,941		$ 83,294,313	$ 45,306,588		$ 83,294,313	$ 45,306,588
10	56,942		$ 108,753,105	$ 55,284,564		$ 115,719,144	$ 58,825,745		$ 115,719,144	$ 58,825,745		$ 98,802,367	$ 50,226,113		$ 83,294,313	$ 42,342,605		$ 83,294,313	$ 42,342,605
11	53,217		$ 108,753,105	$ 51,667,817		$ 115,719,144	$ 54,977,332		$ 115,719,144	$ 54,977,332		$ 98,802,367	$ 46,940,293		$ 83,294,313	$ 39,572,528		$ 83,294,313	$ 39,572,528
12	49,736		$ 108,753,105	$ 48,287,679		$ 115,719,144	$ 51,380,684		$ 115,719,144	$ 51,380,684		$ 98,802,367	$ 43,869,433		$ 83,294,313	$ 36,983,671		$ 83,294,313	$ 36,983,671
13	46,482		$ 108,753,105	$ 45,128,672		$ 115,719,144	$ 48,019,331		$ 115,719,144	$ 48,019,331		$ 98,802,367	$ 40,999,470		$ 83,294,313	$ 34,564,179		$ 83,294,313	$ 34,564,179
14	43,441		$ 108,753,105	$ 42,176,329		$ 115,719,144	$ 44,877,879		$ 115,719,144	$ 44,877,879		$ 98,802,367	$ 38,317,262		$ 83,294,313	$ 32,302,971		$ 83,294,313	$ 32,302,971
15	40,599		$ 108,753,105	$ 39,417,130		$ 115,719,144	$ 41,941,943		$ 115,719,144	$ 41,941,943		$ 98,802,367	$ 35,810,525		$ 83,294,313	$ 30,189,692		$ 83,294,313	$ 30,189,692
16	37,943		$ 108,753,105	$ 36,838,439		$ 115,719,144	$ 39,198,078		$ 115,719,144	$ 39,198,078		$ 98,802,367	$ 33,467,780		$ 83,294,313	$ 28,214,666		$ 83,294,313	$ 28,214,666
17	35,461		$ 108,753,105	$ 34,428,448		$ 115,719,144	$ 36,633,718		$ 115,719,144	$ 36,633,718		$ 98,802,367	$ 31,278,299		$ 83,294,313	$ 26,368,846		$ 83,294,313	$ 26,368,846
18	33,141		$ 108,753,105	$ 32,176,119		$ 115,719,144	$ 34,237,119		$ 115,719,144	$ 34,237,119		$ 98,802,367	$ 29,232,055		$ 83,294,313	$ 24,643,782		$ 83,294,313	$ 24,643,782
19	30,973		$ 108,753,105	$ 30,071,140		$ 115,719,144	$ 31,997,308		$ 115,719,144	$ 31,997,308		$ 98,802,367	$ 27,319,678		$ 83,294,313	$ 23,031,572		$ 83,294,313	$ 23,031,572
20	28,947		$ 108,753,105	$ 28,103,869		$ 115,719,144	$ 29,904,026		$ 115,719,144	$ 29,904,026		$ 98,802,367	$ 25,532,409		$ 83,294,313	$ 21,524,833		$ 83,294,313	$ 21,524,833
21	27,053		$ 108,753,105	$ 26,265,298		$ 115,719,144	$ 27,947,688		$ 115,719,144	$ 27,947,688		$ 98,802,367	$ 23,862,065		$ 83,294,313	$ 20,116,667		$ 83,294,313	$ 20,116,667
22	25,283		$ 108,753,105	$ 24,547,007		$ 115,719,144	$ 26,119,334		$ 115,719,144	$ 26,119,334		$ 98,802,367	$ 22,300,995		$ 83,294,313	$ 18,800,623		$ 83,294,313	$ 18,800,623
23	23,629		$ 108,753,105	$ 22,941,128		$ 115,719,144	$ 24,410,593		$ 115,719,144	$ 24,410,593		$ 98,802,367	$ 20,842,051		$ 83,294,313	$ 17,570,676		$ 83,294,313	$ 17,570,676
24	22,083		$ 108,753,105	$ 21,440,307		$ 115,719,144	$ 22,813,638		$ 115,719,144	$ 22,813,638		$ 98,802,367	$ 19,478,553		$ 83,294,313	$ 16,421,192		$ 83,294,313	$ 16,421,192
25	20,638		$ 108,753,105	$ 20,037,670		$ 115,719,144	$ 21,321,157		$ 115,719,144	$ 21,321,157		$ 98,802,367	$ 18,204,255		$ 83,294,313	$ 15,346,909		$ 83,294,313	$ 15,346,909
26	19,288		$ 108,753,105	$ 18,726,794		$ 115,719,144	$ 19,926,315		$ 115,719,144	$ 19,926,315		$ 98,802,367	$ 17,013,322		$ 83,294,313	$ 14,342,905		$ 83,294,313	$ 14,342,905
27	18,026		$ 108,753,105	$ 17,501,677		$ 115,719,144	$ 18,622,724		$ 115,719,144	$ 18,622,724		$ 98,802,367	$ 15,900,301		$ 83,294,313	$ 13,404,584		$ 83,294,313	$ 13,404,584
28	16,847		$ 108,753,105	$ 16,356,708		$ 115,719,144	$ 17,404,415		$ 115,719,144	$ 17,404,415		$ 98,802,367	$ 14,860,095		$ 83,294,313	$ 12,527,649		$ 83,294,313	$ 12,527,649
29	15,745		$ 108,753,105	$ 15,286,643		$ 115,719,144	$ 16,265,809		$ 115,719,144	$ 16,265,809		$ 98,802,367	$ 13,887,939		$ 83,294,313	$ 11,708,083		$ 83,294,313	$ 11,708,083
30	14,715		$ 108,753,105	$ 14,286,582		$ 115,719,144	$ 15,201,690		$ 115,719,144	$ 15,201,690		$ 98,802,367	$ 12,979,382		$ 83,294,313	$ 10,942,134		$ 83,294,313	$ 10,942,134
31	13,752		$ 108,753,105	$ 13,351,946		$ 115,719,144	$ 14,207,187		$ 115,719,144	$ 14,207,187		$ 98,802,367	$ 12,130,264		$ 83,294,313	$ 10,226,293		$ 83,294,313	$ 10,226,293
32	12,853		$ 108,753,105	$ 12,478,454		$ 115,719,144	$ 13,277,745		$ 115,719,144	$ 13,277,745		$ 98,802,367	$ 11,336,695		$ 83,294,313	$ 9,557,283		$ 83,294,313	$ 9,557,283
33	12,012		$ 108,753,105	$ 11,662,106		$ 115,719,144	$ 12,409,108		$ 115,719,144	$ 12,409,108		$ 98,802,367	$ 10,595,042		$ 83,294,313	$ 8,932,041		$ 83,294,313	$ 8,932,041
34	11,226		$ 108,753,105	$ 10,899,165		$ 115,719,144	$ 11,597,297		$ 115,719,144	$ 11,597,297		$ 98,802,367	$ 9,901,909		$ 83,294,313	$ 8,347,701		$ 83,294,313	$ 8,347,701
35	10,492		$ 108,753,105	$ 10,186,135		$ 115,719,144	$ 10,838,595		$ 115,719,144	$ 10,838,595		$ 98,802,367	$ 9,254,120		$ 83,294,313	$ 7,801,590		$ 83,294,313	$ 7,801,590
36	9,805		$ 108,753,105	$ 9,519,753		$ 115,719,144	$ 10,129,528		$ 115,719,144	$ 10,129,528		$ 98,802,367	$ 8,648,710		$ 83,294,313	$ 7,291,206		$ 83,294,313	$ 7,291,206
37	9,164		$ 108,753,105	$ 8,896,965		$ 115,719,144	$ 9,466,849		$ 115,719,144	$ 9,466,849		$ 98,802,367	$ 8,082,907		$ 83,294,313	$ 6,814,211		$ 83,294,313	$ 6,814,211
38	8,564		$ 108,753,105	$ 8,314,921		$ 115,719,144	$ 8,847,522		$ 115,719,144	$ 8,847,522		$ 98,802,367	$ 7,554,119		$ 83,294,313	$ 6,368,422		$ 83,294,313	$ 6,368,422
39	8,004		$ 108,753,105	$ 7,770,954		$ 115,719,144	$ 8,268,712		$ 115,719,144	$ 8,268,712		$ 98,802,367	$ 7,059,924		$ 83,294,313	$ 5,951,796		$ 83,294,313	$ 5,951,796
40	7,480		$ 108,753,105	$ 7,262,574		$ 115,719,144	$ 7,727,769		$ 115,719,144	$ 7,727,769		$ 98,802,367	$ 6,598,060		$ 83,294,313	$ 5,562,426		$ 83,294,313	$ 5,562,426
41	6,991		$ 108,753,105	$ 6,787,452		$ 115,719,144	$ 7,222,214		$ 115,719,144	$ 7,222,214		$ 98,802,367	$ 6,166,411		$ 83,294,313	$ 5,198,529		$ 83,294,313	$ 5,198,529
42	6,534		$ 108,753,105	$ 6,343,413		$ 115,719,144	$ 6,749,732		$ 115,719,144	$ 6,749,732		$ 98,802,367	$ 5,763,001		$ 83,294,313	$ 4,858,438		$ 83,294,313	$ 4,858,438
43	6,106		$ 108,753,105	$ 5,928,424		$ 115,719,144	$ 6,308,161		$ 115,719,144	$ 6,308,161		$ 98,802,367	$ 5,385,982		$ 83,294,313	$ 4,540,597		$ 83,294,313	$ 4,540,597
44	5,707		$ 108,753,105	$ 5,540,583		$ 115,719,144	$ 5,895,478		$ 115,719,144	$ 5,895,478		$ 98,802,367	$ 5,033,628		$ 83,294,313	$ 4,243,548		$ 83,294,313	$ 4,243,548
45	5,333		$ 108,753,105	$ 5,178,115		$ 115,719,144	$ 5,509,792		$ 115,719,144	$ 5,509,792		$ 98,802,367	$ 4,704,325		$ 83,294,313	$ 3,965,933		$ 83,294,313	$ 3,965,933
46	4,984		$ 108,753,105	$ 4,839,360		$ 115,719,144	$ 5,149,338		$ 115,719,144	$ 5,149,338		$ 98,802,367	$ 4,396,566		$ 83,294,313	$ 3,706,479		$ 83,294,313	$ 3,706,479
47	4,658		$ 108,753,105	$ 4,522,766		$ 115,719,144	$ 4,812,466		$ 115,719,144	$ 4,812,466		$ 98,802,367	$ 4,108,940		$ 83,294,313	$ 3,463,999		$ 83,294,313	$ 3,463,999
48	4,354		$ 108,753,105	$ 4,226,884		$ 115,719,144	$ 4,497,632		$ 115,719,144	$ 4,497,632		$ 98,802,367	$ 3,840,131		$ 83,294,313	$ 3,237,383		$ 83,294,313	$ 3,237,383
49	4,069		$ 108,753,105	$ 3,950,359		$ 115,719,144	$ 4,203,394		$ 115,719,144	$ 4,203,394		$ 98,802,367	$ 3,588,907		$ 83,294,313	$ 3,025,591		$ 83,294,313	$ 3,025,591
50	3,803		$ 108,753,105	$ 3,691,924		$ 115,719,144	$ 3,928,406		$ 115,719,144	$ 3,928,406		$ 98,802,367	$ 3,354,119		$ 83,294,313	$ 2,827,655		$ 83,294,313	$ 2,827,655
51	3,554		$ 108,753,105	$ 3,450,396		$ 115,719,144	$ 3,671,407		$ 115,719,144	$ 3,671,407		$ 98,802,367	$ 3,134,691		$ 83,294,313	$ 2,642,669		$ 83,294,313	$ 2,642,669
52	3,321		$ 108,753,105	$ 3,224,670		$ 115,719,144	$ 3,431,222		$ 115,719,144	$ 3,431,222		$ 98,802,367	$ 2,929,617		$ 83,294,313	$ 2,469,784		$ 83,294,313	$ 2,469,784
53	3,104	$ 16,560,000		$ 458,902		$ 115,719,144	$ 3,206,749		$ 115,719,144	$ 3,206,749	$ 16,560,000		$ 458,902		$ 83,294,313	$ 2,308,209		$ 83,294,313	$ 2,308,209
54	2,901					$ 115,719,144	$ 2,996,962		$ 115,719,144	$ 2,996,962					$ 83,294,313	$ 2,157,205		$ 83,294,313	$ 2,157,205
55	2,711					$ 115,719,144	$ 2,800,899		$ 115,719,144	$ 2,800,899				$ 16,560,000		$ 400,823		$ 83,294,313	$ 2,016,079
56	2,534					$ 115,719,144	$ 2,617,663		$ 115,719,144	$ 2,617,663							$ 16,560,000		
57	2,368					$ 115,719,144	$ 2,446,414	$ 16,560,000		$ 350,094									
58	2,213					$ 115,719,144	$ 2,286,368												
59	2,068				$ 16,560,000														
Total PV costs				$ 2,748,747,190			$ 4,114,013,149			$ 4,105,136,893			$ 2,722,363,512			$ 3,903,421,100			$ 4,073,658,766
Unit cost				$ 2,036			$ 4,573			$ 3,985			$ 2,016			$ 3,310			$ 3,696

Table D.4.4 Life cycle cost analysis, 100 MGD facility, 7% discount rate, 50-year project life

APPENDIX E: Data Related to OCWD Willingness to Pay

Appendix E provides the background data and assumptions we used to estimate OCWD willingness to pay (WTP) for water from the desalination facility in the future. As described in the main report, per the current term sheet, OCWD has indicated that it would be willing to pay an amount equal to the price of MWD water, plus a reliability premium and the amount of MWD's local water supply subsidy. Thus, to estimate WTP we first estimated future MWD rat based on established forecasts developed by MWD. The base rate that MWD charges for treate water (Tier 1 rate) is currently (2015) $1,081 per acre-foot. In recent history, the Tier 1 rate ha increased between 1% and 5% annually in real dollars. As shown in Table B-1, in this analysis, we assume the Tier 1 rate will increase in the near future as it has in the recent past, by 3.3% between 2015 and 2025, on average. We then assume the annual rate of increase will drop bac to 3% per year starting in 2025.

In addition to the MWD rates, OCWD has indicated that it is willing to pay a reliability premiu for locally produced water. Consistent with our understanding of the ongoing contract discussions, in our projections we assume that the reliability premium amounts to 20% of MWD's Tier 1 water price for 10 years after construction. The premium drops to 15% of the T 1 price for the next ten years, to 10% for 10 more years, to 5% for ten years, and then finally to 0%. For this analysis, we assume that the reliability premium kicks in as the facility comes onli - around 2020 (although in reality this will differ by alternative).

In addition, MWD currently provides a subsidy to communities that develop local water suppli (including desalination) to offset reliance on MWD water. We assume that MWD will continue provide this subsidy into the future. The subsidy varies according to the unit cost of the local supplies that are developed. There are currently three subsidy options that may be available to OCWD, including a sliding scale of up to $340/AF for 25 years, a sliding scale for up to $475/ for 15 years and a fixed $305/AF for 25 years. OCWD's current term sheet is based on the second option, a maximum of $475 per AF for up to 15 years, provided that the cost of the loca supply exceeds MWD rates by this amount.

Table E.1 shows what the subsidy would be in any given year of the analysis, based on the average cost of each intake option. The table shows more than 15 years of the subsidy because year that the subsidy runs out will depend on when the project actually comes online.

Based on these assumptions, the final columns in Table B-1 show OCWD's WTP for water fro a desalination facility with the different intake options. Uncertainty surrounding these estimate include uncertainty regarding the rate at which MWD prices will increase in the future, as well the actual unit cost of the desalination facility with different intake options. As unit costs chang the subsidy that MWD provides may also change, depending on how close it is to the project MWD rate.

						Amount over/below MWD rate			Subsidy (only available for 15 years following construction)			**Willingess to pay (MWD cost+reliability premium+subsidy)**		
		MWD rates - Tier 1 Treated	Forecasted increase	Reliability premium per current term sheet	MWD rate w/reliability premium	Open Ocean	SIG Trestle	SIG Float-in	Open Ocean	SIG Trestle	SIG Float - in	Open Ocean	SIG Trestle	SIG Float-in
1	2015	$1,081		0%	$1,081.00	906.31	2,518.13	2,453.75	$ 475	$ 475	$ 475	$1,556.00	$1,556.00	$1,556.00
2	2016	$1,103	2.1%	0%	$1,103.25	884.06	2,495.87	2,431.50	$ 475	$ 475	$ 475	$1,578.25	$1,578.25	$1,578.25
3	2017	$1,140	3.3%	0%	$1,139.56	847.75	2,459.57	2,395.19	$ 475	$ 475	$ 475	$1,614.56	$1,614.56	$1,614.56
4	2018	$1,170	2.7%	0%	$1,170.01	817.30	2,429.12	2,364.74	$ 475	$ 475	$ 475	$1,645.01	$1,645.01	$1,645.01
5	2019	$1,203	2.8%	0%	$1,202.80	784.51	2,396.32	2,331.95	$ 475	$ 475	$ 475	$1,677.80	$1,677.80	$1,677.80
6	2020	$1,252	4.1%	20%	$1,502.39	735.32	2,347.13	2,282.76	$ 475	$ 475	$ 475	$1,977.39	$1,977.39	$1,977.39
7	2021	$1,298	3.6%	20%	$1,557.20	689.64	2,301.46	2,237.08	$ 475	$ 475	$ 475	$2,032.20	$2,032.20	$2,032.20
8	2022	$1,342	3.4%	20%	$1,610.61	645.14	2,256.95	2,192.58	$ 475	$ 475	$ 475	$2,085.61	$2,085.61	$2,085.61
9	2023	$1,391	3.7%	20%	$1,669.64	595.95	2,207.76	2,143.39	$ 475	$ 475	$ 475	$2,144.64	$2,144.64	$2,144.64
10	2024	$1,444	3.8%	20%	$1,732.88	543.25	2,155.06	2,090.68	$ 475	$ 475	$ 475	$2,207.88	$2,207.88	$2,207.88
11	2025	$1,487	3.0%	20%	$1,784.87	499.92	2,111.74	2,047.36	$ 475	$ 475	$ 475	$2,259.87	$2,259.87	$2,259.87
12	2026	$1,532	3.0%	20%	$1,838.41	455.30	2,067.12	2,002.74	$ 455	$ 475	$ 475	$2,293.71	$2,313.41	$2,313.41
13	2027	$1,578	3.0%	20%	$1,893.56	409.34	2,021.15	1,956.78	$ 409	$ 475	$ 475	$2,302.91	$2,368.56	$2,368.56
14	2028	$1,625	3.0%	20%	$1,950.37	362.00	1,973.82	1,909.44	$ 362	$ 475	$ 475	$2,312.37	$2,425.37	$2,425.37
15	2029	$1,674	3.0%	20%	$2,008.88	313.24	1,925.06	1,860.68	$ 313	$ 475	$ 475	$2,322.13	$2,483.88	$2,483.88
16	2030	$1,724	3.0%	15%	$1,982.93	263.02	1,874.83	1,810.46	$ 263	$ 475	$ 475	$2,245.96	$2,457.93	$2,457.93
17	2031	$1,776	3.0%	15%	$2,042.42	211.29	1,823.11	1,758.73	$ 211	$ 475	$ 475	$2,253.72	$2,517.42	$2,517.42
18	2032	$1,829	3.0%	15%	$2,103.69	158.01	1,769.83	1,705.45	$ 158	$ 475	$ 475	$2,261.71	$2,578.69	$2,578.69
19	2033	$1,884	3.0%	15%	$2,166.81	103.13	1,714.95	1,650.57	$ 103	$ 475	$ 475	$2,269.94	$2,641.81	$2,641.81
20	2034	$1,941	3.0%	15%	$2,231.81	46.61	1,658.42	1,594.05	$ 47	$ 475	$ 475	$2,278.42	$2,706.81	$2,706.81
21	2035	$1,999	3.0%	15%	$2,298.76	(11.61)	1,600.20	1,535.82	$ -	$ 475	$ 475	$2,298.76	$2,773.76	$2,773.76
22	2036	$2,059	3.0%	15%	$2,367.73	(71.58)	1,540.23	1,475.86	$ -	$ 475	$ 475	$2,367.73	$2,842.73	$2,842.73
23	2037	$2,121	3.0%	15%	$2,438.76	(133.35)	1,478.47	1,414.09	$ -	$ 475	$ 475	$2,438.76	$2,913.76	$2,913.76
24	2038	$2,184	3.0%	15%	$2,511.92	(196.97)	1,414.85	1,350.47	$ -	$ 475	$ 475	$2,511.92	$2,986.92	$2,986.92
25	2039	$2,250	3.0%	15%	$2,587.28	(262.50)	1,349.32	1,284.94	$ -	$ 475	$ 475	$2,587.28	$3,062.28	$3,062.28
26	2040	$2,317	3.0%	10%	$2,549.03	(329.99)	1,281.82	1,217.45	$ -	$ 475	$ 475	$2,549.03	$3,024.03	$3,024.03
27	2041	$2,387	3.0%	10%	$2,625.50	(399.51)	1,212.30	1,147.93	$ -	$ 475	$ 475	$2,625.50	$3,100.50	$3,100.50
28	2042	$2,458	3.0%	10%	$2,704.27	(471.11)	1,140.70	1,076.32	$ -	$ 475	$ 475	$2,704.27	$3,179.27	$3,179.27
29	2043	$2,532	3.0%	10%	$2,785.40	(544.87)	1,066.95	1,002.57	$ -	$ 475	$ 475	$2,785.40	$3,260.40	$3,260.40
30	2044	$2,608	3.0%	10%	$2,868.96	(620.83)	990.98	926.61	$ -	$ 475	$ 475	$2,868.96	$3,343.96	$3,343.96
31	2045	$2,686	3.0%	10%	$2,955.03	(699.08)	912.74	848.36	$ -	$ 475	$ 475	$2,955.03	$3,430.03	$3,430.03
32	2046	$2,767	3.0%	10%	$3,043.68	(779.67)	832.15	767.77	$ -	$ 475	$ 475	$3,043.68	$3,518.68	$3,518.68
33	2047	$2,850	3.0%	10%	$3,134.99	(862.68)	749.14	684.76	$ -	$ 475	$ 475	$3,134.99	$3,609.99	$3,609.99
34	2048	$2,935	3.0%	10%	$3,229.04	(948.18)	663.64	599.26	$ -	$ 475	$ 475	$3,229.04	$3,704.04	$3,704.04
35	2049	$3,024	3.0%	10%	$3,325.91	(1,036.24)	575.57	511.20	$ -	$ 475	$ 475	$3,325.91	$3,800.91	$3,800.91
36	2050	$3,114	3.0%	5%	$3,269.97	(1,126.95)	484.86	420.49	$ -	$ 475	$ 420	$3,269.97	$3,744.97	$3,690.46
37	2051	$3,208	3.0%	5%	$3,368.07	(1,220.38)	391.44	327.06	$ -	$ 391	$ 327	$3,368.07	$3,759.51	$3,695.13
38	2052	$3,304	3.0%	5%	$3,469.11	(1,316.61)	295.21	230.83	$ -	$ 295	$ 231	$3,469.11	$3,764.32	$3,699.95
39	2053	$3,403	3.0%	5%	$3,573.19	(1,415.72)	196.09	131.71	$ -	$ 196	$ 132	$3,573.19	$3,769.28	$3,704.90
40	2054	$3,505	3.0%	5%	$3,680.38	(1,517.81)	94.00	29.62	$ -	$ 94	$ 30	$3,680.38	$3,774.38	$3,710.01
41	2055	$3,610	3.0%	5%	$3,790.80	(1,622.97)	(11.16)	(75.53)	$ -	$ -	$ -	$3,790.80	$3,790.80	$3,790.80
42	2056	$3,719	3.0%	5%	$3,904.52	(1,731.28)	(119.46)	(183.84)	$ -	$ -	$ -	$3,904.52	$3,904.52	$3,904.52
43	2057	$3,830	3.0%	5%	$4,021.65	(1,842.83)	(231.02)	(295.40)	$ -	$ -	$ -	$4,021.65	$4,021.65	$4,021.65
44	2058	$3,945	3.0%	5%	$4,142.30	(1,957.74)	(345.93)	(410.30)	$ -	$ -	$ -	$4,142.30	$4,142.30	$4,142.30
45	2059	$4,063	3.0%	5%	$4,266.57	(2,076.09)	(464.28)	(528.65)	$ -	$ -	$ -	$4,266.57	$4,266.57	$4,266.57
46	2060	$4,185	3.0%	0%	$4,185.31	(2,197.99)	(586.18)	(650.56)	$ -	$ -	$ -	$4,185.31	$4,185.31	$4,185.31
47	2061	$4,311	3.0%	0%	$4,310.86	(2,323.55)	(711.74)	(776.11)	$ -	$ -	$ -	$4,310.86	$4,310.86	$4,310.86
48	2062	$4,440	3.0%	0%	$4,440.19	(2,452.88)	(841.07)	(905.44)	$ -	$ -	$ -	$4,440.19	$4,440.19	$4,440.19
49	2063	$4,573	3.0%	0%	$4,573.40	(2,586.08)	(974.27)	(1,038.65)	$ -	$ -	$ -	$4,573.40	$4,573.40	$4,573.40
50	2064	$4,711	3.0%	0%	$4,710.60	(2,723.29)	(1,111.47)	(1,175.85)	$ -	$ -	$ -	$4,710.60	$4,710.60	$4,710.60
51	2065	$4,852	3.0%	0%	$4,851.92	(2,864.60)	(1,252.79)	(1,317.17)	$ -	$ -	$ -	$4,851.92	$4,851.92	$4,851.92
52	2066	$4,997	3.0%	0%	$4,997.47	(3,010.16)	(1,398.35)	(1,462.72)	$ -	$ -	$ -	$4,997.47	$4,997.47	$4,997.47
53	2067	$5,147	3.0%	0%	$5,147.40	(3,160.09)	(1,548.27)	(1,612.65)	$ -	$ -	$ -	$5,147.40	$5,147.40	$5,147.40
54	2068	$5,302	3.0%	0%	$5,301.82	(3,314.51)	(1,702.69)	(1,767.07)	$ -	$ -	$ -	$5,301.82	$5,301.82	$5,301.82
55	2069	$5,461	3.0%	0%	$5,460.87	(3,473.56)	(1,861.75)	(1,926.12)	$ -	$ -	$ -	$5,460.87	$5,460.87	$5,460.87

Table E.1 Assumptions and inputs used to estimate OCWD WTP

APPENDIX F: Sensitive Plants and Animals in the Huntington Beach Wetland Area

Table F.1 Sensitive species known from the vicinity with potential to occur in the Huntington Beach Wetland complex

Species	**Common Name**
Plants	
Aphanisma blitoides	Aphanisma
Atriplex coulteri	Coulter's Saltbush
Atriplex pacifica	South Coast Saltscale
Atriplex serenana var. davidsonii	Davidson's Saltscale
Astragalus pycnostachyus var. lanosissimus	Ventura Marsh Milk-vetch
Centromadia parryi ssp. Australis	Southern Tarplant
Cordylanthus maritimus ssp. maritimus	Salt Marsh Bird's-beak
Juncus acutus ssp. leopoldii	Southwestern Spiny Rush
Lasthenia glabrata ssp. coulteri	Coulter's Goldfields
Nemacaulis denudata var. denudata	Coast Woolly-Heads
Nama stenocarpum	Mud Nama
Navarretia prostrata	Prostrate
Navarretia Suaeda esteroa	Estuary Seablite
Animals	
Athene cunicularia	Burrowing Owl
Charadrius alexandrinus nivosus	Western Snowy Plover
Cicindela gabbi	Gabb's Tiger Beetle
Panoquina errans	Salt Marsh Skipper
Passerculus sandwichensis beldingi	Belding's Savannah Sparrow
Pelecanus occidentalis	California Brown Pelican
Rallus longirostris levipes	Light-footed Clapper Rail
Sterna antillarum browni	California Least Tern
Trigonoscuta dorothea dorothea	Dorothy's El Segundo Dune Weevil
Tryonia imitator	Mimic Tryonia (California Brackish Water Snail)

Source: Merkel & Associates, 2004