APPENDIX K

Participants Comment Letter
Attachment B through Attachment K

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Attachment B

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
Hazardous and Radiological Materials						
HAZ-1: Release of Hazardous Radioactive Materials during Decommissioning and Disposal	**APM-1: Waste Management Program.** The Applicant ~~and/~~or its contractor shall prepare and implement a Waste Management Program prior to the start of Proposed Project waste shipment activities ~~decommissioning~~. The Program shall be submitted to California State Lands Commission staff at least 60 days prior to the commencement of Proposed Project waste shipment activities. The Program shall include, but not be limited to the following: • Processes for identification, characterization, handling, transport, and disposal of the various radiological and non-radiological waste types • Training for waste management personnel • Procedures for documentation of all shipments in accordance with applicable regulations established by the appropriate governing agencies (e.g., Nuclear Regulatory Commission or California Department of Toxic Substances Control) for various radiological and non-radiological waste types Specifications that the Program shall only use qualified and permitted waste disposal carriers and disposal facilities licensed for the specific waste stream to be transported.	Onshore/ Offshore	Compliance	Prior to the start of Proposed Project waste shipment activities ~~and during decommissioning~~	Applicant or contractor	Reduce impacts related to waste disposal

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	APM-4: Dust Suppression. During Proposed Project activities, disturbed Project area surfaces, including unpaved access roads, shall be effectively stabilized of dust emissions (e.g., watered, covered, stabilized, or treated with a dust suppressant), consistent with the Storm Water Pollution and Prevention Plan.	Onshore	Compliance with SWPPP as determined by San Diego RWQCB	During Proposed Project ~~decommissioning~~ activities	Applicant ~~and~~/or contractor	Reduce impacts associated with air quality
	APM-12: Stormwater Pollution Prevention Plan (SWPPP). The Applicant ~~and~~/or its contractor shall obtain coverage for the Proposed Project under the Construction General Permit (Order No. 2009-009-DWQ, as amended by 2010-0014-DWQ and 2012-006-DWQ). Per the requirements of the California State Water Resources Control Board (SWRCB), the Applicant ~~and~~/or its contractor shall prepare a SWPPP to reduce the potential for water pollution and sedimentation from Proposed Project activities. The SWPPP will be project specific and expressly address site runoff, assuring that project runoff would not affect or alter drainage patterns to sensitive habitat, including but not limited to vernal pool habitat. The SWPPP shall set forth a best management practices including, but not limited to the following: • Silt fences, fiber rolls, and other measures shall be placed where they are	Onshore	Notification to CSLC staff that the SWPPP has been certified	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant ~~and~~/or contractor	Reduce impacts associated with water quality

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	determined to be appropriate for erosion and sediment control. • A monitoring, maintenance, and reporting schedule shall be prepared and implemented and shall identify the responsible entities. The Applicant ~~and~~/or its contractor shall notify California State Lands Commission staff that the SWPPP has been certified and is available in the SWRCB's Stormwater Multiple Applications and Reports Tracking System not less than 30~~60~~ days prior to commencement of ground disturbing activities.					
	APM-13: Spill Prevention Control and Countermeasure (SPCC) Plan. The Applicant ~~and~~/or its contractor shall continue compliance with the requirements of the U.S. Environmental Protection Agency (U.S. EPA; 40 CFR Part 112) through continued use of the existing SONGS SPCC Plan, including amendments as required. The SPCC is certified by a licensed professional engineer and then provided to the U.S. EPA's Regional Administrator (San Diego County Department of Environmental Health, Hazardous Materials Division). The SPCC Plan shall continue to include, but is not and shall not be limited to the following: • A facility description	Onshore	Submittal of initial ~~C~~certified SPCC Plan for the Proposed Project to CSLC staff ~~for consultation, review and approval.~~	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant ~~and~~/or contractor	Reduce impacts associated with water quality

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	• A complete list of all oil storage containers (aboveground containers and completely buried tanks) with a capacity of 55 U.S. gallons or more. • A description of tanks and containers with the potential for an oil discharge; mode of failure, flow direction and potential quantity of the discharge; and the secondary containment method and containment capacity provided • A description of the inspection or testing program for all aboveground bulk storage containers including record-keeping of these inspections or tests • A requirement for training of oil-handling personnel in the operation and • maintenance of equipment to prevent discharges; discharge procedure protocols; applicable pollution control laws, rules and regulations; general facility operations; and the contents of the SPCC Plan • A requirement for annual discharge prevention briefings conducted for all oil-handling personnel. Briefings would highlight and describe past reportable discharges or failures, malfunctioning components, and any recently developed precautionary measures					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	• Implementation of security measures to prevent unauthorized access to oil handling and/or storage area(s) • A description of immediate actions to be taken by facility personnel in the event of a discharge to navigable waters or adjoining shorelines The Applicant shall submit the initial certified Plan to California State Lands Commission (CSLC) staff for review ~~and approval by CSLC staff,~~ in consultation with the U.S. EPA and California Coastal Commission staffs, not less than 30 days prior to commencement of Proposed Project activities. In accordance with regulatory requirements, the SPCC Plan and any subsequent updates will be maintained onsite throughout the Proposed Project for review.					
	APM-14: Spill Contingency Plan. The Applicant ~~and~~/or its contractor shall maintain compliance with the requirements of the U.S. Environmental Protection Agency (40 CFR Part 112) through implementation of the existing Spill Prevention Control and Countermeasure Plan, including amendments if required, that describes the actions facility personnel shall take in response to hazards to human health or the environment from fires, explosions, or any unplanned sudden or non-sudden release of	Onshore	Submittal of initial Spill Contingency Plan for the Proposed Project to CSLC staff ~~for consultation, review, and approval~~	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant ~~and~~/or contractor	Reduce impacts associated with water quality

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	hazardous waste or hazardous waste constituents to air, soil, or surface water during the Proposed Project. At a minimum, the Spill Contingency Plan shall include: • A description of all arrangements agreed to by local police departments, local and federal fire departments, hospitals, contractors, and state and local emergency response teams to coordinate emergency services • Names, addresses, and phone numbers (office and home) of all persons designated to act as primary and alternate emergency coordinators • A list of all emergency equipment at the facility (such as fire extinguishing systems, spill control equipment, communications and alarm systems (internal and external), and decontamination equipment), as required, as well as the location and a physical description of each item on the list, and a brief outline of its capabilities • An evacuation plan that includes evacuation procedures and instructions, as well as primary and alternate evacuation route • Procedures to be followed for notification and reporting of hazardous releases • The current telephone number of the State Office of Emergency Services					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	The Applicant shall submit the initial Plan to California State Lands Commission (CSLC) staff, for review and approval by CSLC staff in consultation with the Regional Water Quality Control Board and California Coastal Commission staffs, not less than 30 days prior to commencement of Proposed Project activities. In accordance with regulatory requirements, the Spill Contingency Plan and any subsequent updates will be maintained onsite throughout the Proposed Project for review.					
HAZ-4: Handling of Non- Radiological Hazardous Wastes	**MM HAZ-4: Facility Hazardous Waste Permit Extension.** The Applicant ~~and~~/or its contractor shall coordinate with the California Department of Toxic Substances Control to ~~add all decommissioning activities to the existing facility permit and~~ obtain time extensions or amendments to the Hazardous Waste Facility Permit as necessary ~~until all regulated waste is removed from the site~~. A copy of the Hazardous Waste Permit Extension shall be provided to the California State Lands Commission 2 weeks prior to the ~~start of decommissioning activities~~ expiration of the existing Hazardous Waste Facility Permit.	Onshore and Offshore	Copy of permit extension to CSLC staff	Two weeks prior to the expiration of the existing hazardous waste facilities permit ~~Prior to decommissioning activities~~	Applicant ~~and~~/or contractor	Reduce impacts associated with hazardous wastes.
	Implement APM-1 (provided above)					
	APM-2: Hazardous Materials Business Plan (HMBP). The existing HMBP shall continue to be updated as required by law	Onshore	Certified HMBP Plan to CSLC staff	Prior to and during Proposed Project	Applicant ~~and~~/or contractor	Reduce impacts associated with water quality

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	and as prescribed by the County of San Diego, Department of Environmental Health, Hazardous Materials Division (County HMD), but not less than annually. The Plan shall include: • A detailed hazardous materials inventory for the site • Emergency contacts, a site plan, and response strategies • Procedures for on-site refueling (refueling stations and fuel tanks locations, maintenance, and operation The HMBP shall be uploaded to the California Environmental Reporting System per County HMD requirements, and the certified document submitted to California State Lands Commission staff at least 30 days prior to the commencement of Proposed Project decontamination and dismantlement activities and annually thereafter while Proposed Project activities are occurring.			~~decommissioning~~ activities		
HAZ-5: Risk of Fire, Explosion, or Hazardous Material Release	**MM HAZ-5: Worker Registration/ Certification.** The Applicant ~~and/~~or its contractor shall require workers ~~to have the required registrations to~~ removeing asbestos, lead-based paint, and other hazardous materials to have the required registrations. The Applicant shall submit a list of all workers with certification records to California State Lands Commission staff ~~60 days~~ prior to the implementation of	Onshore and Offshore	Worker certifications to CSLC staff	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant ~~and/~~or contractor	Reduce impacts associated with hazardous wastes.

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	applicable activities, and once every 60 days thereafter, as long as the work requiring such certifications is occurring ~~start of demolition~~.					
	Implement APM-1, APM-12, APM-13, and APM-14 (provided above)					
HAZ-6: Mobilization of Existing Contaminants	**MM HAZ-6: Soil and Groundwater Site Characterization ~~Study~~ and Soil Management Plan.** The Applicant or its contractor shall prepare a comprehensive Site Characterization ~~Study~~ and Soil Management Plan for non-radiological contamination testing, which shall include: • Subsurface soil and groundwater sampling, after site safety constraints have been addressed (i.e., underground utilities deactivated or removed) • An investigation work plan, including boring and sampling locations, to investigate where known and suspected soil and groundwater contamination may be present • Identification of the limits of contamination based on the results of the soil and groundwater testing, and procedures to protect workers during excavation, handling, and disposal of materials exceeding regulatory limits • A Soil Management Plan for the identification and disposal of potentially contaminated soil, which shall: ○ Consider that some contaminated soil may be present outside the limits	Onshore	Compliance. ~~Study and Plan to CSLC staff for review.~~ ~~Monthly~~ Quarterly soil sampling ~~monitoring~~ reports to County of San Diego, Dept. of Environmental Health, Hazardous Materials Division.	Prior to the start of and during ground-disturbing ~~decommissioning~~ activities	Applicant or contractor	Reduce mobilization of contaminants

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	identified in the soil characterization study ○ Include the required qualifications for professionals who shall monitor soil conditions, conduct soil sampling, coordinate laboratory testing, oversee soil excavation and disposal, determine the anticipated field screening methods, and appropriate regulatory limits ○ Contain requirements for documentation and reporting of incidents of encountered contaminants, such as documenting locations of occurrence, sampling results, and reporting actions taken to remediate non-radiological contaminated materials The Applicant or its contractor shall submit the ~~Study and~~ Plan to California State Lands Commission staff a minimum of 60 days prior to ~~decommissioning~~ the start of ground-disturbing activities, for review. In addition, ~~monthly~~ quarterly soil ~~monitoring~~ sampling reports shall be submitted to the County of San Diego, Department of Environmental Health, Hazardous Materials Division.					
Air Quality						
AQ-3: Result in a Cumulatively Considerable Net	**MM AQ-3a. Off-Road Equipment Emissions Control.** Off-road diesel-fueled equipment, not including locomotive and	Onshore	Compliance	During Proposed Project	Applicant ~~and~~/or contractor	Reduce impacts

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
Increase of Any Criteria Air Pollutant for which the Project Region is in Nonattainment	marine vessel engines, with engines larger than 50 horsepower shall have engines that meet or exceed U.S. Environmental Protection Agency/California Air Resources Board full Tier 4 emissions standards. This includes Project-related off-road equipment operating at the SONGS site and the Project-related equipment operating at the Port of Long Beach/Los Angeles. Exceptions shall be allowed only on a case-by-case basis for three specific situations: (1) interim Tier 4 equipment shall be allowed in place of full Tier 4 equipment through the end of calendar year 2020; (2) off-road equipment items that are a specialty, or unique, piece of equipment that cannot be found with a Tier 4 or better engine after a due diligence search that includes contacting at least three relevant equipment rental firms; and (3) an off-road equipment item that shall be used for a total of no more than 10 days. Additionally, all engines shall be maintained in good operating condition and in tune per manufacturers' specification.			~~decommissioning~~ activities		associated with air quality
	MM AQ-3b. Marine Vessel Emissions Control. The Applicant or its contractor shall ensure that diesel-fueled marine vessel engines (37 kilowatt or larger) meet or exceed U.S. Environmental Protection Agency Tier 2 emissions standards.	Offshore	Compliance	During Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce impacts associated with air quality

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	APM-3: Vehicle Emission Reductions. The Applicant ~~and~~/or its contractor shall, employ vehicle emissions reduction measures which could include, but are not limited to: the use of newer model engines (model year 2010 and newer), low emissions diesel products, alternative fuels, engine retrofit technology, after-treatment products, or other similar available options. The following exceptions apply: • This measure does not apply to any gasoline-fueled or other alternatively fueled heavy-duty haul trucks, but does apply to trucks using other types of fuel such as diesel. • This measure does not apply to the trucks used to haul radioactive Class B or C decommissioning wastes.	Onshore	Compliance	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant ~~and~~/or contractor	Reduce impacts associated with air quality
AQ-4: Expose Sensitive Receptors to Substantial Pollutant Concentrations	**Implement MM AQ-3a and MM AQ-3b and APM-3 (see above)**					
	APM-4: Dust Suppression. During Proposed Project activities, disturbed Project area surfaces, including unpaved access roads, shall be effectively stabilized of dust emissions (e.g., watered, covered, stabilized, or treated with a dust suppressant), consistent with the Storm Water Pollution and Prevention Plan.	Onshore	Compliance with SWPPP as determined by San Diego RWQCB	During Proposed Project decommissioning activities	Applicant ~~and~~/or contractor	Reduce impacts associated with air quality
	APM-5: Vehicle Speeds. Decommissioning crew vehicle speeds on unpaved roadways shall be restricted to 15 miles per hour or	Onshore	Compliance	Prior to and during Proposed Project	Applicant ~~and~~/or contractor	Reduce impacts associated with air quality

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	less, in accordance with SONGS procedures.			~~decommissioning~~ activities		
	APM-6: Track-Out to Public Streets. Gravel or track-out control devices, such as shaker plates, shall be installed at the points of egress from the unpaved or disturbed surfaces, consistent with the Storm Water Pollution and Prevention Plan.	Onshore	Compliance with SWPPP as determined by San Diego RWQCB	~~Prior to and~~ ~~d~~During ~~decommissioning~~ Proposed Project activities	Applicant ~~and~~/or contractor	Reduce impacts associated with air quality
	APM-7: Tarping Trucks. Consistent with the Storm Water Pollution and Prevention Plan, haul trucks transporting material with potential to generate fugitive dust emissions to and from the site shall be tarped from the point of origin until point of delivery. For trucks that cannot be tarped, the Applicant ~~and~~/or its contractor shall stabilize material while loading to reduce fugitive dust emissions; maintain at least 6 inches of freeboard on haul vehicles; and, stabilize material while transporting.	Onshore	Compliance with SWPPP as determined by San Diego RWQCB	~~Prior to and~~ ~~d~~During ~~decommissioning~~ Proposed Project activities	Applicant ~~and~~/or contractor	Reduce impacts associated with air quality
Biological Resources						
BIO-1: Contribute to the Loss and Degradation of Sensitive Habitat	**MM BIO-1a: Worker Environmental Awareness Program.** A Worker Environmental Awareness Program (WEAP) shall be developed and provided to California State Lands Commission (CSLC) staff for review and approval at least 60 days prior to Proposed Project implementation. The WEAP shall include:	Onshore	Provide WEAP to CSLC staff for review and approval and evidence of training attendance	Prior to ~~decommissioning~~ ground-disturbing activities	Applicant ~~and~~/or contractor	Reduce impacts to wildlife and special-status species

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	• A CSLC-approved biologist to conduct the training who is qualified to discuss both potential onshore and offshore species • A discussion of all sensitive species that may be encountered adjacent to and at the Proposed Project site, the laws and codes that regulate these species, and the protection measures that must be followed to avoid and minimize impacts • The process of reporting any dead or injured special-status wildlife species found at the Proposed Project site, including notification to the CSLC and applicable agencies ~~Prior to Project implementation, t~~The Applicant or its contractor shall provide to the CSLC evidence that all on-site personnel have completed the educational training prior to the start of their work on-site~~ground disturbance~~. A weather-protected bulletin board or binder shall be centrally placed or kept on site in an easily accessible area for the Project duration.					
	MM BIO-1b: Weed Management ~~Habitat Restoration and Revegetation Plan~~. ~~The Applicant shall prepare a Habitat Restoration and Revegetation Plan. The Plan shall include:~~ ~~Plans for soil-contouring, restoration, enhancement, and revegetation of soil exposed by removal of hardscape within the~~	Onshore	Compliance ~~Provide Habitat Restoration and Revegetation Plan to CSLC staff for consultation,~~	Post-Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce impacts to wildlife and special-status species habitat

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	San Onofre Nuclear Generating Station facility, which shall include at a minimum (a) the plant species to be used; (b) seed and cutting collecting guidelines; (c) a schematic depicting the mitigation area; (d) time of year that the planting will occur and the methodology of the planting; (e) a description of the irrigation methodology for container, bareroot, or other planting needing irrigation; (f) measures to control exotic vegetation on site; (g) success criteria; (h) a detailed monitoring program; and a (i) a weed monitoring plan To control the introduction and Weed monitoring shall include restoration areas and controlling the spread of invasive weed species plants in demolition disturbed areas. Mmeasures to control the introduction and spread of noxious weeds will be implemented following completion of Proposed Project activities, where necessary. in the Project work area shall be taken as follows: (1) all plant materials used during restoration shall be native, certified weed-free, and approved by the California State Lands Commission (CSLC) and Department of the Navy (DoN) staffs; (2) site-dedicated vVehicles shall be used to the extent feasible and all equipment accessing unpaved areas from off-site shall that will travel off-pavement will be washed (including wheels, undercarriages, and bumpers) at		review, and approval			

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	existing construction yards or legally operating car washes before entering unpaved areas; and a log kept. (3) Control measures may include physical (hand-pulling, mechanical removal) and chemical (herbicide application) treatment methods. tTools such as chainsaws, hand clippers, pruners, etc. shall be washed before and after entering all unpaved project work areas.; (a written daily log shall be kept for all vehicle/equipment/tool washing that states the date, time, location, type of equipment washed, methods used, and staff present. These control methods shall be dependent on the weed species, location of the weeds, and the time of year that weed control operations occur. Logs of equipment and tools washed shall be available to the CSLC and DoN staffs for inspection at any time and shall be submitted monthly. The Applicant shall submit the Plan to CSLC staff, for review and approval by CSLC staff in consultation with the DoN, U.S. Fish and Wildlife Service, and California Department of Fish and Wildlife staffs, no more than 60 days after completion of demolition activities.					
	MM BIO-1c: Rare Plant Surveys. In the event that ground disturbing activities would occur within areas of disturbed or ruderal vegetation, Tthe Applicant or its contractor shall implement the following tasks to	Onshore	Compliance and provide Salvage and Relocation Plan to CSLC staff for	Prior to, and during, and post decommissioning Proposed Project activities	Applicant or contractor	Reduce impacts to rare plants

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	mitigate the Project's direct and indirect impacts to special-status plants. • **Surveys.** Prior to initial ground disturbance <u>in areas of disturbed or ruderal vegetation</u>, a California State Lands Commission (CSLC)-approved, qualified plant ecologist or botanist shall conduct surveys for special-status plants (state- and federally-listed threatened and endangered, proposed, petitioned, and candidate plants and California Rare Plant Rank [CRPR] 1 and 2 plants) in all areas subject to ground-disturbing activity <u>containing suitable habitat</u> and the surrounding areas within 100 feet <u>when access is feasible</u>. The surveys shall be conducted during the appropriate blooming period(s) according to protocols established by the U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), and California Native Plant Society (CNPS). Surveys shall be valid for a period of 3 years. If vegetation removal or initial site disturbance in a surveyed area does not occur within 3 years, surveys must be repeated. All listed plant species found shall be marked and avoided, if feasible. • Any populations of special-status plants found during surveys shall be fully described, mapped, and a CNPS Field		consultation, review, and approval			

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Survey Form or written equivalent shall be prepared. A report detailing the results of each rare plant survey shall be provided to the CSLC staff 30 days prior to ground disturbance. • **Avoidance.** Prior to any grading, vegetation clearing, or site disturbance, the Applicant shall delineate the limits of disturbance with lathe, snow fencing, or other suitable markers. Prior to grading or vegetation removal, any populations of special-status plants (and areas of ESHA) identified during the surveys within the Proposed Project footprint and surrounding 100-foot area shall be protected and construction fencing established around each population. The buffer for herbaceous and shrub species shall be, at a minimum, 50 feet from the perimeter of the population or the individual. A smaller buffer may be established, provided there are adequate measures in place to avoid the take of the species, in coordination with USFWS and CDFW staffs. If impacts to listed plants cannot be avoided, USFWS and CDFW staffs shall be consulted for authorization, with notification to the CSLC. If Project activities result in the loss of more than 10 percent of an onsite population of any CRPR 1 plant species,					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	mitigation shall be required as described below. • **Salvage.** If Project activities result in the loss of more than 10 percent of an onsite population of any CRPR 1 plant species, the Applicant shall develop a Salvage and Relocation Plan based on the life history of the species affected. The Plan shall include at minimum: (a) collection/salvage measures for plants or seed banks, to retain intact soil conditions and maximize success likelihood; (b) details regarding storage of plants or seed banks; (c) location of the proposed recipient site, and detailed site preparation and plant introduction techniques; (d) time of year that the salvage and replanting or seeding will occur and the methodology of the replanting; (e) a description of the irrigation, if used; (f) success criteria; and (g) a detailed monitoring program, commensurate with the Plan's goals. The Salvage and Relocation Plan shall be submitted to CSLC staff for review and approval by CSLC staff in consultation with USFWS and CDFW staffs, a minimum of 30 days prior to start of salvage activities.					
	Implementation of APM-4 and APM-12 (provided above).					
BIO-2: Adversely Affect Terrestrial	**MM BIO-2a: Special-Status Reptiles and Amphibians.** Prior to any ground disturbance	Onshore	Compliance and provide survey	Prior to and during Proposed	Applicant or contractor	Reduce impacts to

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
Special-Status Species	in undeveloped areas of the SSA or associated with access road reconfiguration, ~~and daily during decommissioning activities,~~ the Applicant or its contractor shall retain a qualified herpetologist(s) with demonstrated expertise and all required permits to handle special- status reptiles and amphibians that could occur onsite.~~,~~ The herpetologist(s) shall ~~to~~ survey undeveloped areas of the SSA or areas associated with access road reconfiguration prior to ground-disturbing activities. ~~and~~ Thereafter, the herpetologist shall monitor daily the areas where such activities would occur ~~the reconfiguration of site access roads and external demolition activities proposed within the Supplemental Support Area~~. In addition: • Any special-status reptiles or amphibians found within a Project impact area shall be relocated to suitable habitat outside the impact area by the biological monitor(s) in coordination with the U.S. Fish and Wildlife Service (USFWS) or the California Department of Fish and Wildlife (CDFW) • The biological monitor(s) shall have the authority to temporarily halt work to avoid impacts to special-status species or other protected biological resources Survey results shall be provided to California State Lands Commission, Department of the Navy, USFWS, and CDFW staffs within 30 days of the survey.		results to CSLC staff ~~for consultation, review, and approval~~	Project ~~decommissioning~~ activities		special-status reptiles and amphibians

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	MM BIO-2b: Surveys and Monitoring for Breeding Birds. A qualified biologist with demonstrable experience surveying for active bird nests and monitoring shall conduct surveys for breeding birds protected by the Migratory Bird Treaty Act and Fish and Game Code no more than 72 hours prior to construction and removal activities carried out during the breeding season (from February 1 to September 15). In addition: • Nesting bird surveys shall be performed in all potential nesting habitat within 500 feet of construction activities, including stationary construction equipment and structures to be removed. The 500-foot survey area may be reduced if topography and/or buildings screen visual and noise impacts. • If an active nest is detected, a no-disturbance buffer around the active nest site(s) (typically 300 feet for most species and up to 500 feet for raptors) shall be established around the nest. For a non-listed species, the prescribed buffer may be adjusted by ~~the~~a qualified avian specialist. For listed species, ~~biologist~~ the buffer may be adjusted by the qualified avian specialist in coordination with the U.S. Fish and Wildlife Service (USFWS) and California Department of Fish and Wildlife (CDFW), and the Department of the Navy (DoN). The biologist shall	Onshore	Compliance and provide survey and monitoring results	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Impacts to special-status reptiles and amphibians

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	conduct regular monitoring of the nest to determine success/failure and to ensure that Project activities are not conducted within the buffer(s) until the nesting cycle is complete. • The biologist shall be responsible for documenting the results of the surveys and the ongoing monitoring and shall provide a copy of the survey and monitoring reports to the California State Lands Commission, DoN, USFWS, and CDFW staffs within 30 days of the survey.					
	MM BIO-2c: Burrowing Owl. A qualified biologist with demonstrable experience surveying and monitoring active burrowing owl burrows shall conduct focused burrowing owl surveys no more than 72 hours prior to: (1) the disturbance of coastal sage scrub and ruderal habitat types regardless of time of year, with the survey area to include the Proposed Project area in addition to a 500-foot buffer around the Proposed Project area; and (2) demolition or ground disturbing activities occurring during the breeding season (between February 1 and August 31), with the survey area to include all potentially occupied habitat within 500 feet of demolition or ground disturbing activities. • Focused surveys shall follow the protocols set forth in the Staff Report on	Onshore	Compliance and provide survey results CSLC, DoN, USFWS, and CDFW staffs	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce impacts to burrowing owl

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Burrowing Owl Mitigation (California Department of Fish and Game 2012). • Should an inhabited nest be identified, direct impacts to active nest burrows shall be prohibited until the young have fledged, and shall only proceed after replacement burrows have been provided outside of the disturbance and 500-foot buffer areas. • Demolition and ground disturbance shall be prohibited within 500 feet of active nest burrows to allow adults to raise young until fledglings can forage independently. The prescribed buffer may be adjusted by the biologist in coordination with the U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), and the Department of the Navy (DoN). A copy of the survey reports shall be provided to California State Lands Commission, DoN, USFWS, and CDFW staffs within 30 days of the survey.					
	MM BIO-2d: Western Snowy Plover/California Least Tern. A qualified biologist with demonstrable experience surveying and monitoring western snowy plovers, California least tern, and their nests shall conduct surveys of appropriate habitat for these species and their nests within 500 feet of the Project site no more than 72 hours prior to ground disturbing activities occurring	Onshore	Compliance and provide survey results and species avoidance plan (if required) to CSLC, DoN, USFWS, and CDFW staffs	Prior to and during ~~decommissioning~~ Proposed Project activities	Applicant or contractor	Reduce impacts to Western Snowy Plover/ California Least Tern

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	during the breeding season (March 1 to August 31). • If an active nesting site is observed during the surveys, a no-disturbance buffer shall be maintained 500 feet from the site and work in the area shall be postponed until the young have fledged. The prescribed buffer may be adjusted by the qualified biologist in coordination with U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), and the Department of the Navy (DoN). • If individuals are observed outside of the breeding season within 500 feet of the work area, the qualified biologist shall establish a no-disturbance buffer until it can be verified that the individuals have left the area. If individuals are routinely observed in or within 500 feet of the work area, or do not leave the work area, a species avoidance plan shall be developed in coordination with USFWS and CDFW. • If no individuals are observed in accordance with the survey protocols, no buffers shall be required. • A copy of the survey reports shall be provided to California State Lands Commission (CSLC), DoN, USFWS, and CDFW staffs within 30 days of the survey, and (if required) the species					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	avoidance plan shall be submitted to CSLC staff for review and approval in coordination with other agencies.					
	MM BIO-2e: Coastal California Gnatcatcher. A qualified avian biologist with appropriate federal permits shall conduct protocol-level surveys for coastal California gnatcatchers in coastal sage scrub habitat within 500 feet of ground disturbing and construction activities. The surveys shall include at least one survey no more than 72 hours prior to construction activities during the nesting season (February 15 to August 31) until the completion of ~~decommissioning~~ Proposed Project activities. The surveys shall include at least one survey no more than 72 hours prior to construction activities. • If an active nest is detected, demolition activities shall be prohibited within a 500-foot buffer until the nestling(s) has fledged, as determined by the biologist. The prescribed buffer may be adjusted by the biologist in consultation with the U.S. Fish and Wildlife Service (USFWS) and California Department of Fish and Wildlife (CDFW). • The surveys and monitoring reports shall be submitted to California State Lands Commission, Department of the Navy, USFWS, and CDFW staffs within 30 days of the survey or monitoring event.	Onshore	Compliance and provide survey and monitoring results to CSLC, DoN, USFWS, and CDFW staffs	Prior to and during ~~decommissioning~~ Proposed Project activities	Applicant or contractor	Reduce impacts to Coastal California Gnatcatcher

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	MM BIO-2f: Noise Minimization Plan. The Applicant shall prepare a Noise Minimization Plan which shall identify expected noise levels at Environmentally Sensitive Habitat Areas (ESHAs) where sensitive bird species may breed/nest, and shall describe all measures that will be implemented to minimize Project-generated noise within those areas. The plan shall include: A description of the basis for the expected noise levels at ESHAs and identification of modeling methods used to determine those levels Identification of all measures to be implemented to reduce sound levels within those areas to no greater than 60 dBA or 5 dBA above ambient noise levels when active nests are present. Measures may include enclosing sound-generating sources within structures or temporary sound barriers, moving sound-generating sources to locations farther from these boundaries, reducing the number of concurrent sound generating activities, using sound baffles to redirect sound away from the ESHAs, timing restrictions, or other similarly effective measures needed to meet the 60 dBA limit or 5 dBA below ambient noise levels The location and a description of sound monitoring equipment that will allow	Onshore	Compliance and provide survey for review and approval, and monitoring results to CSLC, USFWS, and CDFW staffs	Prior to and during decommissioning activities	Applicant	Reduce impacts to Coastal California Gnatcatcher

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	~~continuous monitoring of sound levels during project activities~~ ~~A description of how monitoring data will be compiled and reported to allow confirmation that sound levels do not exceed 60 dBA or 5 dBA above ambient levels within those areas when active nests are present The Noise Minimization Plan shall be submitted to CSLC staff for review and approval by CSLC staff, in consultation with USFWS and CDFW staffs, a minimum of 60 days prior to start of decommissioning activities.~~					
	Implement MM BIO-1a and MM BIO-1b, and APM-4, and APM-12 (provided above).					
	APM-8: Nesting Bird Deterrents. The Applicant ~~and/~~or its contractor shall implement nesting bird deterrents to deter nesting within and adjacent to active decommissioning areas. A qualified biologist shall inspect the proposed deterrent area for active nests and wildlife before implementing any deterrents. Deterrents that may be conducted without oversight from California State Lands Commission (CSLC) or regulatory agency staff could include, but are not limited to, the following: • Cover straw wattle and other potential nesting materials in active decommissioning areas and yards with tarp or another material that does not pose wildlife entrapment hazards	Onshore	Compliance and consult with CSLC, CCC, and CDFW staffs, as needed.	Prior to and during ~~decommissioning~~ Proposed Project activities	Applicant or contractor	Reduce impacts to nesting birds

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	• Wrap, stuff, or cover ends of pipes or other materials within which birds could nest • Use colored gravel, such as red or white, in active decommissioning areas and yards • Manage trash in a manner to reduce potential point food sources in active decommissioning areas and yards • Create disturbance by removing or moving equipment, vehicles, and materials on a daily basis within active decommissioning areas and yards • Install appropriate-sized mesh netting on decommissioning equipment and materials in staging areas, laydown yards, and other Proposed Project facilities and work areas. To prevent wildlife entrapment hazards, no monofilament netting will be used • Use mooring balls placed in inactive nests, directly on structures, or in other potential nest locations • Install visual deterrents such as tangle guard bird repellent ribbon in active decommissioning areas, yards, and on materials and equipment • Place wires or wire spikes on towers, buildings, or other facilities to discourage birds from perching and nesting on these structures					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Deterrents that may directly impact birds, nests, or habitat (therefore requiring consultation) could include, but are not limited to, the following: • Prior to the nesting season, remove vegetation from areas that would be directly disturbed by Proposed Project decontamination and dismantlement activities • Hire a U.S. Fish and Wildlife-permitted falconer to fly raptors in the area to deter birds from perching or nesting on structures If the deterrent method may directly impact birds, nests, or habitat, the Applicant and/or its contractor and the construction team shall consult with CSLC staff (or its contracted monitor) and California Department of Fish and Wildlife and California Coastal Commission staffs (if requested) to determine specific locations for the use of exclusionary or deterrent devices.					
BIO-3: Disturb Non-Listed Roosting or Breeding Bats	**MM BIO-3: Sensitive Bats Species.** Within 7 14 days prior to dismantling and external demolition activities of the onshore site facilities, a qualified biologist with demonstrated expertise with bats shall conduct a pre-activity survey for roosting bats within Proposed Project structures. All Proposed Project structures with exterior openings shall be surveyed by a qualified bat biologist using radio telemetry and visual	Onshore	Compliance and provide survey results to CSLC, DoN, and CDFW staffs	Prior to decommissioning Proposed Project activities	Applicant or contractor	Reduce impacts to bat species

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	inspection, or other methods approved by the California Department of Fish and Wildlife (CDFW). The resume of the biologist and survey methodology shall be provided to the CDFW for concurrence prior to any Proposed Project activities, with a copy to California State Lands Commission (CSLC) and Department of the Navy (DoN) staff. If active maternity roosts are found, impacts to the occupied structure shall be delayed until the end of the breeding period for the species identified. If delay is infeasible, the bat biologist shall survey the surrounding area using radio telemetry or other methods approved by CDFW to locate nearby alternative maternity colony sites. If the bat biologist determines that there are alternative roost sites used by the maternity colony, and young are not present, then no further action is required. However, if there are no alternative maternity roosts near the site, substitute roosting habitat for the maternity colony shall be provided on, or near, the terrestrial study area in consultation with CDFW and DoN staff prior to eviction of the colony. A copy of the survey, including how any impacts to the species were resolved, shall be submitted to CSLC, DoN, and CDFW staff within 30 days of completion.					
BIO-4: Modify Potential Onshore U.S./ Waters of the	**MM BIO-4: Potential Waters of the U.S./State.** If the California Department of Fish and	Onshore	Evidence of compliance with regulatory	Prior to ~~decommissioning~~ Proposed Project	Applicant or contractor	Reduce impacts to

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
State	Wildlife (CDFW), California Coastal Commission, Regional Water Quality Control Board (RWQCB), or U.S. Army Corps of Engineers (USACE) determine that the concrete ditches onsite are waters of the state/U.S., the Applicant or its contractor shall obtain, and shall comply with all mitigation and conditions associated with, one or more of the following permits, as applicable: a CDFW Lake and Streambed Alteration Agreement; RWQCB Section 401 Water Quality Certification; or Section 404 USACE permit. Permit compliance shall be met through the purchase of in-lieu credits for non-vegetated streams at an approved mitigation bank, implementation of in-kind or out-of-kind restoration, or a combination of these actions. The mitigation replacement ratio shall be determined by the regulatory agencies during the permitting process. Evidence of compliance with agency requirements shall be provided to CSLC staff prior to decommissioning activities.		agencies to CSLC staff	activities		Potential waters of the U.S./State
BIO-6: Conflict with Adopted Conservation Plans	**Implement MM BIO-1a, MM BIO-1b, MM BIO-2a, MM BIO-2b, MM BIO-2c, MM BIO-2d, MM BIO-2e, ~~MM BIO-2f,~~ and MM BIO-4, and APM-4, APM-8, and APM-12 (provided above).**					
BIO-7: Contribute to the Degradation of Marine Habitats	**APM-17: Offshore Spill Response Plan.** As part of the Spill Prevention Control and Countermeasure Plan, the Applicant ~~and/~~or its contractor shall prepare an Offshore Spill	Offshore	Offshore Spill Response Plan to CSLC staff in	Prior to ~~and during decommissioning~~	Applicant and/or contractor	Reduce impacts associated with

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Response Plan that shall, at a minimum, include: • Procedures and protocols to be used in the event of an offshore oil spill • Discussion of potential sources of hydrocarbons (limited to leakage or spillage of fuel or lubricants from onshore and from marine equipment used during dispositioning operations) • Description of marine spill scenarios and response procedures to be used in the event of an onshore or offshore oil or chemical spill • List of the spill response team members, including contact information and the notification process • Shipboard copies of the Plan and all necessary equipment to implement said Plan onboard The Applicant shall submit the Plan to California State Lands Commission (CSLC) staff, for review and approval by CSLC staff, for review and approval in consultation with the Office of Spill Prevention and Response a minimum of 60 days prior to commencement of conduit disposition work operations.		consultation with OSPR	commencement of offshore work activities		marine degradation
	Implement APM-1 and APM-12 (provided above).					
BIO-8: Risk of Oil Spill Mortality to Protected Marine Species	**Implement of APM-17 (provided above).**					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
~~**BIO-9: Release of H2S Gas from Intake and Discharge Conduits**~~	~~**MM BIO-9: Hydrogen Sulfide (H2S) Gas Control Plan.** Prior to accessing any enclosed spaces within the conduits, a qualified H2S inspector, capable of assessing the level of risk from H2S build-up, shall conduct an inspection to determine if H2S gas occurs at sufficient levels to pose a danger of release and subsequent mortality of listed marine species.~~ ~~If the inspection confirms the presence of levels of H2S gas sufficient to cause a risk to marine life in the area if released, the inspector shall develop and implement a H2S Gas Control Plan as part of the detailed demolition planning. This H2S Control Plan must allow for controlled safe removal/release of H2S during the demolition activities.~~ ~~The Plan shall be provided for review to California State Lands Commission staff, California Coastal Commission staff, and other agencies as appropriate no less than 60 days prior to any conduit decommissioning work.~~	~~Offshore~~	~~Hydrogen Sulfide Gas Control Plan for review, or evidence of absence~~	~~Prior to removal of conduit components~~	~~Applicant~~	~~Reduce potential impacts associated with Hydrogen Sulfide Gas~~
BIO-10: Seabed Disturbance, Dredging, and Debris Accumulation	**MM BIO-10: Anchoring Plan.** The Applicant or its contractor shall prepare an Anchoring Plan for the derrick barge and any other vessels requiring large or frequent anchoring. The Plan shall describe the offshore activities for which vessel anchoring is required, including anchoring arrangements, general procedures	Offshore	Provide Anchoring Plan for review and approval	Prior to removal of conduit components	Applicant or contractor	Reduce potential impacts associated with marine degradation

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	for deploying and recovering anchors, and identify the locations of any temporary laydown areas along with the process for avoiding hard substrate and sensitive marine areas (e.g., surfgrass). The Plan shall include: • The positioning of large anchors used to moor the derrick barge to locations that avoid damage to the seabed, surfgrass, and canopy kelp habitat from both the anchors and mooring chains. If alternative anchor sites with no habitat cannot be identified, consultation with U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) shall be required prior to finalization of the Plan • Anchor positions shown within a spatial accuracy sufficient to allow comprehensive survey mapping of benthic habitats, particularly surfgrass and canopy kelp habitats by qualified SCUBA divers prior to anchoring. Mapping shall include stipe density counts, precise areal coverage, and associated flora and fauna • Locations and size of temporary laydown areas that avoid damage to the seabed, surfgrass, and canopy kelp habitat, and measures to address the positioning of materials.					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	• Additional protective measures such as anchor deployment speeds (to avoid impacts to epifaunal fishes and invertebrates) • A statement that surveys shall be repeated within 1 month after anchors have been removed to demonstrate areas are not affected by anchor damage or to evaluate/quantify the area that was affected for purposes of determining mitigation The Anchoring Plan shall be completed and submitted to USFWS, NMFS, and California State Lands Commission staffs for review and approval 60 days prior to start of offshore activities.					
	APM-9: Conduit Work Plan. The Applicant and/or its contractor shall prepare a Conduit Work Plan, which shall fully describe the nature, structure, and sequence of activities comprising the approach to offshore conduit decommissioning work, including anchor positioning, dredge footprint, and side-casting footprints in relation to seabed habitat descriptions. Seabed habitat descriptions should include identification of biotic (vegetation type, species accounts, etc.) and abiotic (nature of the sediment/benthos, etc.) habitat character. The Plan shall include details regarding the vessels used to transport conduit components and debris, and the means and	Offshore	Provide Conduit Work Plan for review and approval	Prior to removal of conduit components	Applicant or contractor	Reduce potential impacts associated with marine degradation

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	methods for the work activities related to the dispositioning of the offshore conduit components. The Plan shall be submitted to California State Lands Commission staff for review and approval at least 60 days prior to start of offshore activities.					
	APM-15: Dredging Plan. To protect marine water quality during dredging and related offshore activities, the Applicant ~~and~~/or its contractor shall develop and implement a Dredging Plan prior to Proposed Project offshore activities. The Dredging Plan shall include protocols for dredging based on approved methods and standards set by the U.S. Army Corps of Engineers (USACE), California State Lands Commission (CSLC), California Coastal Commission (CCC), and the San Diego Regional Water Quality Control Board (RWQCB), including but not limited to: • Number and type of vessels required to conduct dredging • Information on the specific location of intended side-casting areas for each structure if using a long-reach excavator or similar method is intended. Including the predominant habitat type of the side-casting area (hard or soft sediment, presence of aquatic vegetation or other seabed habitat likely to be impacted)	Offshore	Provide Dredging Plan for review and approval	Prior to removal of conduit components	Applicant or contractor	Reduce potential impacts associated with marine degradation

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	• Requirements to avoid areas of sensitive habitat; particularly rocky reefs and seagrass beds. If no seabed areas with suitable soft sediment habitat for side-casting exists within the proximity of the structures intended for removal, the contractor must consider diver-guided suction dredging methods that remove sediment to either the discharge conduits, or relocation of sediments to an appropriate side-casting location • Deployment of a floating boom and skirt around offshore and shoreline Proposed Project activities to prevent or minimize impacts to marine water quality • Appropriate methods for dealing with dredged material based on sediment sampling, testing, and analysis results The Applicant shall submit the Dredging Plan to CSLC staff, for review and approval by CSLC staff in consultation with the USACE, CCC, and RWQCB, not less than 30 days prior to commencement of Proposed Project offshore work.					
	APM-16: Turbidity Monitoring. Turbidity monitoring shall be performed during	Offshore	Provide monitoring reports for	Prior to and during all offshore ~~decommissioning~~	Applicant or contractor	Reduce potential impacts

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Proposed Project offshore work to monitor any effects on water clarity in the immediate areas of the offshore work. Work shall be performed by a qualified water quality specialist who shall record turbidity from a suitable vantage point during each day of offshore dredging and decontamination and dismantlement. The Applicant ~~and/~~or its contractor shall send weekly electronic copies of the turbidity monitoring reports for review by California State Lands Commission and San Diego Regional Water Quality Control Board staffs.		review	work		associated with marine degradation
BIO-11: Harassment of Marine Life	**MM BIO-11: Marine Mammal and Sea Turtle Mitigation and Monitoring Plan.** The Applicant or its contractor shall prepare a Marine Mammal and Sea Turtle Mitigation and Monitoring Plan. The purpose of the Plan is to ensure that no harassment of marine mammals or other marine life occurs during Proposed Project activities. The Plan, which may be a part of a National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) consultation under the Marine Mammal Protection Act, shall include: • A description of the work activities including vessel size, activity types and locations, and Proposed Project timeframes	Offshore	Provide Marine Mammal and Sea Turtle Mitigation and Monitoring Plan	Prior to the implementation of offshore work	Applicant or contractor	Reduce potential impacts to marine mammals and sea turtles

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	• A risk analysis (likelihood and consequence) of noise effects to marine mammals and sea turtles based on the most recent activity plans • The qualifications, number, location, and roles/authority of dedicated marine wildlife observers (MMOs). A minimum of two MMOs, approved by California State Lands Commission (CSLC) and NMFS staffs, shall be placed on major support vessels • The distance, speed, and direction transiting vessels shall maintain when in proximity to a marine mammal or turtle, as follows: ○ Vessel operators shall make every effort to maintain a distance of at least 300 feet from sighted whales, and 150 feet or greater from sea turtles or smaller cetaceans whenever possible ○ When small cetaceans are sighted while a vessel is underway (e.g., bow-riding), vessel operators shall attempt to remain parallel to the animal's course. When paralleling whales, vessels shall operate at a constant speed that is not faster than the whales' and shall avoid excessive speed or abrupt					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	changes in direction until the cetacean has left the area ○ Per NMFS recommendations, and when safety permits (i.e., excluding during poor sea and weather conditions, thereby ensuring safe vessel maneuverability under those special conditions), vessel speeds shall not exceed 11.5 miles per hour (10 knots) when mother/calf pairs, groups, or large assemblages of cetaceans (greater than five individuals) are observed near an underway vessel. A single cetacean at the surface may indicate the presence of submerged animals in the vicinity; therefore, prudent precautionary measures, such as decreasing speed and avoiding sudden changes in direction, should always be exercised. The vessel shall route around the animals, maintaining a minimum distance of 300 feet. Whales may surface in unpredictable locations or approach slowly moving vessels. When an animal is sighted in the vessel's path or in close proximity to a moving vessel and when safety permits,					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	operators shall reduce speed and shift the engine to neutral. Vessel operators shall not engage the engines until the animals are clear of the area ○ Support vessels (i.e., barge tows) shall not cross directly in front of migrating whales, other threatened or endangered marine mammals, or sea turtles ○ Vessels shall not separate female whales from their calves or herd or drive whales. If a whale engages in evasive or defensive action, support vessels shall drop back until the animal moves out of the area ○ Observation recording procedures and reporting requirements in the event of an observed impact to marine wildlife. Collisions with marine wildlife shall be reported promptly to the federal and state agencies listed below pursuant to each agency's reporting procedures. National Marine Fisheries Service Southwest Region Stranding Coordinator Long Beach, CA 90802 Phone: (562) 980-3230 or (562) 506-4315 (24-hour cell)					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	California State Lands Commission Mineral Resources Management Division Long Beach, CA 90802 Phone: (562) 590-5201 ○ An acoustic monitoring strategy. If underwater sound pressure levels are thought to exceed limits established by NMFS, a marine acoustics specialist shall install acoustic monitoring devices before saw cutting occurs to monitor and establish Level B behavioral harassment zones, which shall be enforced by qualified marine wildlife observers. This mitigation is subject to NMFS and USFWS consultation. The plan shall be submitted to CSLC staff a minimum of 30 days prior to the implementation of offshore work.					
BIO-12: Spread of Invasive and Non-Native Marine Species	**MM BIO-12: Invasive Non-Native Aquatic Species (NAS).** To prevent the introduction of NAS, all Project vessels shall: • Originate from Oceanside Harbor, the Ports of Long Beach/Los Angeles, Dana Point Harbor, or San Diego Bay and be continuously based out of Oceanside Harbor, the Ports of Long Beach/Los Angeles, Dana Point Harbor, or San Diego Bay since last dry docking or have underwater	Offshore	Compliance	During offshore work	Applicant or contractor	Reduce potential impacts related to NAS

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	surfaces cleaned before entering southern California at vessel origination point and immediately prior to transiting to the Project site • Be managed consistent with California State Lands Commission (CSLC) Ballast Management Regulations regardless of vessel size. Biofouling Removal and Hull Husbandry Reporting Forms shall be submitted to CSLC staff Project vessels shall be available for inspection by CSLC staff for compliance. • Further, as part of the Project kickoff meeting, a qualified marine biologist, approved by CSLC staff, shall provide information to all Project personnel about the spread of NAS in California waters and the programs that will be implemented to minimize this hazard (CSLC Ballast Water Management Program and Biofouling Removal and Hull Husbandry Reporting).					
Cultural and Paleontological Resources						
CR-2: Change Significance of Previously Unidentified Historical or Unique	**MM CR/TCR-2a: Develop Cultural Resource Management Plan (CRMP) –** The Applicant or its contractor shall prepare and submit to California State Lands Commission (CSLC) staff for approval a Cultural Resource Management Plan (CRMP) to guide all cultural resource	Onshore	Compliance	During Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce potential impacts to cultural resources

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
Archaeological Resources	management activities during the Proposed Project. Management of cultural resources shall follow all applicable federal and state standards and guidelines for the management of historic properties/historical resources. The CRMP shall be submitted to CSLC staff for activities. The CRMP shall include, but not be limited to, the following: **a. Cultural Resources Protection Plan:** The CRMP shall define and map all known NRHP- and CRHR-eligible properties in or within 100 feet of the Proposed Project Area of Potential Effect (APE). A cultural resources protection plan shall be included that details how NRHP- and CRHR-eligible properties will be avoided and protected during construction. Measures shall include, at a minimum, designation and marking of Environmentally Sensitive Areas (ESAs), archaeological monitoring, personnel training (including training and certification of monitors as appropriate in hazardous materials response), and reporting. The plan shall also detail what avoidance measures will be used, where and when they will be implemented, and how avoidance					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	measures and enforcement of ESAs will be coordinated with construction personnel. b. **Cultural Resource Monitoring and Field Reporting:** Detail procedures for archaeological and Native American monitoring as appropriate. This will include when monitoring is required, reporting matrix, and a spot check program during ground disturbance. c. **Unanticipated Discovery Protocol:** Detail procedures for halting ground-disturbing activities, defining work stoppage zones, notifying stakeholders (including but not limited to Marine Corps Base Camp Pendleton Environmental Science, Cultural Resources Management Branch in the event of an offshore discovery, California State Lands Commission Division of Environmental Planning and Management staff in the event of an onshore discovery and tribal representatives as appropriate), and assessing NRHP and/or CRHR eligibility in the event unanticipated					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	discoveries are encountered during the Proposed Project. Include methods, timelines for assessing NRHP and/or CRHR eligibility, formulating mitigation plans, and implementing treatment. Mitigation and treatment plans for unanticipated discoveries shall be reviewed by appropriate Native American tribes and approved by MCBCP or CSLC staff as applicable, prior to implementation. d. **Data Analysis and Reporting:** Detail methods for data analysis in a regional context, reporting of results to applicable stakeholders within one year of completion of field studies, curation of artifacts and data (maps, field notes, archival materials, recordings, reports, photographs, and analysts' data) at a facility that is approved by MCBCP or CSLC staff as applicable, and dissemination of reports to appropriate repositories. e. **Tribal Engagement Plan:** Include details regarding how Native American tribes will be engaged and informed throughout the Proposed					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Project. Among other things, an archaeological monitor and tribal monitor who is culturally affiliated with the Proposed Project area may be present for all ground-disturbing activities within or directly adjacent to any identified tribal cultural resources. The archaeological and tribal monitors will consult the CRMP to determine when to alter the monitoring effort should the monitoring results indicate a change is warranted. ~~**Archaeological and Tribal Monitoring.** A California State Lands Commission (CSLC) staff-approved archaeological monitor that meets the Secretary of the Interior's Professional Qualifications Standards (as defined in 36 Code of Federal Regulations Part 61), and is certified in hazardous materials response, shall be present for all ground-disturbing activities that may exceed 3 feet in depth in onshore areas. A Tribal monitor that is culturally affiliated with the area may also be present during these activities. The Tribal monitor shall also have certification in hazardous materials response, to be provided by the Applicant, if working in or near radiologically contaminated structures,~~					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	remains of structures, or soils. The archaeological monitor shall complete daily monitoring forms and prepare a summary monitoring report to be submitted weekly to CSLC staff. The archaeological and Tribal monitors have the authority to increase or decrease the monitoring effort should the monitoring results indicate that a change is warranted.					
	MM CR/TCR-2b: Training of Proposed Project Workers – Prior to initiating ground-disturbing activities, all personnel involved in such activities shall be trained by: a) a qualified archaeologist regarding the recognition of possible buried cultural resources (*i.e.*, prehistoric and/or historical artifacts, objects, or features) and protection of all archaeological resources during construction and b) a qualified archaeologist and tribal monitor regarding special considerations when working within or directly adjacent to tribal cultural resources. Training shall inform all such personnel of the procedures to be followed upon the discovery of cultural materials and tribal cultural resources. All such personnel shall be instructed that unauthorized removal or collection of artifacts is a violation of Federal and State laws. Any excavation contract (or contracts for other activities that may have subsurface soil impacts) shall include clauses that require construction personnel	Onshore	Compliance and provide Treatment Plan, if needed	During Proposed Project decommissioning activities	Applicant or contractor	Reduce potential impacts to cultural resources

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	to attend a Worker's Environmental Awareness Program (WEAP). The WEAP will address the Proposed Project's potential for inadvertently exposing buried archaeological deposits, how to operate adjacent to and avoid any potential ESA, and procedures to treat unanticipated discoveries. **Unanticipated Cultural/Tribal Resources.** If potentially significant archaeological or Tribal cultural resources are discovered during demolition activities, work within 100 feet of the find shall be temporarily suspended or redirected away from the discovery. The Applicant shall notify California State Land Commission (CSLC) staff and any local, state, or federal agency with approval or permitting authority over the Project that has requested/required notification within 48 hours of discovery, consistent with guidelines for Tribal involvement stated in the CSLC Tribal Policy (www.slc.ca.gov/About/Tribal.html). The Applicant shall retain a CSLC-approved archaeologist and request a culturally affiliated Tribal representative to evaluate the nature and significance of the discovery. In addition, the following shall apply: Impacts to previously unknown significant archaeological or Tribal cultural resources shall be avoided through preservation in place if feasible					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	If the lead archaeologist and culturally affiliated Tribal representative believe that damaging effects to archaeological or Tribal cultural resources will be avoided or minimized, then work in the area may resume. Damaging effects shall be avoided or minimized following the measures in Public Resources Code section 21084.3, subdivision (b), unless other measures that would be as or more effective are mutually agreed to by the lead archaeologist and culturally affiliated Tribal representative • If resources cannot be avoided, a Treatment Plan developed by the archaeologist and culturally affiliated Tribal representative shall be submitted to CSLC staff for review and approval prior to further disturbance of the area. The plan shall: State requirements for professional qualifications of all cultural resources specialists and Tribal cultural resource workers Identify appropriate methods of resource recording, artifact cataloguing, and analyses Determine appropriate levels of recovery or stabilization of resources Provide documentation of a curatorial facility or museum that will be responsible for the permanent preservation of any unique or sensitive cultural materials resulting from site recovery and stabilization efforts					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	~~• If the discovery is made in radiologically-contaminated Project areas, the archaeologist, Tribal representative, or other Tribal participant(s) shall follow safety protocols not less than those currently established by the U.S. Nuclear Regulatory Commission and Southern California Edison's Requirements for Site Access and Access to Protected/ Restricted Radiologically Controlled Areas, which include: (1) authorized searches; (2) processing and training requirements; (3) radiation protection; and (4) maintenance of a safety-conscious work environment.~~					
	MM CR/TCR-2c: Cultural Resource Identification during Offshore Geophysical Surveys. The Applicant or its contractor shall ensure that a qualified maritime archaeologist that meets Secretary of the Interior Professional Qualifications Standards defined in 36 Code of Federal Regulations Part 61, approved by California State Lands Commission (CSLC) staff, participates in the development and implementation of the geophysical surveys conducted to develop the Anchoring and Dredging Plans. The archaeologist shall identify any cultural resources found during the surveys and prepare a summary report to be submitted to CSLC staff. Title to all abandoned shipwrecks, archaeological sites, and historic or cultural resources on or in the	Offshore	Compliance	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce potential impacts to cultural resources

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	tide and submerged lands of California is vested in the State and under the jurisdiction of the CSLC. The final disposition of archaeological, historical, and paleontological resources recovered on State lands under the jurisdiction of the CSLC must be approved by the Commission.					
	APM-10: Cultural Resources Protection. To ensure the Proposed Project does not impact cultural resources, all ground disturbing activities shall be conducted within the historically excavated ~~existing disturbed area~~ footprint of the site and shall not encroach on the adjacent surrounding undisturbed areas. ~~The archeological and/or Tribal monitor shall halt work if archaeological materials (e.g., shell, wood, bone, or stone artifacts) are found or suspected during Proposed Project activities, or the Proposed Project footprint is altered in the area of discovery. The following parties shall be notified within 24 hours of the discovery:~~ ~~Onshore: Marine Corps Base Camp Pendleton (MCBCP) Environmental Science, Cultural Resources Management Branch Offshore: California State Lands Commission Division of Environmental Planning and Management (CSLC) staff Proposed Project work at the discovery site shall not proceed until the MCBCP~~	Onshore and Offshore	Compliance	During Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce potential impacts to cultural resources

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	~~Archaeologist (onshore) or CSLC staff or its approved monitor (offshore) has evaluated the find and gives permission to resume Proposed Project activities.~~					
CR-3: Disturb Unidentified Human Remains	**APM-11: Appropriate Treatment of Human Remains.** In accordance with state law (Health & Saf. Code, § 7050.5; Pub. Resources Code, § 5097.98), if human remains are found, all ground disturbing activities shall halt within 165 feet (50 meters) of the discovery. The County Coroner shall be notified within 24 hours of the discovery. No further excavation or disturbance of the discovery or any nearby area reasonably suspected to overlie potential remains shall occur until the County Coroner has determined whether the remains are subject to his or her authority. The County Coroner must make this determination within 2 working days of notification of the discovery (pursuant to Health & Saf. Code, § 7050.5, subd. (b)). If the County Coroner determines that the remains do not require an assessment of cause of death and that the remains are, or are believed to be Native American, the Coroner must notify the Native American Heritage Commission (NAHC) by telephone within 24 hours, which must in turn immediately notify those persons it believes to be the Most Likely Descendant (MLD) of	Onshore and Offshore	Compliance	During Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce potential impacts to cultural resources

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	the deceased Native American. The MLD shall complete its inspection and make recommendations within 48 hours of being granted access to the site. The MLD may recommend means for treatment or disposition, with appropriate dignity, of the human remains and any associated grave goods. CSLC staff shall discuss and confer with the MLD regarding their recommendations (pursuant to Pub. Resources Code, § 5097.98, subds. (b) and (c)).					
CR-4: Destruction of Unique Paleontological Resources	**MM CR-4a: ~~Paleontological Monitoring.~~ Develop Paleontological Resource Mitigation and Monitoring Plan (PRMMP).** The Applicant or its contractor shall prepare and submit to California State Lands Commission (CSLC) staff for approval a Paleontological Resources Mitigation and Monitoring Plan (PRMMP) to guide all paleontological management activities during the Proposed Project. The PRMMP shall be submitted to CSLC staff for review and approval at least 30 days prior to the start of ground-disturbing activities. The PRMMP shall be prepared by a qualified paleontologist, based on Society of Vertebrate Paleontology (SVP) 2010 guidelines, and meet all regulatory requirements. The qualified paleontologist shall have a Master's Degree or Ph.D. in paleontology, have local paleontology	Onshore	Compliance	During Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce potential impacts to paleontological resources

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	knowledge, and shall be familiar with paleontological procedures and techniques. The PRMMP will include, but not be limited to, the following sections: a. **Paleontological Resource Monitoring and Reporting:** Detail monitoring procedures and methodologies, which shall require a qualified paleontological monitor for all D&D-related ground disturbance activities that extend into previously undisturbed sediments, which may contain significant paleontological resources with moderate (PFYC 3a) to very high (PFYC 5) sensitivity. Sediments of undetermined sensitivity shall be monitored on a part-time basis as outlined in the PRMMP. Sediments with very low or low sensitivity will not require monitoring. Paleontological monitors shall meet standard qualifications per the SVP (2010) and shall be provided training and certification in hazardous materials response. In addition, monitors shall follow safety protocols established by the Southern California Edison's Requirements for Site Access and Access to					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Protected/Restricted-Radiologically Controlled Areas. b. **Unanticipated Discovery Protocol:** Detail procedures for halting ground-disturbing activities, defining work stoppage zones, notifying stakeholders, and assessing the paleontological find for scientific significance. If indicators of potential microvertebrate fossils are found, screening of a test sample shall be carried out as outlined in SVP 2010. **Data Analysis and Reporting:** Detail methods for data recovery, analysis in a regional context, reporting of results to applicable stakeholders within one year of completion of field studies, curation of all fossil specimens in an accredited museum repository approved by MCBCP or CSLC staff as applicable, and dissemination of reports to appropriate repositories. A qualified paleontologist must be present to monitor all ground disturbing activities within the onshore area. The paleontological monitor shall: • Have certification in Hazardous Materials procedures if working in or near radiologically contaminated structures, remains of structures, or soils • Follow safety protocols established by the Southern California Edison's					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	~~Requirements for Site Access and Access to Protected/Restricted-Radiologically Controlled Areas, which includes: (1) authorized searches; (2) processing and training requirements; (3) radiation protection; and (4) maintenance of a safety-conscious work environment~~ • ~~Fill out daily monitoring forms and prepare a weekly summary monitoring report~~ • ~~Have the authority to increase or decrease the monitoring effort should the monitoring results indicate that a change is warranted~~					
	MM CR-4b: ~~Unanticipated Paleontological Resources~~ Training of Proposed Project Workers. Prior to the initiation of ground-disturbing activities, all personnel involved in such activities shall be trained, by a qualified paleontologist, regarding the recognition of possible buried paleontological resources (*i.e.*, fossils) and protection of all paleontological resources during construction. Training shall inform all construction personnel of the procedures to be followed upon the discovery of paleontological materials. All such personnel shall be instructed that unauthorized removal or collection of fossils is a violation of Federal and State laws. Any excavation contract (or contracts for other activities that	Onshore	Compliance, and provide a Paleontological Resources Management Plan, if needed, for review and approval	During Proposed Project ~~decommissioning~~ activities	Applicant or contractor	Reduce potential impacts to cultural resources

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	may have subsurface soil impacts) shall include clauses that require all personnel involved in ground-disturbing activities to attend a Worker's Environmental Awareness Program (WEAP). The WEAP will address the Proposed Project's potential for inadvertently exposing buried paleontological resources, how to operate adjacent to and avoid any potential Environmentally Sensitive Area, and procedures to treat unanticipated discoveries. In the event unanticipated paleontological resources or unique geologic resources are encountered during demolition activities, work within 100 feet of the find shall be temporarily suspended or redirected away from the discovery until the Applicant retains a qualified paleontologist, who has demonstrated experience in carrying paleontological projects to completion, to evaluate the nature and significance of the discovery. If the resource cannot be avoided, the paleontologist shall develop and implement a Paleontological Resources Management Plan for the Proposed Project area that includes specimen identification to the lowest taxonomic level possible, analysis, curation, and the preparation of a final report. The plan shall be submitted to California State Lands Commission staff for review and approval prior to further disturbance of the area.					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
Cultural Resources- Tribal						
TCR-2: Change Significance of Previously Unidentified Tribal Cultural Resources	Implement MM CR/TCR-2a, MM CR/TCR-2b, MM CR/TCR-2c, and APM-10 and APM-11 (provided above).					
TCR-3: Disturb Unidentified Tribal Human Remains	Implement APM-11 (provided above).					
Geology, Soils, and Coastal Processes						
GEO/ CP-2: Construction Triggered Erosion	Implement APM-12 (provided above).					
Hydrology and Water Quality						
WQ-1: Violation of Water Quality Standards or Waste Discharge Requirements, or Generation of Substantial Additional Sources of Polluted Runoff	Implement APM-1, APM-2, APM-12, APM-13, and APM-14 (provided above).					
WQ-2: Groundwater Characterization and Discharge	Implement MM HAZ-6 (above).					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
WQ-4: Erosion or Siltation due to Altered Drainage Patterns	**MM WQ-4. ~~Interim Erosion Control~~ Onshore Site Stabilization Plan.** The Applicant ~~and/~~or its contractor shall prepare and implement an Onshore Site Stabilization Plan to cover the onshore site condition following Proposed Project completion. This Plan shall include ~~interim~~ erosion-control, ~~plan, including~~ monitoring, and adaptive management measures, to prevent Project-induced fugitive dust and erosion that may occur ~~subsequent to the initial decommissioning activities~~ after Proposed Project completion. Site stabilization would be accomplished either through use of non-vegetative cover such as gravel, or vegetative cover through the application of a native erosion control mix. During preparation of the plan, the Applicant shall consult with California State Lands Commission (CSLC), California Coastal Commission, and the San Diego Regional Water Quality Control Board~~, and Department of the Navy staffs~~, and a final copy provided to CSLC staff for review and approval a minimum of 60 days prior to start of ~~decommissioning~~ Proposed Project ground-disturbing activities. This Plan shall remain in effect until the beginning of Future Activities.	Onshore	Provide ~~an interim erosion-control~~ the Onshore Site Stabilization ~~p~~Plan for review and approval	~~During decommissioning activities~~ At the conclusion of Proposed Project activities until the start of Future Activities	Applicant ~~and/~~or contractor	Reduce potential impacts due to erosion following completion of the Proposed Project
	Implement APM-12 (provided above).					

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
WQ-5: Flooding due to Altered Drainage Patterns or Increased Surface Runoff	**MM WQ-5: Walkway Flood Protection Plan.** In consultation with the California Coastal Commission (CCC)~~,~~ and San Diego Regional Water Quality Control Board (RWQCB)~~, and Department of the Navy (DoN)~~, the Applicant ~~and/~~or its contractor shall prepare an alternate drainage plan that avoids discharging surface waters directly to the surface of the public access walkway. This may be accomplished by discharging under the walkway through culverts or other methods acceptable to the CCC~~ and DoN~~. Any discharge beneath the walkway shall be engineered to avoid damage to the walkway subgrade. The Applicant shall submit the Plan to California State Lands Commission staff for review and approval in consultation with the CCC~~,~~ and RWQCB~~, and DoN~~, a minimum of 60 days prior to start of ~~decommissioning~~ Proposed Project activities.	Onshore	Provide a~~n interim erosion-control~~ plan for review and approval	Prior to Proposed Project ~~decommissioning~~ activities	Applicant ~~and/~~or contractor	Reduce potential impacts due to water discharge
WQ-6: Increased Ocean Turbidity and Marine Debris	**Implement APM-1, APM-15, and APM-16 (provided above).**					
WQ-7: Degraded Marine Water Quality from Oil or Chemical Spills	**Implement APM-17 (provided at the end of this MMP).**					
Land Use and Planning						

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
LU-2: Disrupt, Displace, or Divide Existing or Approved Land Uses	**MM LU-2a: Deconstruction Liaison.** At least 1 month prior to the start of any deconstruction activities, and thereafter for the duration of the Project, the Applicant or its contractor shall appoint a Deconstruction Liaison and provide a toll-free general number and the name and contact information for the liaison (or liaisons) for all Marine Corps Base Camp Pendleton (MCBCP) operations and residents within 5 miles of the Project site by U.S. Postal Service mail. The identified deconstruction liaison(s) shall: • Act as a point of contact and interface between MCBCP personnel and local residents and the San Onofre Nuclear Generating Station deconstruction crews • Be available both in person and by phone, as necessary, for at least 1 month prior to the start of deconstruction, and for 6 months following the completion of the Project • Respond to all Project-related questions and concerns within a 72-hour period when contact information is provided In addition, the Applicant shall provide the California State Lands Commission and Department of the Navy staffs with summary documentation of all complaints, comments, and concerns communicated to the liaison(s) every 3 months for the duration of	Onshore	Provide summary documentation of all complaints, comments, and concerns	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant ~~and~~/or contractor	Reduce potential impacts related to construction

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	deconstruction activities, and 2 times (once every 3 months) for the 6-month period following the completion of Project activities. The compliance documentation shall include the name and address of the person contacting the liaison(s), the date of contact, and what actions were taken by the liaison(s) to rectify or address the complaints, comments, or concerns expressed.					
	MM LU-2b: Advance Notification of Deconstruction. The Applicant or its contractor shall give at least 30 days advanced notice of the start of any deconstruction activities to Marine Corps Base Camp Pendleton operations and residents within 5 miles of the Project site by U.S. Postal Service mail. The notification shall include the location, types, and expected duration of each deconstruction activity scheduled for the first 3 months following publication of the notification. The notification shall also include the toll-free general phone number and contact information for the deconstruction liaison(s), as well as an internet website address where additional information related to deconstruction activities can be found.	Onshore	Compliance	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant ~~and/~~or contractor	Reduce potential impacts related to construction
	MM LU-2c: Quarterly Deconstruction Updates. Following distribution of the advance notification of deconstruction, the Applicant or its contractor shall provide	Onshore	Compliance	Prior to and during Proposed Project	Applicant or contractor	Reduce potential

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Marine Corps Base Camp Pendleton operations and residents within 5 miles of the Project site with updates to all current and scheduled deconstruction activities on the Project's internet website and by U.S. Postal Service mail. The updates shall be provided every quarter for the duration of deconstruction activities. The updates shall continuously include the location, types, and expected duration of each deconstruction activity scheduled for the 3-month period following each update's publication date. The updates shall also include a toll-free number and the name and phone number of the deconstruction liaison(s) to respond to all deconstruction-related questions and concerns.			~~decommissioning~~ activities		impacts related to construction
Recreation and Public Access						
REC-1: Reduction of Public Access to Recreational Facilities	**MM REC-1a: Public Notification.** In areas where decommissioning activities would impact recreational facilities, the Applicant ~~and~~/or its contractor shall place warning signs, and if needed, implement detour routes, 24 hours prior to implementation of those activities. In addition, the Applicant or its contractor shall maintain for the duration of Proposed Project activities a public website that provides Proposed Project-related information including but not	Onshore	Compliance	Prior to and during Proposed Project ~~decommissioning~~ activities	Applicant ~~and~~/or contractor	Reduce potential impacts related to public access

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	necessarily limited to offshore work schedules, Traffic Plans, Local Notices to Mariners, and any anticipated closures to bicycle and pedestrian lanes, public accessways, or beaches.					
	MM REC-1b: Public Access Plan. The Applicant ~~and~~/or its contractor shall develop a Public Access Plan to ensure public access around the Proposed Project area is not significantly affected. The Plan shall avoid: • Any long-term increase in traffic that would conflict with adopted policies, plans, or programs supporting alternative transportation; or obstruct current access to and around the Proposed Project area. • Restrictions on roads used to access San Onofre State Beach both north and south of the Proposed Project area that would result in a full road closure or significant disruptions. The Plan would require, but not be limited to the following: • Implementation of the Plan by trained personnel • Appropriate posting of traffic and safety signs • Haul truck trips to be concentrated during off-peak hours during project construction to the extent practicable. Trucks trips shall be scheduled to avoid	Onshore	Provide Public Access Plan to CSLC staff for review and approval	Prior to and during ~~decommissioning~~ Proposed Project activities	Applicant ~~and~~/or contractor	Reduce potential impacts related to public access

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	weekends and holidays to maximum extent possible. The plan shall be submitted to California State Lands Commission staff for review and approval a minimum of 30 days prior to ~~decommissioning~~ Proposed Project activities.					
	APM-18: Notification to Local Mariners. The Applicant ~~and/~~or its contractor shall be responsible for Local Notices to Mariners (as per U.S. Coast Guard requirements) and compliance with all navigational protocols of the U.S. Department of the Navy, including vessel and diving restrictions in the Proposed Project's offshore area. The notifications shall include the location of moored vessels, likely transit routes, and approximate dates, durations, and working hours. The notices shall be submitted prior to start of any offshore activities and electronic copies posted for review by California State Lands Commission and California Coastal Commission staffs.	Offshore	Compliance	Prior to offshore ~~decommissioning~~ Proposed Project activities	Applicant or contractor	Reduce potential impacts to recreation and public access
REC-3: Create Hazards for Recreationists	**Implement MM REC-1a and APM-18 (provided above).**					
Transportation and Traffic						
TR-1: Reduce Local Transportation and Circulation	**Implement MM REC-1b (provided above)**					
	APM-19: Emergency Services Access. The Applicant or its contractor shall coordinate with U.S. Marine Corps Camp Pendleton, San	Onshore	Compliance	Prior to and during ~~decommissioning~~	Applicant or contractor	Reduce potential impacts to

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
	Diego County, and the City of San Clemente prior to road/lane closures to ensure that Proposed Project activities and associated road and lane closures would not significantly affect emergency response vehicles.			Proposed Project activities		traffic and transportation
	APM-20: Oversize/Overweight Loads. Prior to the first transport of an oversize/overweight load, the Applicant ~~and/~~or its contractor shall coordinate with the California Department of Parks and Recreation to establish protocols to ensure that equipment, components, and materials, including heavy haul loads, being transported to/from the site as part of the Proposed Project via Basilone Road (Old Pacific Highway) and across associated bridges (San Onofre Creek and Railroad Overhead) would not exceed established limitations or safe operating conditions.	Onshore	Compliance	Prior to and during ~~decommissioning~~ Proposed Project activities	Applicant or contractor	Reduce potential impacts to traffic and transportation
TR-2: Reduce Pedestrian and Bicycle Rider Safety	**Implement MM REC-1a (provided above)**					
	APM-21: Pedestrian and Bicycle Access and Safety. To minimize impacts associated with temporary access to local sidewalks or other pedestrian or bicyclist rights-of-way, the Applicant or its contractor shall coordinate with the California Department of Parks and Recreation to ensure that appropriate steps are taken to ensure continued pedestrian and bicyclist access and safety. Steps may include providing alternative access paths, signage, and advance notification.	Onshore	Compliance	Prior to and during ~~decommissioning~~ Proposed Project activities	Applicant or contractor	Reduce potential impacts to traffic and transportation

Table 7-1. Mitigation Monitoring Program

Potential Impact	Mitigation Measure (MM)	Location	Monitoring / Reporting Action	Timing	Responsible Party	Effectiveness Criteria
TR-5: Reduce Marine Vessel Safety	**APM-22: Private Aids to Navigation.** If required, the Applicant or its contractor shall obtain or update a permit from the U.S. Coast Guard for Private Aids to Navigation prior to the start of offshore activities. The permit shall include any buoys or other markers used as part of the Proposed Project and appropriate methods to install and maintain said markers.	Onshore	Compliance	Prior to and during ~~decommissioning~~ offshore activities	Applicant or contractor	Reduce potential impacts to traffic and transportation
	Also, implement APM-9, APM-15, and APM-18 (see above)					

Attachment C

SUMMARY OF NUCLEAR REGULATORY COMMISSION REGULATIONS RELATED TO RADIOLOGICAL MATERIALS STORED OR GENERATED AT DECOMMISSIONED NUCLEAR PLANT FACILITIES

The U.S. Nuclear Regulatory Commission ("NRC" or "Commission") is the federal agency with plenary regulatory authority over all domestic nuclear power plant facilities, including activities related to radiological controls, and the licensing and storage of radioactive waste and spent nuclear fuel ("SNF"), for both operating and shutdown nuclear power facilities. Throughout the life of the plant, NRC maintains oversight of all radiological activities through a comprehensive regulatory and inspection regime to ensure strict compliance with the Commission's regulations for the protection of public health and safety, the common defense and security, and the environment. This oversight is maintained long after a plant ceases operation, throughout the decommissioning process and through license termination. NRC's inspection and regulatory programs generally address all aspects and stages of a nuclear power plant's life, but there are also more-specific provisions that address different activities and plant stages. Summaries of key nuclear regulatory controls are provided below.

Radiological Controls During Decommissioning

NRC regulations in 10 C.F.R. Part 20, "Standards for Protection Against Radiation" are applicable to all nuclear power plants—operating and shutdown—and establish mandatory dose limitations to protect both site workers and members of the public. The regulations found in Part 20 establish comprehensive standards for protection against radiation resulting from activities of NRC licensees and are intended to control, among other things, the possession and use of licensed radioactive materials such that the total dose to an individual member of the public does not exceed strict radiation protection standards.

Pursuant to 10 C.F.R. § 20.1301(a), licensees must conduct operations so that the total dose above background at the boundary of unrestricted areas (*i.e.*, areas for which access is not limited or controlled by a licensee) does not exceed 100 millirem ("mrem") in a year to individual members of the public. Furthermore, 10 C.F.R. § 20.1301(e) incorporates by reference the U.S. Environmental Protection Agency ("EPA") environmental radiation protection standard found at 40 C.F.R. § 190.10. Section 190.10 imposes dose limits on any member of the public resulting from planned discharges of radioactive materials to the general environment from nuclear power plant operations.

To demonstrate compliance with dose limits for members of the public, 10 C.F.R. § 20.1302 requires that licensees conduct regular extensive surveys of radiation levels in both unrestricted and controlled areas, and of radioactive materials in effluents released to unrestricted and controlled areas. In addition to the Part 20 and EPA limits, 10 C.F.R. Part 50 places additional restrictions on public dose from nuclear power plants. Specifically, 10 C.F.R. § 50.36a imposes mandatory conditions in the form of Technical Specifications (*i.e.*, enforceable license conditions) on effluents from nuclear power plants. These specifications are intended to keep radiological releases to unrestricted areas "as low as reasonably achievable" ("ALARA").

Appendix I to 10 C.F.R. Part 50 provides numerical guidance on design objectives and limiting conditions for effluents from power reactor to meet the ALARA requirement. The numerical design objectives of Appendix I to Part 50 are a fraction of the Part 20 limits (including the EPA 40 C.F.R. § 190.10 limits) and, therefore, highly conservative.

As noted, decommissioning reactors continue to be licensed by the NRC and must comply with NRC regulations and conditions specified in the license, including those related to radiological safety. As documented in NRC's comprehensive "Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities," NUREG-0586, doses to individual workers and members of the public during decommissioning activities are expected to be well below the regulatory dose standards in 10 CFR Part 20 and Part 50. Therefore, the NRC has made the generic conclusion, applicable to all decommissioning reactors, that the radiological impacts of nuclear plant decommissioning activities are SMALL. SMALL is defined by the NRC as "not detectable" or very minor.

To ensure the effectiveness of and compliance with the above regulations, NRC mandates that licensees, including those in decommissioning, regularly monitor the environment in the vicinity of the nuclear power plant to assess the cumulative impact of the radioactive material that has been released and submit the results of this environmental monitoring program to the NRC. In addition, during the decommissioning process, the NRC routinely oversees the site activities through inspections of numerous programs including Radiation Protection, Emergency Planning, Security, Engineering, and Operations. Results of these inspections are publicly available.

In summary, the NRC has in place a comprehensive regulatory, inspection, and reporting regime expressly designed to protect the public from unsafe levels of radiation exposure during plant operation and decommissioning. This is consistent with the Commission's position that the Atomic Energy Act requires that the NRC "promulgate, inspect and enforce standards that provide an adequate level of protection of the public health and safety and the environment" and that "[t]he implementation of these regulatory programs provides a margin of safety."

Radiological Criteria for License Termination

Upon completion of site decommissioning activities, the NRC has prescribed criteria in 10 CFR Part 20, Subpart E that must be met in order to terminate a site's NRC Part 50 license. The criteria in this regulation are often referred to as the NRC's License Termination Rule, or "LTR". The rule contains provisions for an unrestricted release and a restricted release of properties and buildings on a licensed site.

In order for a site to achieve license termination with an unrestricted release, the site must prove that any residual radioactivity remaining in soil, groundwater, or on building surfaces is extremely low and results in an average of 25 mrem per year or less to individuals living on the property for the future out to 1000 years. The rule also states that the level of residual radioactivity must be reduced using the ALARA principle which means that for some of the residual radioactivity, a site could be required to remediate radioactivity to levels that are below the 25 mrem criteria. The NRC has also published several additional guidance documents that describe methods to convert the dose criteria (25 mrem) to levels of any residual radioactivity on building surfaces, in soils, or in groundwater using sophisticated modeling software. These levels of radioactivity are referred to as Derived Concentration Guideline Levels, and they are used to design and implement the final site radiological surveys used to demonstrate compliance with the LTR.

As part of implementing the LTR, a licensee must prepare and submit a License Termination Plan ("LTP") to the NRC for review and approval at least 2 years prior to being ready for license termination as required by 10 CFR 50.82.8(C)(vii). The LTP must include the following: (1) a site characterization; (2) plans for site remediation; (3) detailed plans for the final radiation survey; (4) a description of the end use of the site, if restricted; and (5) a supplement to the environmental report, pursuant to § 51.53, describing any new information or significant environmental change associated with the licensee's proposed termination activities.

Safe Storage of SNF

NRC's comprehensive regulatory regime also governs the safe storage of SNF in both spent fuel pools ("wet storage") and in dry storage canisters on an independent spent fuel storage installation ("ISFSI" or "dry storage"). The NRC's requirements for both wet and dry storage are found in Title 10 of the Code of Federal Regulations, including the general design criteria in Appendix A to Part 50 and the SNF storage requirements in Part 72. These rules, which address radiation shielding, heat removal and criticality, ensure that the fuel will remain safe under both operating and accident conditions over long periods of time. In addition, the NRC reviews fuel storage designs for protection against natural hazards, such as seismic events and flooding, dynamic effects, such as drops of fuel storage and handling equipment, and hazards to the storage site from nearby activities. These regulations ensure that both wet and dry storage systems provide adequate protection of the public health and safety and the environment.

The NRC authorizes storage of SNF at an ISFSI under two licensing options: general license and site-specific license. A general license authorizes licensee to store SNF in NRC-approved casks at a site that is licensed under 10 CFR Part 50. Licensees are required to perform detailed evaluations of their site to demonstrate that the site is safe for storing SNF in dry casks. These evaluations must show that the cask Certificate of Compliance conditions and technical specifications can be met, including analysis of earthquake events and tornado missiles. The licensee must also review their security program, emergency plan, quality assurance program, training program and radiation protection program, and make any necessary changes to incorporate the ISFSI at its reactor site. The SONGS ISFSI is authorized under these general license provisions.

Under a site-specific license, an applicant submits a license application to NRC, and the NRC performs a technical review of all the safety aspects of the proposed ISFSI in accordance with the requirements of 10 CFR Part 72. The application must address the safety and operational characteristics of the facility, including the site seismic and environmental conditions, the planned storage system, an accident analysis, and the radiological impact of normal operations. If the application is approved, the NRC issues a license that is valid for up to 40 years. A spent fuel storage license contains technical requirements and operating conditions (fuel specifications, cask leak testing, surveillance, and other requirements) for the ISFSI and specifies what the licensee is authorized to store at the site.

The 10 CFR Part 72 site-specific license process also applies to the licensing of a consolidated interim storage facility ("CISF"), including CISFs proposed by Holtec International in Lea County, New Mexico and by Interim Storage Partners LLC in Andrews, Texas. The review and approval of a CISF license is, therefore, under the exclusive regulatory jurisdiction of the NRC. The Department of Energy ("DOE") could be involved in the project if it contracts with the licensee for the CISF for the storage of utility SNF on the CISF or through the transportation of the SNF to the ISFSI, but DOE is not responsible for the licensing or operation of the facility itself.

The NRC has generically addressed, through a generic environmental impact statement ("GEIS") and rulemaking, the environmental impacts of continued storage of SNF at reactor sites and away-from-reactor sites after a reactor's licensed life for operation and until a permanent repository becomes available. The NRC's analyses and conclusions are documented in the GEIS for Continued Storage of Spent Nuclear Fuel, NUREG-2157, and codified in 10 CFR 51.23. This is referred to as the Continued Storage Rule ("CSR").

Because the timing of repository availability is uncertain, the CSR GEIS analyzes potential environmental impacts over three possible timeframes: a short-term timeframe, which includes 60 years of continued storage after the end of a reactor's licensed life for operation; an additional 100-year timeframe (60 years plus 100 years) to address the potential for delay in repository availability; and a third, indefinite timeframe to address the possibility that a repository never becomes available. All potential impacts in each environmental resource area are analyzed for each continued storage timeframe.

For the first timeframe, which for SONGS runs through around 2073, NRC has determined that the environmental impacts of continued storage of SNF are all SMALL. The NRC has also determined that the environmental impacts of postulated accidents involving continued storage of SNF in spent fuel pools are also SMALL because all important safety structures, systems, and components involved with spent fuel storage are designed to withstand design basis accidents without compromising safety functions. Similarly, impacts of postulated design basis accidents in dry cask storage are SMALL, as all NRC-licensed dry cask storage systems are designed to withstand all postulated design basis accidents without any loss of safety functions.

Disposition of Radioactive and Clean Waste

For operating and decommissioning nuclear power plants, 10 C.F.R. Part 20 (Subpart K) provides for four methods for disposing of materials containing radioactive materials, including the following:

- By transfer to a facility that is specifically licensed to receive the quantity and type of radioactive materials (such as a radioactive waste disposal site);

- By decay in storage;

- By release through monitored effluent pathways controlled by specific release limits in 10 CFR Part 20;
- As authorized by the NRC under other provisions of 10 CFR Part 20.

For all of the above options, a general requirement is that the radioactive material is known and quantified. There are no allowances for unconditionally releasing any items which have detectable surface radioactive material or detectable radioactive material within soils or liquids. To address this, the NRC has issued numerous guidance documents that describe the level of rigor that should be used to measure the presence of surface or volumetric radioactivity for materials that are released from sites that have the potential to contain licensed radioactive material. These guidance documents discuss methods that should be used to measure the potential presence of very low levels of radioactivity on equipment surfaces and other volumetric materials (*i.e.* sludge and soils) and if no radioactivity is detected using these methods, the materials can be released as non-radioactive, or clean.

DOE'S Spent Fuel Removal Obligations

Pursuant to 10 CFR 50.54(bb), licensees of nuclear power plants must, within 2 years following permanent cessation of operation, submit to the NRC for review and approval, the plan by which the licensee intends to manage and provide funding for the management of all SNF at the reactor site, until title and possession of the SNF is transferred to DOE for its ultimate disposal. This is referred to as an Irradiated Fuel Management Plan ("IFMP"). In addition, pursuant to 10 CFR 50.82(a)(4)(i), the licensee must submit a post-shutdown decommissioning activities report ("PSDAR"). A site-specific decommissioning cost estimate, containing the projected cost of managing SNF, is part of the PSDAR.

To prepare the IFMP and PSDAR, licensees must make certain assumptions regarding the expected duration of storage of SNF at the site and timing of DOE removal. But the plan and schedule for the shipment of SNF stored on a nuclear site is currently affected by several constraints. First, an off-site location for disposal must be available. Current law (i.e., the Nuclear Waste Policy Act of 1982, as amended) requires that utilities store SNF and high-level waste ("HLW") on-site until it can be shipped to the Yucca Mountain Repository for permanent disposal. The second is the agreement between the DOE and licensees, including SCE, known as the Standard Contract, which defines licensees' and DOE's respective obligations regarding shipments of spent fuel from SONGS and, through similar contracts, with more than 100 operating and closed commercial nuclear power plants. The Standard Contact includes several provisions regarding the rate by which fuel could be removed from SONGS by DOE, including priority for shutdown reactors, allocation trading, and by age of the fuel.

In January 2013, DOE released its "Strategy for Management and Disposal of Used Nuclear Fuel and High Level Radioactive Waste." The DOE Strategy contemplates building the capability to begin executing DOE's commitment to address waste disposal within the next ten years (from 2013). Under this Strategy, by 2021, operation would begin of a "pilot storage facility" with an "initial focus on accepting spent fuel from shutdown reactor sites." By 2025, a "larger interim storage facility" would be available and by 2048 a geologic repository would commence operations. The 2013 DOE Strategy document is the most recent information published by DOE regarding its SNF disposal strategy.

But as there are no current efforts by DOE to build any storage facilities, SCE conservatively assumed—generally based on the 2013 DOE Strategy document—that DOE will not begin accepting SNF until 2028. Accordingly, the IFMP projects that offsite shipments of SONGS SNF would begin by 2028 and would continue until 2049, assuming the rate of removal is based on age of the fuel. SCE conservatively did not assume priority for shutdown reactors or acceleration via exchanges of acceptance allocations with other utilities, both of which are provided for in the DOE Standard Contract.

If a long-term or interim storage facility is available sooner, it is conceivable that the SONGS SNF stored on the ISFSI could be shipped sooner, assuming the thermal requirements for transportation are addressed. The accelerated removal scenario is based on at least four major actions or assumptions that would have to be addressed in order for the alternative to be viable:

- If a federally operated interim storage facility is to be constructed (as proposed in 2013 by DOE), Congress would likely have to pass legislation modifying the Nuclear Waste Policy Act and authorizing interim storage prior to operation of a repository for disposal.
- At least one interim storage facility would need to be licensed by NRC to receive and store SNF. Two private interim storage facilities are in the early licensing stages: (1) Interim Storage Partners LLC, which resumed its license application process with the NRC on June 8, 2018 following a temporary suspension; and (2) Eddy Lea Alliance, LLC ("ELEA"), which submitted a license application to the NRC on March 31, 2017.
- If a privately operated interim storage facility was to be used, payment or reimbursement of construction or storage costs by DOE associated with interim storage would have to be addressed, likely by Congress or the Administration (Executive Branch). (As noted above, DOE is not directly involved in the licensing of a private interim storage facility.)
- The dry storage canisters containing SNF in the SONGS ISFSI would need to have cooled sufficiently to meet NRC requirements for transportation for the SONGS canister design, and sufficient transportation casks would have to be available to meet an accelerated off-site shipment schedule.
- The transportation/shipment logistics would have to be negotiated successfully by SONGS, waste transportation providers, federal and state agencies and regulators (including DOE, NRC, and the U.S. Department of Transportation ("DOT")), and the interim storage facility.

The transportation of any spent fuel would be strictly controlled in accordance with NRC and DOE regulations and in transportation casks certified by the NRC in accordance with 10 CFR Part 71.

Attachment D

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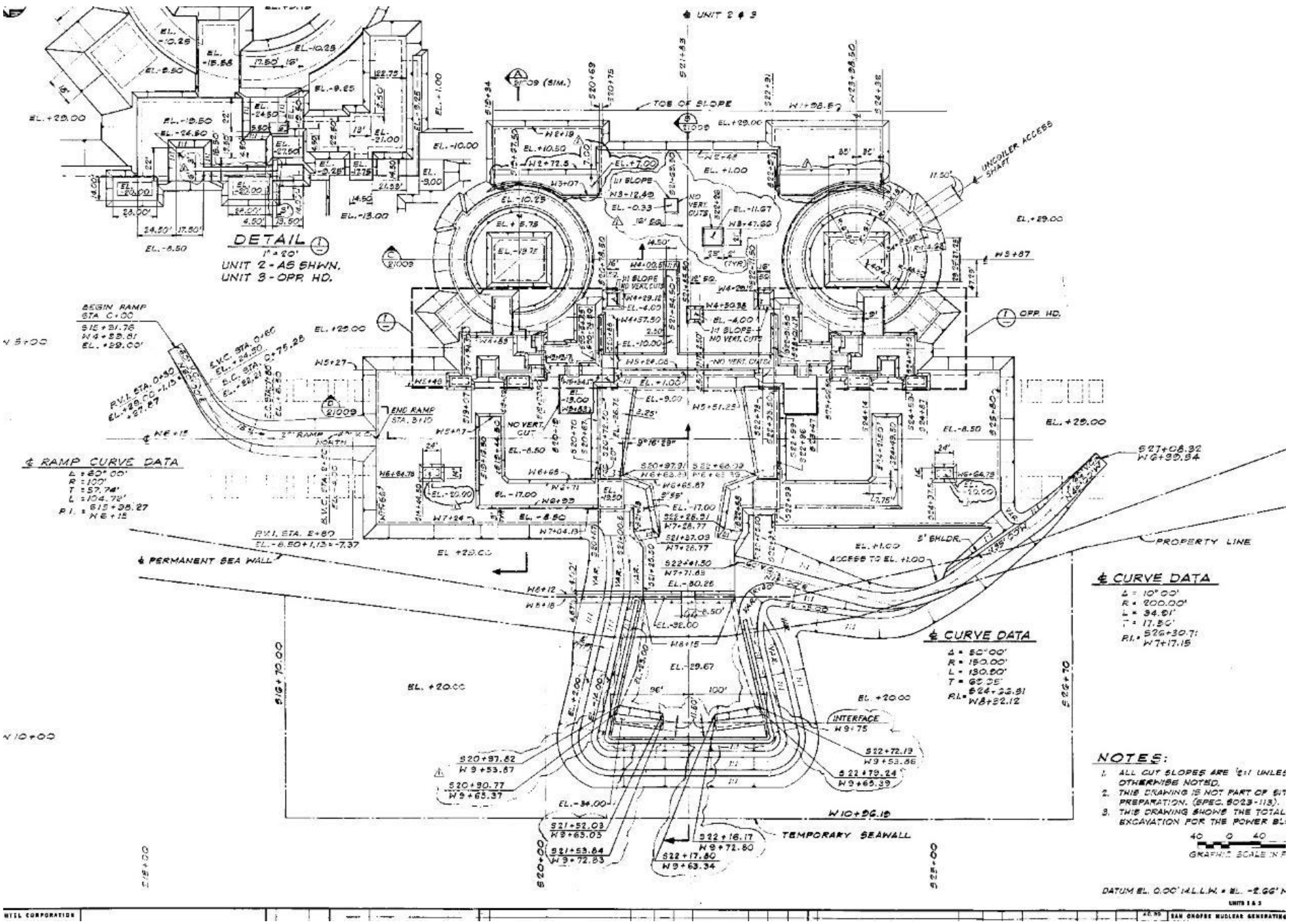
UNIT 2 & 3
TOE OF SLOPE
DETAIL
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UNIT 3 - OPP. HD.
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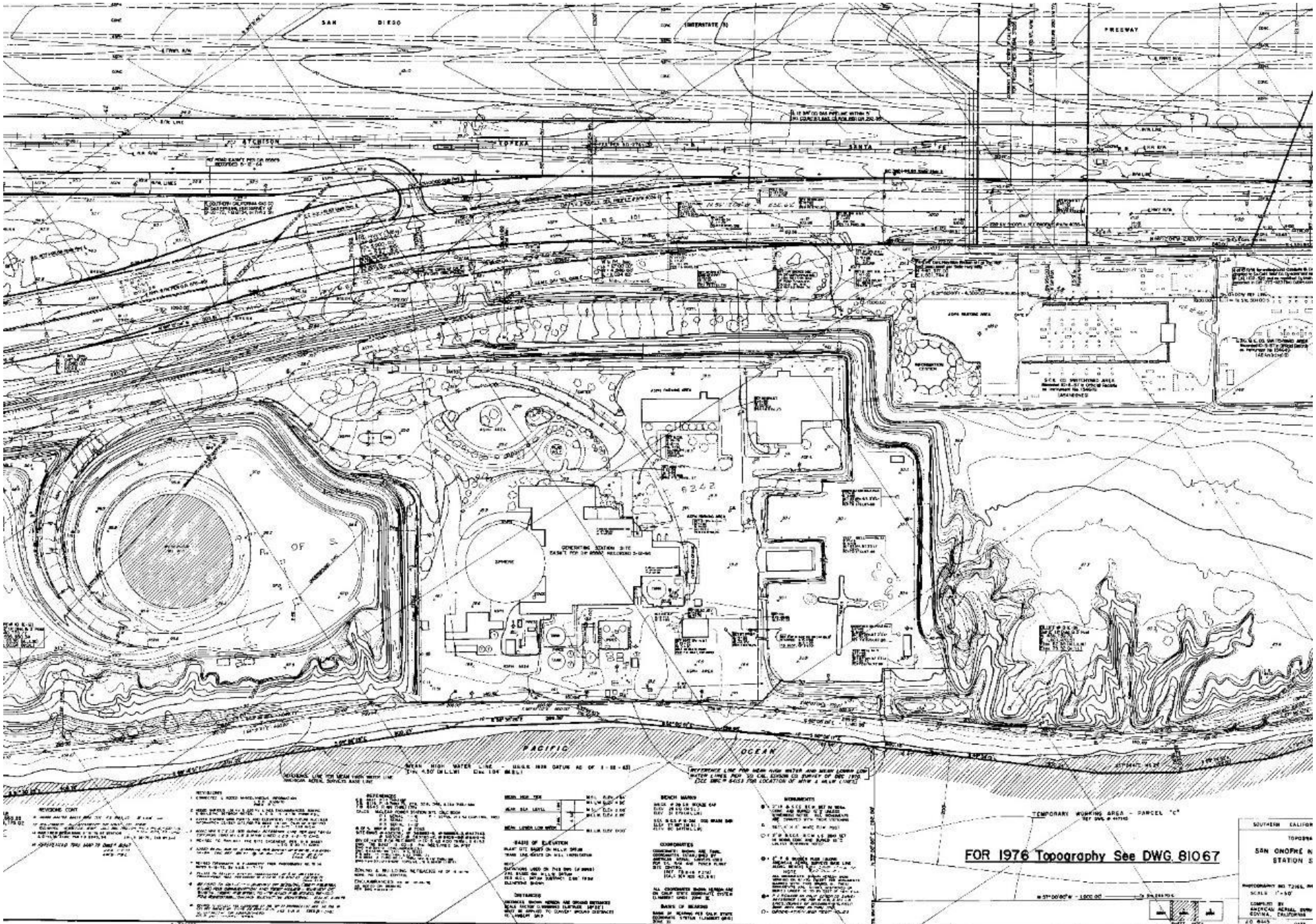
END RAMP
UNCOILER ACCESS SHAFT
OPP. HD.
℄ RAMP CURVE DATA
℄ PERMANENT SEA WALL
PROPERTY LINE
℄ CURVE DATA
INTERFACE
TEMPORARY SEAWALL
NOTES:
1. ALL CUT SLOPES ARE 1:1 UNLESS OTHERWISE NOTED.
2. THIS DRAWING IS NOT PART OF SITE PREPARATION. (SPEC. 5023-113).
3. THIS DRAWING SHOWS THE TOTAL EXCAVATION FOR THE POWER BL
GRAPHIC SCALE IN F
EL. +20.00
EL. +29.00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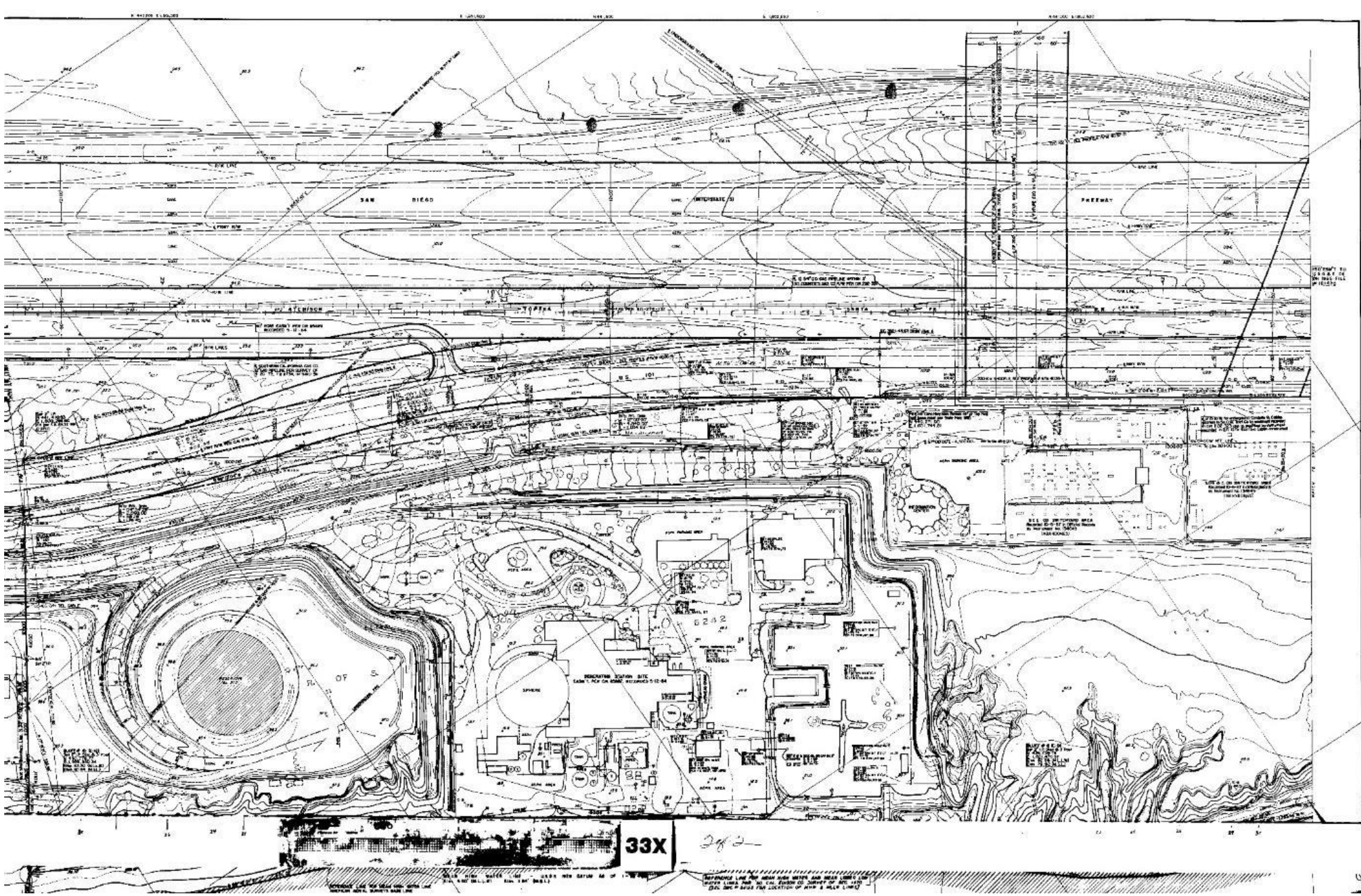
OCEAN
FOR 1976 Topography See DWG. 81067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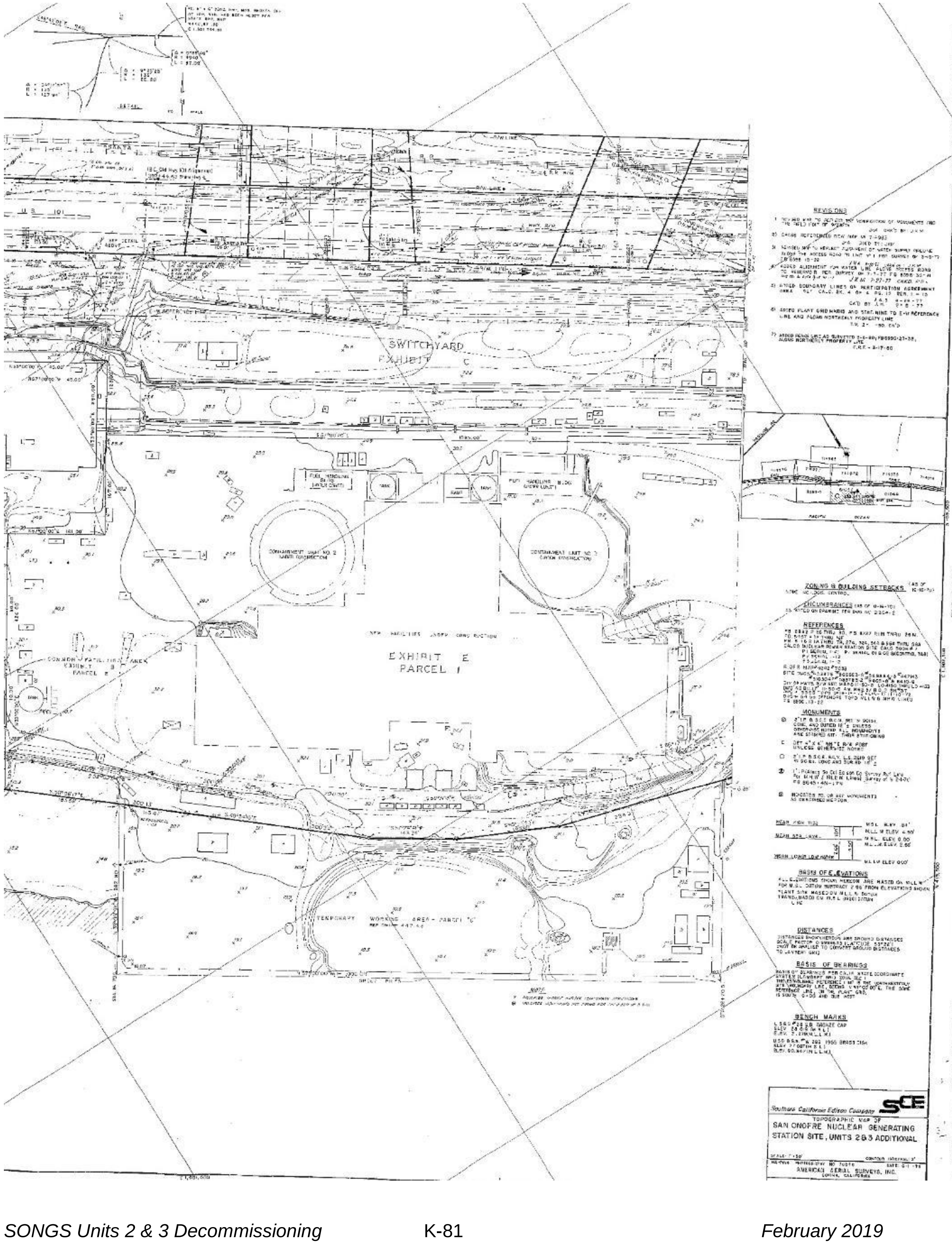


SWITCHYARD
EXHIBIT C
EXHIBIT E
PARCEL 1
REVISIONS
ZONING & BUILDING SETBACKS
REFERENCES
MONUMENTS
BASIS OF ELEVATIONS
DISTANCES
BASIS OF BEARINGS
BENCH MARKS
Southern California Edison Company
TOPOGRAPHIC MAP OF
SAN ONOFRE NUCLEAR GENERATING
STATION SITE, UNITS 2 & 3 ADDITIONAL
AMERICAN AERIAL SURVEYS, INC.

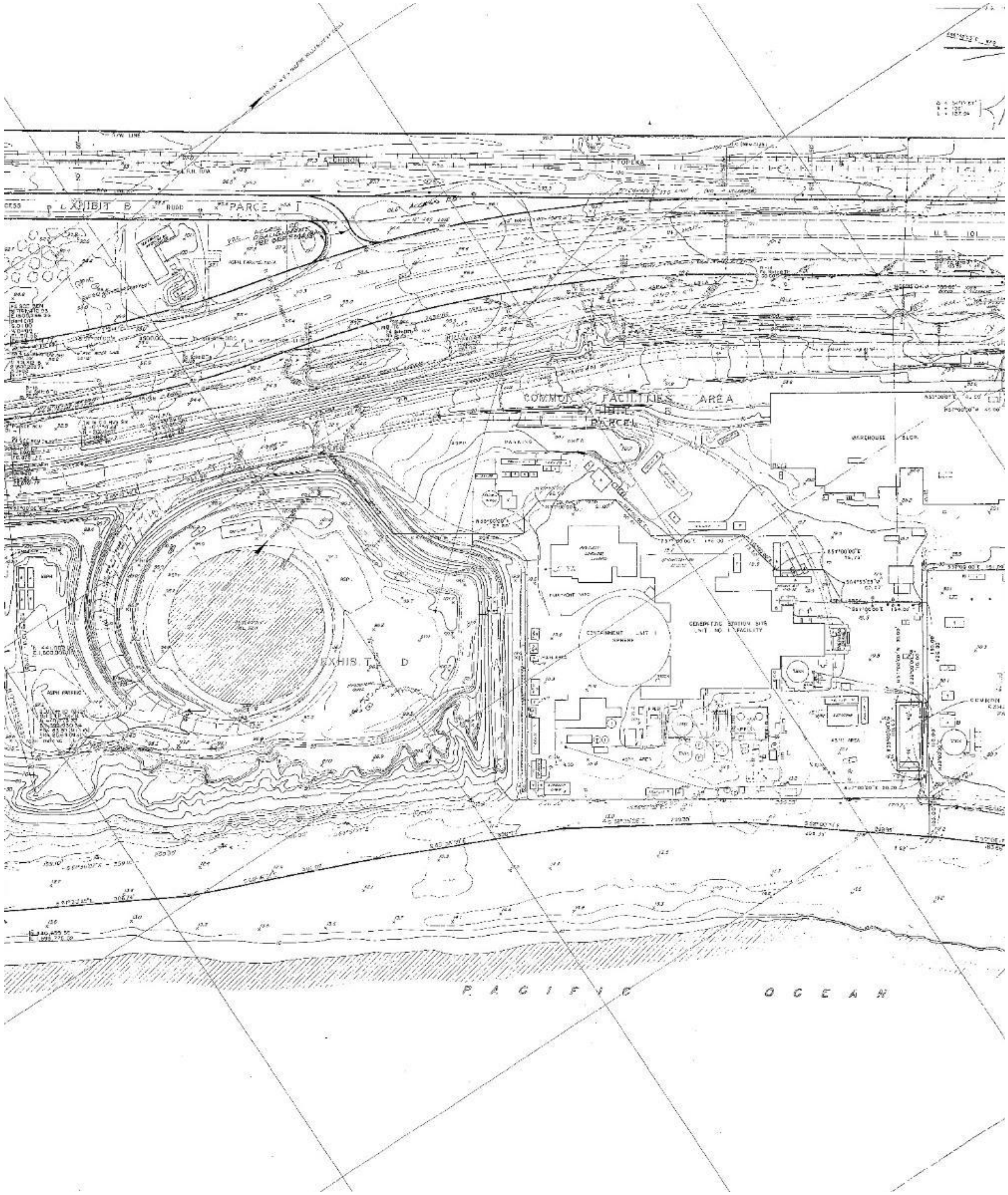
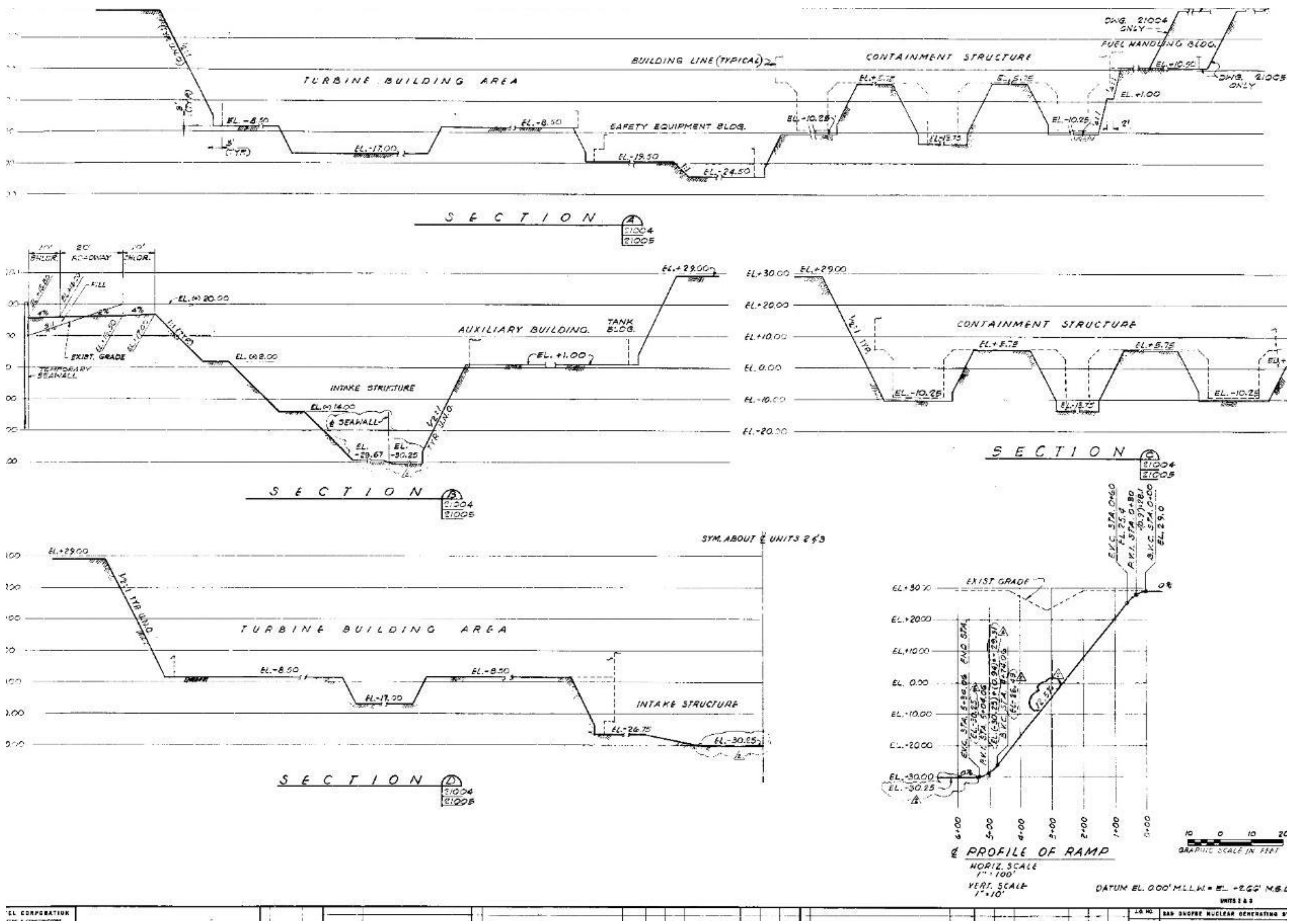


EXHIBIT B
PARCEL
U.S. 101
COMMON FACILITIES AREA
EXHIBIT B
PARCEL
WAREHOUSE
EXHIBIT D
P A C I F I C
O C E A N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BUILDING LINE (TYPICAL)
CONTAINMENT STRUCTURE
FUEL HANDLING BLDG.
SAFETY EQUIPMENT BLDG.
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EL. -19.50
EL. -24.50
EL. -10.25
EL. +1.00
SECTION A 21004 21005
AUXILIARY BUILDING
TANK BLDG.
INTAKE STRUCTURE
EXIST. GRADE
TEMPORARY SEAWALL
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EL. +30.00
EL. +20.00
EL. +10.00
EL. 0.00
EL. -10.00
EL. -20.00
SECTION B 21004 21005
SECTION C 21004 21005
SYM. ABOUT ℄ UNITS 2 & 3
TURBINE BUILDING AREA
INTAKE STRUCTURE
EL. -26.75
EL. -30.25
SECTION D 21004 21005
EXIST GRADE
℄ PROFILE OF RAMP
HORIZ. SCALE 1" = 100'
VERT. SCALE 1" = 10'
GRAPHIC SCALE IN FEET
DATUM EL. 0.00' M.L.L.W. = EL. -2.66' M.S.L.
UNITS 2 & 3
SAN ONOFRE NUCLEAR GENERATING

Attachment E

SAN ONOFRE NUCLEAR GENERATING STATION
LONG TERM SONGS SEISMIC SETTING RESEARCH PROGRAM

SITE CHARACTERIZATION REPORT

Rev 0

March 2013

Prepared for:
Southern California Edison
SONGS – Services
14300 Mesa Road
San Clemente, CA 92672

Prepared by:
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525 N. Cabrillo Park Drive, Suite 280
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GeoPentech

San Onofre Nuclear Generating Station (SONGS)
P.O. Box 128
San Clemente, CA 92672

March 6, 2013
Project No.09024

Attention: Mr. Florin Arsene

Subject: Site Characterization Report Rev0
for the Long Term SONGS Seismic Setting Research Program

Dear Mr. Arsene,

In general accordance with the provisions of our agreement for professional services, we have completed Phases I and II of our work on the subject project and have documented our findings in the accompanying report. The site characterization presented in this report provides material properties, body wave velocity profiles and dynamic properties for use in Probabilistic Seismic Hazard Analyses (PSHAs) and site response analyses (both equivalent linear and non-linear) for SONGS.

We trust that this report meets the present needs of the project. If you should have any questions, please call.

Sincerely,

GeoPentech, Inc. (Federal Tax ID No.33-0909110)

John A. Barneich, CE, GE

Yoshi Moriwaki, PhD, CE, GE

Andrew Dinsick, CE

Steve Duke, RGp, PG, CEG, CHg

525 N. Cabrillo Park Dr., Suite 280, Santa Ana, California 92701
Phone (714) 796-9100 Fax (714) 796-9191 Web Site: www.geopentech.com

RECORD OF SUBMITTALS

Version	Date	Purpose
Rev0	March 1, 2013	Submitted for Southern California Edison review and comment
Rev0	March 6, 2013	Final Rev0 with Southern California Edison comments addressed

SAN ONOFRE NUCLEAR GENERATING STATION
SITE CHARACTERIZATION REPORT

TABLE OF CONTENTS

1. **INTRODUCTION**
   - **1.1 Purpose**
   - **1.2 Site Description**
   - **1.3 Scope of Work**
2. **SITE GEOLOGY AND FOUNDATION CONDITIONS**
   - **2.1 Regional Geologic Setting**
   - **2.2 Local Geologic Setting**
   - **2.3 1-D Base Case Subsurface Profile**
3. **SHEAR AND PRESSURE WAVE VELOCITY PROFILES**
   - **3.1 Data Summary**
   - **3.2 Shear Wave Velocity**
     - 3.2.1 San Mateo Sandstone Shear Wave Velocity Alternative 1
     - 3.2.2 San Mateo Sandstone Shear Wave Velocity Alternative 2
     - 3.2.3 Base Case Shear Wave Velocity
   - **3.3 Compression Wave Velocity**
   - **3.4 Normalized Shear Wave Velocity and Mean Effective Stress Profile**
4. **MODULUS REDUCTION AND DAMPING RATIO CURVES**
   - **4.1 Data Summary**
   - **4.2 Model Development**
     - 4.2.1 Modulus Reduction Modeling
     - 4.2.2 Damping Ratio Modeling
   - **4.3 Base Case Dynamic Properties for Analysis**
     - 4.3.1 San Mateo Sandstone Modulus Reduction Model
     - 4.3.2 San Mateo Sandstone Damping Ratio Model
5. **CONCLUSIONS**
6. **ACKNOWLEDGEMENTS**
7. **REFERENCES**

LIST OF APPENDICES

APPENDIX A Review of Relevant Previous Studies

A-1 Dames & Moore (1970), Seismic and Foundation Studies Proposed Units 2 and 3, San Onofre Nuclear Generating Station

A-2 Woodward-McNeill & Associates (1971), Elastic and Damping Properties Laydown Area, San Onofre Nuclear Generating Station

A-3 Woodward-McNeill & Associates (1972), Material Property Studies, San Onofre Nuclear Generating Station

A-4 Woodward-McNeill & Associates (1973), Stability of Proposed Slopes for Proposed Units 2 and 3, San Onofre Nuclear Generating Station

A-5 Woodward-McNeill & Associates (1974), Liquefaction Evaluation Report Proposed Units 2 and 3, San Onofre Nuclear Generating Station

A-6 Woodward-McNeill & Associates (1974), Development of Soil-Structure Interaction Parameters, San Onofre Nuclear Generating Station

A-7 Woodward-McNeill & Associates (1974), Dynamic Switchyard Slope Stability Confirmation Proposed Units 2 and 3, San Onofre Nuclear Generating Station

A-8 Woodward-McNeill & Associates (1974), Offshore Liquefaction Evaluation for Proposed Units 2 and 3, San Onofre Nuclear Generating Station

A-9 Woodward-Clyde Consultants (1974), Analyses of Properties of Finer-Grained San Mateo Sand, SONGS Units 2 and 3

A-10 Woodward-Clyde Consultants (1975), Analyses of Properties of Finer-Grained San Mateo Sand Encountered in Unit 3 Containment Structure Excavation, SONGS

A-11 Jack C. West (1975), Generalized Sub-Surface Geological and Geophysical Study Capistrano Area, Orange County, California

A-12 Perry L. Ehlig (1977), Geologic Report on the Area Adjacent to the San Onofre Nuclear Generating Station, Northwestern San Diego County, California

A-13 Roy J. Shlemon (1978), Late Quaternary Evolution of the Camp Pendleton - San Onofre State Beach Coastal Area, Northwestern San Diego County, California

A-14 Roy J. Shlemon (1978), Late Quaternary Rates of Deformation Laguna Beach - San Onofre State Beach, Orange and San Diego Counties, California

A-15 Jack C. West (1979), Supplement to the Generalized Sub-Surface Geological and Geophysical Study Capistrano Area, Orange County, California

A-16 Woodward-Clyde Consultants (1979), Summary Report of the Investigation/Demobilization of Construction Dewatering Wells, San Onofre Nuclear Generating Station Units 2 & 3

A-17 P. Ehlig, D. Moore, R. Shlemon, and Woodward-Clyde Consultants (1980), Presentation to NRC/USGS

A-18 Roy J. Shlemon (1987), The Cristianitos Fault and Quaternary geology, San Onofre State Beach, California

A-19 Construction Photographs, San Onofre Nuclear Generating Station Units 2 and 3

APPENDIX B Current Field Investigations

B-1 Cone Penetration Tests

B-2 Core Borings

B-3 Rotary Wash Borings

B-4 Borehole Geophysics (GeoVision)

B-5 Downhole Seismic Measurements (GeoPentech)

APPENDIX C Current Laboratory Testing

C-1 Density Measurements and Gradation Analyses

C-2 Petrographic Analyses

C-3 Biostratigraphic Analyses

C-4 Dynamic Property Testing (University of Texas at Austin)

C-5 Dynamic Property Testing (Fugro Consultants—Houston)

APPENDIX D Regional and Local Geologic Characterization

APPENDIX E Shear and Compression Wave Velocity Profile Development

APPENDIX F Modulus Reduction and Damping Curve Model Development

APPENDIX G Cyclic Stress-Strain Properties for Nonlinear Site Response Analysis

1.0 INTRODUCTION

1.1 Purpose

This report presents the results of the site characterization model update for the San Onofre Nuclear Generating Station (SONGS) following Regulatory Guide 1.208 (RG 1.208, USNRC, 2007). This report presents a base case, one-dimensional (1-D) subsurface profile and dynamic material properties for use in the site response analyses (both equivalent linear and non-linear). The site response analyses based on results of Probabilistic Seismic Hazard Analyses (PSHAs) will be used to develop horizontal and vertical site-specific, hazard consistent ground motion response spectra (GMRS) for SONGS Units 2 and 3, as described in NUREG/CR-6728 (USNRC, 2001).

1.2 Site Description

SONGS is located in the northwest corner of San Diego County, approximately 62 miles southeast of Los Angeles, 51 miles northwest of San Diego, and 5 miles southeast of San Clemente. A regional location map with an inset of the site is shown on Figure 1-1. Interstate 5 (I-5) bounds the project site to the north, the Pacific Ocean to the south, and the public San Onofre State Beach to the east and west. Three nuclear reactor units have been operational at SONGS. Unit 1 began service in 1968 in what is now the North Industrial Area, and Units 2 and 3 came online in 1983 and 1984, respectively. Unit 1 was taken off line in 1992 and decommissioning began in 1998. For the purposes of developing GMRS, the key area of the site corresponds to the safety-related structures for Units 2 and 3. A site plan showing the key structures is presented on Figure 1-2 and the area of interest is highlighted; this area is referred to as the Units 2 and 3 power block herein.

Construction for Unit 1 began in 1964 with site grading. Surficial terrace deposits were removed from the North Industrial Area, and Unit 1 structures were founded on either fill soils derived from San Mateo sandstone or directly on San Mateo Sandstone (FSAR, 1966). In 1974, construction for Units 2 and 3 also began with the removal of surficial terrace deposits. Foundation elevations for Units 2 and 3 power block structures range from -35 ft, Mean Lower Low Water (MLLW) to +30 ft, MLLW; all safety-related structures were founded on native San Mateo sandstone. Figure 1-3 shows a 3-D model of the as-built Unit 2 and 3 power block foundation excavation with key structure locations and foundation elevations identified. For the purpose of this evaluation, because the finished grade of the SONGS facilities is at elevation +30 ft, MLLW, the control point for defining the GMRS is set at +30 ft, MLLW, as conceptually indicated on Figure 1-3. Additional details of the Units 2 and 3 power block construction are presented in Appendix A.

Previous site studies have employed a mixed and inconsistent nomenclature to describe the San Mateo Formation (cf. 1970s Woodward-McNeill reports in Appendix A). Geologically, the unit is a sandstone; however, the dynamic stress-strain-strength characteristics of sampled materials yield a soil-like behavior. Furthermore, the material is friable upon handling and thus readily sieved. Herein, the native or in-situ San Mateo Formation will be referred to as a sandstone on the basis of its geologic history and classification as such by various sources (e.g., Ehlig, 1977; Tan, 1999b, 1999c). Where the unit has been the source material for recompacted fill on the site, the San Mateo will be referred to as a sand.

1.3 Scope of Work

The scope of work for this Site Characterization Project consisted of two phases:

- Phase one included a review of relevant previous studies, completion of a new field exploration program, preliminary laboratory testing, assessment of the site geology, and development of the shear and compression wave velocity profiles for the site.

- Phase two consisted of laboratory testing on undisturbed samples of San Mateo sandstone to characterize dynamic properties of the foundation materials. The testing was followed by modeling of modulus reduction and damping ratio curves for the site and summary of data relevant to PSHA and site response analysis.

Reports and technical memorandums dating to the 1960s were reviewed for geological, geophysical, and geotechnical information relevant to this site characterization study. A brief summary of the data, observations, and findings presented in each of the most pertinent documents is provided in Appendix A. The deep borings drilled during previous studies were of particular importance in the characterization presented herein; boring B-1 by Dames & Moore (1970) which was advanced 1000 ft in the Unit 2 & 3 power block area and boring 80-WW-2 by Woodward-Clyde (1980) which was advanced 800 ft at the eastern extent of the region of interest.

The current field investigations at SONGS were completed between October 18, 2011 and December 16, 2011. The fieldwork for this site characterization update was completed in agreement with the applicable methods and guidelines in RG 1.132 (USNRC, 2003a). This field exploration program consisted of the following:

- Pushing three Cone Penetration Tests (CPTs) to very shallow refusal in foundation bedrock
- Advancing two core borings (SC-1 and SC-3) including lithologic logging of recovered core and downhole geophysical logging
- Advancing two rotary wash borings (SC-2 and SC-4) including Pitcher barrel sampling, lithologic logging of borehole cuttings, and downhole geophysical logging

Figure 1-4 shows the location of the CPTs, two core borings, and two rotary wash holes completed during our recent subsurface field investigation. The location of the borings and wells completed during previous site investigations which were reviewed for this study, are also shown on Figure 1-4. Data, observations, and the applicable QA/QC documentation are presented in Appendix B.

The laboratory testing program completed for this study consisted of gradation analyses, moisture content measurements, dry unit weight measurements, specific gravity measurements, dynamic property testing, petrographic analyses of the San Mateo sandstone, and biostratigraphic analysis of the underlying Monterey Formation siltstone. The dynamic property testing included resonant column testing, cyclic torsional shear testing, cyclic direct simple shear testing, and monotonic direct simple shear testing, focused on undisturbed samples of the San Mateo sandstone. The laboratory testing for this effort was conducted in general agreement with the applicable methods and guidelines in RG 1.138 (USNRC, 2003b). Discussions of sample selection, specimen preparation, data, observations, findings, and the QA/QC documentation for the laboratory testing are presented in Appendix C.

A detailed assessment of the regional and local geologic setting for the SONGS site is presented in Appendix D. Discussion of the development of shear and compression wave velocity profiles is presented in Appendix E. A detailed description of the dynamic property testing and the model developed for the modulus reduction and damping curves is presented in Appendix F. Discussion of the dynamic property test results identified for use in calibrating the soil models in the non-linear site response analysis are included in Appendix G.

2.0 SITE GEOLOGY AND FOUNDATION CONDITIONS

2.1 Regional Geologic Setting

SONGS is sited within the Peninsular Ranges Province, a geomorphic province defined by the northwest-trending Peninsular Ranges, associated faults, and intervening valleys that continue south into Mexico (Ehlig, 1977; CGS, 2002). The Peninsular Ranges Province is generally composed of Cretaceous granitic rocks intruded into metamorphosed sedimentary and volcanic rocks east of the Newport-Inglewood/Rose Canyon Fault System (located approximately 8 km southwest of SONGS). Tertiary sedimentary rocks and Quaternary sediments overlie basement rocks in depositional patterns closely linked to the tectonic evolution of the region. The rate and style of plate boundary motion between the Pacific and North American plates since the early Pliocene has detached the Peninsular Range Province from the North American plate, emplacing the province on the Pacific Plate.

In the early Miocene (ca. 20 Ma), the Borderland region (offshore southern California) was tectonically active, undergoing east-west crustal extension. Such extension facilitated the development of marine basins in which the San Onofre Breccia and the oldest Monterey Formation facies were deposited. Down-to-the-west displacement on the Cristianitos Fault began in the late Miocene at around 10 Ma (Ehlig, 1980), forming the Capistrano Embayment, a flat-bottomed north-trending structural trough, along the western margin of the fault. The Monterey, Capistrano, and San Mateo Formations were subsequently deposited in the embayment (Ehlig, 1977, 1980; West, 1979). Ehlig (1980) suggests the Cristianitos Fault became inactive during Pliocene time (about 3 to 4 Ma) when the Los Angeles Basin filled with sediments that served as a buttress, prohibiting listric movement (or gravity sliding) on the Cristianitos Fault. Inactivity on the Cristianitos was confirmed by observations of an unbroken and undeformed three-foot thick basal marine gravel layer which directly overlies the Cristianitos Fault at an elevation of about +55 ft, MLLW along the coastal bluffs south of SONGS; amino-acid dating of fossils by Shlemon (1978) suggests this platform is about 125,000 years old. Based on these investigations, it was concluded that the Cristianitos fault is not capable as defined by 10CFR100, Appendix A (SCE, UFSAR). Figure 2-1a shows a 3-D representation of the major geologic units of interest and their relation to the Cristianitos Fault and the Unit 2 and 3 power block based on a geologic map produced by Ehlig (1977); the legend for this map is reproduced on Figure 2-1b. Additional discussion of the regional geologic setting is presented in Appendix D.

2.2 Local Geologic Setting

The major geologic units of interest at the project site consist of the Quaternary marine terrace deposits and Tertiary sedimentary rocks including the San Mateo Formation sandstone, the Monterey Formation siltstone/shale and the San Onofre Breccia. Available well log and boring data, including the borings completed for this study, were used to construct geologic cross sections across the site. Cross section X-Y, which is oriented sub-parallel to the Pacific Ocean and oblique to the Cristianitos Fault, is shown on Figure 2-2a. Cross section Z-Z', which is oriented perpendicular to the Pacific Ocean through the middle of the Units 2 and 3 power block area, is shown on Figure 2-2b. The location of these sections are shown on Figure 2-1a. As seen on these cross sections, the San Mateo Formation is laterally continuous throughout the site area and extends at depth to an elevation of at least -847 ft, MLLW below the Units 2 and 3 power block, based on Boring B-1 by Dames & Moore (1970). It is also noted that the Monterey Formation and San Onofre Breccia are encountered at a shallower depths closer to the inactive Cristianitos Fault, likely due to hanging wall drag near the fault.

The marine and nonmarine terrace deposits overlying the first emergent marine terrace platform at SONGS are the youngest and lowest-elevation of the onshore marine terraces in the area. The terrace is about half a mile wide, and is continuous along the coast to the south. As noted above, southeast of SONGS, these terrace deposits cap the Cristianitos Fault and are not offset nor deformed by the fault (Ehlig, 1977). Prior to site construction, the terrace deposits were at an elevation of about +120 ft, MLLW. Terrace deposits within the North Industrial Area and Units 2 and 3 were removed during construction. Native terrace deposits form the reservoir bluff northwest of the North Industrial Area and the benched slopes along the northeastern edge of the plant. Based on geotechnical borings completed onsite during previous studies and those in this current study, the terrace deposits at SONGS are crudely stratified, composed of sand, silt, and clay with interbedded layers of gravel, cobbles, and boulders up to 2 feet in diameter. Based on geotechnical borings, construction records, and photographs, the contacts between the terrace deposits and the underlying San Mateo Formation were generally observed between an elevation of approximately +40 to +50 ft, MLLW (see Appendix A for more details).

The San Mateo Formation sandstone is locally composed of a massive, coarse grained, light yellow-brown to light gray arkosic sandstone with rare discernible bedding and localized rounded pebble-cobble conglomerate lenses (Ehlig, 1977). Ehlig (1977) notes the San Mateo Formation is likely a facies within the Capistrano Formation, based on stratigraphic relationships in the SONGS area. Well logs in the western San Mateo Basin (about 3 to 5 miles northwest of the plant) show the San Mateo sandstone interfingers with the finer-grained Capistrano Formation (Stetson Engineers, 2007). No datable material has been found in the San Mateo Formation, although stratigraphic relations require an early late Miocene to late Pleistocene age (Ehlig, 1977). Since the start of the Pleistocene, the San Onofre area has been subject to slow regional uplift with occasional eustatic fluctuations of sea level resulting in substantial erosion of the San Mateo Formation (SCE, UFSAR), as discussed below. The San Mateo Formation provides the foundation material for the Units 2 and 3 power block and is discussed in more detail below.

Siltstone and shale rocks of the Monterey Formation underlie the San Mateo Formation at SONGS. The Monterey Formation is locally composed of a dark brown to greenish gray, thinly bedded siltstone/clayey siltstone, laminated diatomaceous shale interbedded with silty shale and siltstone, and a massive coarse-grained arkosic sandstone (Ehlig, 1977, 1980; Stetson Engineers, 2007). The variability is mostly due to different depositional environments: thinly bedded siltstones were deposited in a flat-bottomed, pelagic (marine) environment, whereas coarser sandstones were deposited as grain flow near the heads of submarine fans and/or as submarine channel backfill. These various facies interfinger with one another. The Monterey Formation encountered in Dames & Moore's (1970) Boring B-1 onsite was described as a dark gray siltstone and shale with lenses of sand and occasional gypsum stringers. Within Boring SC-4 in the recent field investigation, the Monterey Formation is described as a dark greenish gray to medium gray siltstone/shale.

The Monterey Formation unconformably overlies the San Onofre Breccia near SONGS (Ehlig, 1977). The San Onofre Breccia unit is locally characterized as a coarse, poorly sorted and irregularly bedded breccia containing sedimentary structures common to alluvial fan deposits that rapidly accumulated on a steeply sloping alluvial fan. None of the borings at SONGS have extended deep enough to encounter the breccia. The deep Woodward-Clyde (1980) boring drilled approximately 500 ft west of the Cristianitos Fault encountered the breccia at a fairly shallow depth due to hanging wall drag near the fault. In that boring, the unit was described as a bluish gray breccia in a moderately to well cemented clay and silt matrix with angular sand- to cobble-sized clasts. Boring logs of Camp Pendleton production wells reviewed for this study similarly describe the San Onofre Breccia as containing unique bluish-hued breccia comprised of igneous and metamorphic clasts, and conglomeratic sandstone with sandy siltstone interbeds. The maximum regional thickness of the breccia is about 4600 to 4900 ft (Ehlig, 1977).

Figure 2-3 shows an annotated excerpt of Ehlig's (1977) stratigraphic column summarizing the geologic units in the vicinity of SONGS. Details of the age, lithology, and local thickness of the key geologic units are presented on this figure. Additional discussion of local geologic setting is presented in Appendix D.

San Mateo Sandstone

The San Mateo Formation is a dense to very dense, thickly bedded to massive, mostly homogenous, coarse-grained sandstone with a few clayey, silty, or gravelly lenses or interbeds. The San Mateo Formation represents submarine fan and channel fill materials which were deposited within the Capistrano Embayment by mass flow and turbidity currents (Ehlig, 1979). The provenance of the deposited material is unknown, but the proximity of the formation to the mouth of the San Mateo Creek suggests that material was derived by erosion of sandstone in the Santa Ana and Santa Margarita Mountains. Several natural exposures of the San Mateo Formation are found in the area surrounding SONGS, including along the bluffs at the site. The San Mateo Formation is laterally continuous throughout the site and extends at depth to an elevation of at least -847 ft, MLLW at the Units 2 and 3 power block (based on Dames & Moore [1970] Boring B-1 between Units 2 and 3) and as deep as -908 ft, MLLW at the northwestern end of the site (based on Boring SC-4 from the current field investigation) as shown on Figures 2-2a and 2-2b.

The in-situ San Mateo Formation has very densely packed grains, mainly the result of high prehistoric vertical overburden pressures and horizontal tectonic stresses. Outcrops of the San Mateo Formation are mapped as high as elevation 750 ft, MLLW and the total thickness of the San Mateo has been inferred to be approximately 2,000 ft (SCE, UFSAR). Because the unit was deposited in a relatively flat trough and uplifted uniformly, it is likely that the prehistoric overburden pressure corresponds to approximately 1,150 ft of overlying San Mateo sandstone across the entirety of the Units 2 and 3 power block which has since been eroded. The maximum prehistoric overburden pressures may correspond to as much as 1500 ft of overlying San Mateo Formation which has since been eroded at the site, based on a local Capistrano—San Mateo Formation package thickness of 2400 ft, less the 900 ft of San Mateo still below sea level at SONGS. Over the last several thousand years, the shoreline near SONGS has been uplifted from below sea level to a nominal elevation of +120 ft, MLLW. Historic overburden pressures for the San Mateo Formation in the free-field profile are therefore correlative to at least 90 ft of overlying material. The resulting in-situ San Mateo sandstone is generally highly over-consolidated with very densely packed grains and a reported relative density of approximately 100% (Woodward-McNeill, 1971, Woodward-McNeill, 1974a and Woodward- McNeill, 1975).

Site photographs taken during the construction of Units 2 and 3 demonstrate the San Mateo Formation is laterally extensive and generally homogeneous in the vicinity of the Units 2 and 3 power block. Several of these photographs are shown in Appendix A-18, and two of the foundation excavation photographs are repeated herein on Figures 2-4a and b. As noted in the site photographs, the excavated San Mateo Formation consistently stood at slopes between 1:2 and 1:4 (H:V) for heights up to 95 ft.

Two distinct facies are discernible in the lithologic descriptions of the San Mateo Formation recorded on the boring logs for the two deep borings (Dames & Moore [1970] Boring B-1 and Boring SC-4 completed for this study). The uppermost facies extends from the top of the unit to an elevation of about -500 ft, MLLW and is characterized by a yellowish brown to dusky yellow color. The lowermost facies extends from an elevation of about -500 ft, MLLW to the base of the unit and is characterized by a light olive gray color. The color change between the two facies appears to be gradational, based on the drill cuttings logged in Boring SC-4. In this study, no other distinct changes were noted through visual inspection of the drill cuttings. Deep borings by Woodward-Clyde (1980) near the Cristianitos Fault and logs from wells completed by Stetson Engineers (2007, 2009) in the San Onofre Creek basin near the plant also record this color change, although at higher elevations. Geophysical velocity logs (in both deep borings) and the resistivity and electric logs (Dames & Moore [1970] Boring B-1) show greater variability in the gray San Mateo Formation; this may be associated with approximately 5- to 20-foot thick layers of harder and softer materials within this facies.

Zones of finer-grained (yellow) San Mateo Sandstone were exposed during site grading operations. Investigations by Woodward-McNeill (1974e) and Woodward-Clyde (1975) found that these zones may be associated with more quiescent depositional environment than the coarser-grained San Mateo Formation. These zones were observed to have a limited extent laterally and with depth in the exposed foundation. Clayey and silty rip-up clasts within parts of the (yellow) San Mateo Formation were exposed during construction and are visible in some of the site construction photos just below the terrace deposits. Based on the geotechnical borings and construction records, these clasts ranged in size from a few inches to tens of feet in diameter and were sparsely distributed throughout the depth of the San Mateo Formation.

Chemical and thin section analyses completed by Woodward-McNeill (1971) indicate that the San Mateo is not cemented by hydrophyllic clay. Furthermore, the unit is not strongly cemented by chemicals and has minimal (if any) intergranular cementation. No authigenic quartz cementation (quartz fusion) was identified at grain contacts. A light reddish brown staining, likely due to iron staining, was commonly observed on grains but did not constitute a cemented agent. Woodward-McNeill (1971) concluded that the apparent cementation of the San Mateo Formation is due primarily to extremely close packing of well-graded angular to round grains, and that capillary tension provides an apparent cohesion and cementation at low moisture contents.

Petrographic analyses on two intact San Mateo Formation samples completed for this study support the conclusions by Woodward-McNeill (1971). Specifically, the results (presented in full in Appendix C-2) indicate the San Mateo is an altered sandstone that likely originated as a coarse to very coarse arkose protolith. The results of the thin section analyses show that the sandstone is composed of about 36% quartz, 30% plagioclase, 30% feldspar, 1-4% clay matrix, and less than 1% other minerals. Plagioclase minerals were found to be locally weakly weathered to clay minerals. Quartz and feldspar grains range from angular to round, and the contacts between grains are tangential. No cement was observed in the thin sections.

The uniformity that is consistently observed within the San Mateo Formation is believed to be a result of the high energy depositional environment and the continuity of the source material. The in-situ density measurements, core sample density measurements, grain size analyses results, and construction photographs suggest that the material properties of the San Mateo should generally be consistent across the Units 2 and 3 power block laterally and with respect to elevation.

During foundation excavation for Units 2 and 3, a total of 220 design verification sand cone density tests were performed on in-situ San Mateo sandstone, in accordance with ASTM D-1556. The results of the 220 in-situ density tests are plotted by location within the Unit 2 and 3 power block foundation on

Figure 2-5. These test results were tabulated in the Woodward-Clyde 1983 report with location specified by grid X and Y coordinates; this grid is shown with the footprint of the power block foundation on Figure 2-5. In this figure, the number of tests within each grid is represented by the number of dots plotted in the grid space and the mean density of the tests in each grid is represented by the color of the grid fill. As observed in the figure, there is no systematic trend in dry density as one moves west (away from the Cristianitos) or north (away from the Pacific Ocean). The density test results of the in-situ tests and the core samples from SC-1 are plotted vs. elevation on Figure 2-6; again, no systematic trend in density is observed with respect to elevation. These observations suggest that the density of the San Mateo is uniformly variable within a fairly tight range and selecting mean values for total unit weight and void ratio for analysis is appropriate.

Additional evidence of lateral uniformity of the San Mateo for the full depth of the formation is suggested by evaluation of the geophysical data, as detailed in Section 3. Figure 2-7 shows the compression wave velocity profiles from Boring B-1 in 1970 (located near the center of the Unit 2 and 3 power block) and boring SC-4 in 2011 (located on the reservoir bluff) plotted vs. elevation; it is noted that these locations had similar surface elevations and stratigraphy and therefore should have roughly equivalent stress profiles making the raw geophysical data comparable. As observed on Figure 2-7, the two borings, which are located over 1,700 ft apart with compression wave measurements made over 40 years apart using different methods have similar compression wave velocities for the full depth of the San Mateo.

The key properties of the San Mateo sandstone are summarized in Table 2-1 and discussed below; this table presents the mean value in bold, the range of observations considered in parenthesis and the number of observations considered in italics. As discussed below, the data summarized in Table 2-1 represent what was determined to be the most representative of the San Mateo in the vicinity of the Units 2 and 3 power block.

Table 2-1 Summary of San Mateo Sandstone Material Properties

Property		**Mean**	Range of Observations	*Number of Observations*
Moisture/Density	Dry Unit Weight γ_d (pcf)	**121**	(113 to 128)	*263*
	Moisture Content w_c (%)	**12**	(9.8 to 14.3)	*43*
	Specific Gravity G_S	**2.65**	(2.64 to 2.69)	*10*
Gradation	Gravel (%)	**2**	(0 to 8)	*70*
	Sand (%)	**88**	(82 to 92)	*70*
	Fines (%)	**10**	(5 to 15)	*70*
	Mean Grain Size D_{50} (mm)	**0.57**	(0.47 to 0.74)	*70*
	Coef. of Uniformity C_U	**11.4**	(7.6 to 18.0)	*70*
	Coef. of Curvature C_C	**1.4**	(1.2 to 1.9)	*70*

The cumulative distribution of San Mateo sandstone dry density measurements is shown on Figure 2-8. As observed in this figure, the in-situ field test results generally fall into a narrow range with a median value of 121 pcf and a mean of 121 pcf. Dry densities of samples from geotechnical borings are also shown on Figure 2-5; the core samples from boring SC-1 are in good agreement with the in-situ tests but the samples on pitcher, SPT, and hand carved samples show lower dry densities. These lower densities are believed to be due to sample disturbance effects and are not believed to be representative of the in-situ dry density of the San Mateo Formation; as such they were not included in the development of the material dry density statistics shown on Table 2-1. For the purpose of interpreting laboratory tests performed on Pitcher samples presented later in the report, the difference between the mean in-situ density and the mean Pitcher sample density suggests a change in void ratio on the order of 0.1 (e_o = 0.36 to 0.46); this corresponds to a change in relative density of 15% (D_R = 100% to 85%).

The cumulative distribution of moisture content measurements for the San Mateo sandstone is shown on Figure 2-9; as observed in this figure, the test results from core samples in SC-1 fall into a narrow range (9.8 to 14.3%) with a median value of 12.0% and a mean of 12.1%. It is noted that results from the field tests are significantly lower than the core runs and the range of results from other types of samples drop below 10%, suggesting that evaporation may have influenced these results. For the San Mateo sandstone, the base case estimate of dry density, moisture content and total unit weight adopted for use in the analyses corresponds to mean values presented in Table 2-1; 121 pcf, 12% and 136 pcf, respectively.

The specific gravity of the San Mateo measured during previous investigations ranged from 2.64 to 2.69 with a mean value of 2.65. Four out of five tests performed during the current investigation showed the same range and same mean specific gravity; one low test (2.49) is considered anomalous and not representative of the San Mateo and was discarded accordingly. A specific gravity of 2.65 was adopted as the best estimate for the San Mateo sandstone and was used along with dry density measurements to estimate initial void ratio for intact specimens tested in this study; this specific gravity is generally consistent with the mineralogical composition of the San Mateo sandstone (quartz and feldspar grains).

Gradation analyses show the sandstone is predominantly composed of well-graded sand, well-graded sand with silt and silty sand (SW, SW-SM, and SM by USCS). As summarized in Appendix C, a total of 830 grain size analysis tests were performed on San Mateo sandstone samples collected during previous investigations and the plant construction; this was supplemented with 70 grain size analysis tests performed during the current investigation. Individual gradation curves of the 830 previous tests were not available for review but the range of tests is shown on Figure 2-10; this range includes the finer-grained San Mateo sandstone samples described above. The results of the 70 grain size analysis tests performed during the current study are plotted over the previous results and it is noted that the current test results generally form a narrow band in the center of the previous test range; these current tests cover an elevation range of +42 to -524 ft (MLLW) and are believed to be more representative of the characteristics of the San Mateo Formation, in general. As summarized in Table 2-1, results from the current study suggest the San Mateo sandstone has mean gravel, sand, and fines contents of 2%, 88%, and 10%, respectively. For the San Mateo sandstone, the best estimate of mean grain size and coefficient of uniformity adopted for use in the analyses corresponds to mean values presented in Table 2-1; 0.57 mm and 11.4, respectively.

The zones of finer-grained San Mateo sandstone which were exposed during site grading operations were found to have slightly lower dry density and slightly higher fines content but the same relative density (approximately 100%) as the coarser-grained San Mateo. Studies by Woodward-McNeill (1974e) and Woodward-Clyde (1975) also showed the finer unit generally has the same static and dynamic strength and stiffness as the more coarse-grained San Mateo; as such, specific properties for this material are not developed herein. Details of the finer-grained San Mateo sandstone characterization carried out by Woodward-McNeill and Woodward-Clyde are presented in Appendix A.

2.3 1-D Base Case Subsurface Profile

The free-field control point is defined as an idealized location in the vicinity of the Units 2 and 3 power block at final grade where no structures exist and no structures affect the ground motions. This provides a common location to specify ground motion response spectra (GMRS) corresponding to free-field motions at the ground surface. At locations where structures exist, the local stress conditions will likely be different than the free-field stress conditions due to high or low bearing stresses imposed by the structures locally at shallow depths below the structures, but that influence will decrease with depth.

For the purpose of this evaluation, because the finished grade in the vicinity the SONGS Unit 2 and 3 power block is at elevation +30 ft, MLLW, the control point surface elevation is specified at +30 ft, MLLW. This elevation represents the post-construction top of the San Mateo Formation, following the excavation of approximately 75 ft of terrace deposits and 15 ft of San Mateo sandstone. As discussed below, the pressure wave velocity data collected at the project site suggests that fully saturated conditions exist below an elevation of approximately -5 ft, MLLW. As such, the ground water table at the site is understood to be nominally at elevation -5 ft, MLLW, additional discussion is provided in Appendices D and E. Based on Boring B-1, the San Mateo sandstone extends to a depth of 880 ft, elevation of -850 ft, MLLW in the free-field profile. Below this depth, the Monterey Formation, San

Onofre Breccia and undifferentiated sedimentary rocks extend to crystalline basement rock located at a depth of approximately 1 km below the free-field ground surface, based on the UFSAR (SCE, 2003). The 1-D base case subsurface profile defined for the site response analysis is shown schematically on Figure 2-11. As discussed below, base case dynamic properties have been developed for the full depth of the San Mateo sandstone.

3.0 SHEAR AND PRESSURE WAVE VELOCITY PROFILES

3.1 Data Summary

The body wave velocity profile within the San Mateo Formation under the site free-field surface elevation (+30 ft, MLLW) was evaluated based on in-situ borehole shear wave velocity (V_S) and compression wave velocity (V_P) measurements. Velocity data were collected using the OYO Suspension PS Logging System (OYO Suspension System) in all three boreholes (SC-1, SC-2 and SC-4) drilled during the 2011 field investigations. Previously, compression wave velocity measurements were collected in boring B-1 (Dames and Moore, 1970) using Sonic logging at the time of drilling. A summary of the body wave velocity measurements used to develop the shear and compression wave velocity model for the San Mateo sandstone is shown on Figure 3-1. The shear wave velocity profile shown for boring B-1 on Figure 3-1 is inferred from the compression wave velocity data using elastic theory and a smoothed profile of Poisson's ratio vs. elevation obtained from boring SC-4. This is considered appropriate based on the general uniformity of the material, as discussed in Section 2.2 and the similarity of the compression wave velocity profiles shown on Figure 2-7. Additional details of the development of these data are presented in Appendix E.

Body wave velocity data were also collected using downhole seismic test methods to supplement the OYO Suspension System data; these data were not explicitly used in the modeling presented herein but were used to support the trends observed and conclusions developed using the OYO data, as discussed in Appendix E. Regional crustal velocity models were evaluated to provide an understanding of the velocity profile below the bottom of the OYO Suspension System measurements (approximate elevation -1,020 ft, MLLW). The following subsections present the model development and base case velocities for the 1-D subsurface profile. A detailed discussion of the development of the body wave velocity profile is included in Appendix E.

3.2 Shear Wave Velocity

3.2.1 San Mateo Sandstone Shear Wave Velocity Alternative 1

Shear wave velocity and small strain shear modulus of sandy materials are understood to be strongly influenced by mean effective stress, σ'_m (e.g., Hardin, 1978). The shear wave velocity for the free-field profile has not been measured directly and the differences between the stress conditions at the boreholes and the free-field profile are not explicitly known. To address this, two interpretations of the measured data were used to develop the base case shear wave velocity model using different assumptions on the stress conditions and their effects on the measured data.

The first interpretation, Alternative 1, uses the assumption that the differences in the in-situ stress conditions between the boreholes and the free-field are small; effectively, the borehole data is used as collected with no corrections. This interpretation is considered potentially appropriate given the very high horizontal stresses that are likely to be locked into the material from the original consolidation and lithification of the sandstone. It has previously been postulated that the consolidation stresses have been supplemented by large horizontal tectonic stresses from the local "squeezing" of the San Mateo sandstone block caused by listric slip on the Cristianitos fault, as described in the UFSAR (SCE, 2003). These horizontal stresses would be significantly higher than the in-situ vertical stress which would make the difference in mean effective stress negligible between the boreholes and the free-field stress profile at any given elevation.

The raw data for SC-1, SC-2, and SC-4 and the inferred data from B-1 between elevation 30 ft and -850 ft, MLLW are presented on Figure 3-2 plotted vs. elevation. As noted in the figure, the data from SC-1 are significantly higher than the rest of the data, which are in strong agreement. If this interpretation of the stress conditions is appropriate, this discrepancy may be a result of the proximity of boring SC-1 to the Cristianitos Fault. This proximity may have caused the tectonic horizontal stresses at this location to be even higher than the San Mateo Formation in the vicinity of the Units 2 and 3 power block; as shown in Figure 2-2a, hanging wall drag along the Cristianitos may have rotated and compressed the geology in the area of SC-1 resulting in higher horizontal stresses near the fault. Because the magnitude of this stress increase is unknown and the stress conditions would be different than the Unit 2 and 3 power block area, the data from SC-1 were not included in the Alternative 1 interpretation.

The remaining three data sets, SC-2, SC-4, and B-1 were locally averaged to develop a layer velocity model as shown on Figure 3-2; this is described in detail in Appendix E. As observed on Figure 3-2, the San Mateo formation has been broken up into 45 layers that generally increase in thickness and shear wave velocity with depth. The layer velocity model captures rapid changes in shear wave velocity using layers as thin as 2.5 feet thick. Layers as thick as 50 feet are used to define deeper layers and portions where the changes in velocity are small.

3.2.2 San Mateo Sandstone Shear Wave Velocity Alternative 2

The second interpretation of the free-field shear wave velocity profile, Alternative 2, was developed to account for differences in vertical effective stress (which, unlike mean effective stress, is considered to be adequately estimated for in situ conditions) at the various locations across the site. The vertical effective stress profiles for each borehole and the free-field were estimated using the logged stratigraphy, a total unit weight for the terrace deposits of 135 pcf, a total unit weight for the San Mateo of 136 pcf, and groundwater elevation of -5 ft, MLLW. Because the ground surface at the boreholes are between 15 and 84 feet higher than the free-field control point, the estimated vertical effective stresses in the free field profile are lower than each boreholes at a given elevation. For this reason, the shear wave velocity data require reductions to develop data sets that represent vertical effective stress conditions equivalent to the free-field profile. This modification was developed using the ratio of the vertical effective stresses at a given elevation raised to a dimensionless exponent, *n*, which represents an empirical parameter to describe the effect of confining stress on the shear wave velocity of the San Mateo sandstone. The function form described below, including the dimensionless exponent, n, is based on the generalized relationship between confining stress and small strain modulus (Hardin, 1978).

As discussed in Appendix E, the parameter *n* was determined experimentally by measuring the shear wave velocity of intact and reconstituted specimens under isotropically consolidated effective stresses ranging from 10 to 320 psi. Figure 3-3 shows the data from intact samples from all three boreholes drilled during the current study as well as samples of San Mateo sand reconstituted to 100% relative density. The left half of Figure 3-3 shows the measured velocities and the right half shows the shear wave velocity normalized by the shear wave velocity of the specimen tested at an isotropic confining stress of 20 psi. The normalized data is presented to focus on the slope of the linear trend rather than the absolute value; the differences in absolute values shown on the left half are likely the results of differences in sample disturbance and void ratio of the specimens tested. As shown on the right half of Figure 3-3, the linear trend in log-log space between shear wave velocity and mean effective stress has a slope of approximately 0.3 which has been adopted as the dimensionless stress exponent, *n,* for the San Mateo sandstone. Using these results, the shear wave velocity modification factors, Δ_{VS}, for the measured data in each borehole at a given elevation were determined as follows:

$$\Delta_{VS} = \left(\frac{\sigma'_{v,FF}}{\sigma'_{v,BH}}\right)^{n}$$

(Equation 3-1)

where:

Δ_{VS} = overburden modification factor for shear wave velocity

$\sigma'_{v,FF}$ = estimated vertical effective stress at a given elevation in the free-field profile

$\sigma'_{v,BH}$ = estimated vertical effective stress at the corresponding elevation in the borehole

n = 0.3, experimentally determined exponent describing the relationship between effective stress and shear wave velocity

The data from all four boreholes modified to represent vertical stress conditions equivalent to the free-field profile are presented vs. elevation in Figure 3-4. As shown on Figure 3-4, the data sets are in general agreement suggesting that horizontal stress conditions may vary slightly between the boreholes but is generally constant across the site. The data near the ground surface has been treated differently because the OCR and K_O values are significantly higher near the ground surface than the rest of the profile due to the vertical effective stress being very low. As such, modifying the borehole data using the vertical stress only would lead to unrealistically low values of shear wave velocity in this zone. To address this, a local average of the data from the upper 35 ft of borehole SC-2 was used without correction to represent the upper 35 ft of the San Mateo in the free-field for Alternative 2. This data set represents direct measurement of the San Mateo sandstone under similar stress conditions as the material in the upper 35 ft of the free-field profile. For the remaining depth of the San Mateo, the four data sets modified for stress conditions were locally averaged with equal weight to develop a layer velocity model as shown on Figure 3-4. As shown on Figure 3-4, the layer velocity model for Alternate 2 uses the same layers developed for Alternate 1.

3.2.3 Base Case Shear Wave Velocity

The layer velocity models for Alternatives 1 and 2 are shown together on Figure 3-5; as observed in the figure, the differences in the models are minor for the full depth of the San Mateo. As such, a single base case shear wave velocity profile within the San Mateo was developed for the site and is shown in black on Figure 3-6. The single base case profile was calculated by giving each alternative equal weight as each was overall considered to be equally credible. To generate random profiles for the site response analysis, the aleatory variability and correlation structure of the shear wave velocity can be adequately captured by the site specific layering and velocity model presented in Appendix C of the Brookhaven National Laboratory Report (Toro, 1996). Based on the data collected within the San Mateo and the uniformity observed at the site, a relatively low standard deviation for shear wave velocity at the site is considered reasonable. The residuals between the Alternative 1 and 2 data sets and the base case shear wave velocity profile adopted are shown in natural log units on Figure 3-7. As noted on the figure, the standard deviation in natural log units decreases with depth from 0.16 at the ground surface to 0.08 at a depth of 150 ft. This is illustrated in Figure 3-8; the base case profile plus and minus 1 standard deviation capture the data well regardless of which alternative data reduction is used.

As noted on Figure 3-8, a rapid increase in shear wave velocity exists between an elevation of approximately -530 and -620 ft, MLLW. This "bump" occurs near the logged contact (approximately elevation -512 ft, MLLW in SC-4 and -530 ft, MLLW in B-1) where the San Mateo Formation transitions from being iron-oxide stained (light yellowish brown) to not being iron-oxide stained (greenish gray), see the log of boring SC-4 in Appendix B-3 and the log of boring B-1 in Appendix A. The iron-oxide staining would suggest that the San Mateo Formation above approximately elevation -512 to -530 ft, MLLW was subjected to weathering and that the material below elevation -512 to -530 ft, MLLW is fresh and unweathered. It is noted that elevation -512 to -530 ft, MLLW is also the approximate deepest elevation of the offshore marine shelf and the estimated elevation of the low sea level stand that occurred approximately 18 kya.

Below the San Mateo sandstone, the Monterey formation siltstone has an average shear wave velocity of 2,800 ft/s and an approximate gradient of 0.5 ft/s/ft based on the two borings that directly measured this unit. The Monterey formation is underlain by San Onofre Breccia and undifferentiated sedimentary rock, which extends to a depth of approximately 3,180 ft below the ground surface (elevation of -3,150 ft, MLLW); this sedimentary rock is underlain by crystalline basement rock, which has a shear wave velocity of approximately 3,000 m/s. The depth and shear wave velocity of the crystalline basement rock is based on the regional velocity model developed by the Structural Geology and Earth Resources Department at Harvard University, designated the CVM-H (Süss and Shaw [2003], updated by Plesch et al. [2011]). Additional discussion of this model and its limitation is presented in Appendix E. The shear wave velocity for the portion of the free-field profile which exists between the Monterey and the crystalline basement is not well constrained by data. As such, the shear wave velocity profile between the bottom of the measured data and the top of the crystalline basement rock was extrapolated using an approximate gradient of 1.0 ft/s/ft which is generally consistent with velocity gradient of the tertiary sedimentary rock over a similar depth range which has been observed in the downhole seismic array at the Varian Well in Parkfield, California (Jongmans and Malin, 1995). It is noted that this gradient falls within the range observed in 79 profiles of Tertiary sedimentary rock from California compiled by Wills and Clahan (2006). The base case shear wave velocity profile for the free-field between the ground surface and the top of crystalline basement rock is shown on Figure 3-9.

Key shear wave velocity parameters for ground motion prediction equations, such as the Next Generation Attenuation relationships (NGA, 2008), include the following:

- $V_{S,30}$: Mean shear wave velocity within the upper 100 ft (30 m) of the site, $V_{S,30}$ from the free-field surface elevation (+30 ft, MLLW).
- $Z_{1.0}$: Uppermost depth below the site free-field surface elevation (+30 ft, MLLW) at which the base case shear wave velocity is equal to or above 3,280 ft/s (1,000 m/s).
- $Z_{2.5}$: Uppermost depth below site free-field surface elevation (+30 ft, MLLW) at which the base case shear wave velocity is equal to or above 8,200 ft/s (2,500 m/s).

The top of seismic bedrock is an additional parameter that is defined by site shear wave velocity measurements for site response analyses. The top of seismic bedrock is defined as the shallowest depth at which the calculated $V_{S,30}$ is equal to or above 2,500 ft/s (760 m/s). Table 3-1 summarizes the estimated shear wave velocity parameters for the site referenced to the free-field surface elevation (+30 ft MLLW). Table 3-1 lists the base case, Alternate 1 and Alternate 2 parameter values. These key shear wave parameters are discussed in detail within Appendix E.

Table 3-1 Summary of the Key Shear Wave Velocity Parameters

	$V_{S,30\ (elev\ 30)}$	$Z_{1.0}$	$Z_{2.5}$	Depth to Top of Seismic Bedrock
Base Case	1,450 ft/s (440 m/s)	735 ft (225 m)	3,180 ft (970 m)	410 ft (125 m)
Alternate 1	1,590 ft/s (485 m/s)	690 ft (210 m)	N/A	370 ft (115 m)
Alternate 2	1,290 ft/s (390 m/s)	830 ft (250 m)	N/A	480 ft (145 m)

*Note: Values in Table 3-1 have been rounded to the nearest 5 ft or m.

Measurement and calculation uncertainties associated with the OYO Suspension System methods and interpretation and the parameters used to calculate stress conditions which can introduce errors in the velocity measurements and overburden stress relationships are discussed in Appendix E.

3.3 Compression Wave Velocity

The recently collected OYO Suspension System P-wave data suggests that the nominal ground water elevation at the site is -5 ft, MLLW. The portion of the San Mateo that exists above this elevation is unsaturated and has a compression wave velocity profile that is best defined by local averaging of the data collected in the upper 35 ft of borehole SC-2.

As discussed above, below elevation -5 ft, MLLW, the compression wave velocity data from borings B-1 and SC-4 have similar values for the full depth of the San Mateo. This is of particular importance given that these borings are located over 1,700 ft apart in distance and the measurements were made over 40 years apart using different techniques. In order to maintain consistency with the base case shear wave velocity profile and the smoothed profile of Poisson's ratio vs. elevation used to develop the B-1 shear wave velocity data set, the base case compression wave velocity for the saturated portion of the San Mateo was developed by combining these two data sets using elastic theory. The profile of the base case compression wave velocity profile for the San Mateo is shown on Figure 3-10 including the unsaturated portion between elevations 30 and -5 ft, MLLW and the saturated portion from -5 to -850 ft, MLLW. The base case compression wave velocity profile for the remaining portion of the free-field was inferred from the base case shear wave velocity using Poisson's ratio estimates of 0.35 for the Monterey, San Onofre Breccia and Undifferentiated sedimentary rock and 0.27 for crystalline basement rock. Using this approach, the crystalline basement rock has an estimated compression wave velocity of 5,000 m/s which is in generally agreement with regional crustal velocity models including the CVM-H (Süss and Shaw [2003], updated by Plesch et al. [2011]). The complete base case compression wave velocity profile in the upper 3,180-feet at the site is shown on Figure 3-11.

In developing the compression wave velocity profile, it is noted and as discussed in Appendix E, the P-wave velocity data from SC-1 was not used due to unknown differences in stress conditions: SC-4 in the unsaturated portion of the San Mateo was not used because borehole casing interference negatively affected the quality of the data, and the P-wave data from boring B-1 was only collected in the saturated zone.

3.4 Normalized Shear Wave Velocity and Mean Effective Stress Profile

Figure 3-11 shows V_s and V_p profiles as a function of elevation. However, for a consistent assignment of V_s, V_p, shear modulus reduction curve, and damping ratio curve in the field, it is desirable to use mean effective stress, σ'_m, as the common independent variable. As noted above, the mean effective stress profile in the free field is a key unknown; this parameter is important for defining the appropriate modulus reduction and damping curves for a given elevation, as discussed in detail in Section 4 below. The lithification of the San Mateo sandstone is likely to have locked in very high horizontal stresses throughout the geologic unit. Therefore the mean effective stress likely reflects a high K_O value (K_O is the ratio of horizontal to vertical effective stress). As discussed above, shear wave velocity for sandy materials is known to depend on mean effective stress. This relationship can take the following functional form:

$$V_S = V_{S1} \times \left(\frac{\sigma'_m}{P_a}\right)^n$$

(Equation 3-2)

where:

V_S = shear wave velocity

V_{S1} = shear wave velocity at mean effective stress of 1 atm

σ'_m = mean effective stress, = $\sigma'_v \times \left(\frac{1+2K_O}{3}\right)$

P_a = atmospheric pressure

n = experimentally determined stress exponent, described above

Based on the numerous specimens tested in the laboratory, the exponent that captures this relationship, n, is approximately 0.3 for the San Mateo sandstone. The shear wave velocity normalized to a mean effective stress of 1 atm, V_{S1}, varied considerably between the specimens tested; laboratory results ranged from 595 to 819 ft/s. This range is likely due to differences in the level of sample disturbance and the initial void ratio of the specimens; the specimens with less apparent sample disturbance and lower void ratios generally had higher calculated V_{S1} values. Even the highest quality samples collected have undergone significant stress relief and non-recoverable changes of interparticle contacts. This suggests that it is likely that the in-situ V_{S1} is some unknown value that is likely higher than the laboratory observations on the highest quality samples.

Because in-situ V_{S1} and K_O are both unknown, the V_S data cannot be used to directly calculate either value for a given layer in the free field. It is believed that the K_O values near the surface are significantly higher because the vertical effective stress is very low. Also, the V_{S1} values in the gray, less weathered portion of the San Mateo sandstone are likely higher, resulting in the "bump" in shear wave velocity observed between elevation -530 and -620 ft, MLLW, as noted on Figure 3-8. Otherwise, based on the uniformity observed within the San Mateo, it is believed that V_{S1} and K_O are generally constant with depth between elevations -5 and -600 ft, MLLW; this assumption is supported by the generally linear increase in shear wave velocity over this interval. As such, these two parameters were estimated by least squares minimization using the two alternative interpretations of free-field V_S described above. The combination of estimated values for V_{S1} and K_O results in an inferred shear wave velocity for any vertical effective stress given the functional form presented above. The estimates of V_{S1} and K_O were calculated as the set of parameters that minimized the sum of squared residuals between the predicted shear wave velocity and the shear wave velocity from the two alternative interpretations, this process is described in detail in Appendix E. Using this process, the best estimates of V_{S1} and K_O were determined to be 875 ft/s and 2.5, respectively. These values are considered reasonable given that the laboratory tests on disturbed samples suggests a V_{S1} of at least 819 ft/s and the geologic history of the San Mateo sandstone suggest high in-situ values of K_O.

Further, a V_{S1} of 875 ft/s implies that intact laboratory specimens tested under mean effective stress conditions estimated for the field conditions are between 0.70 and 0.85 of the corresponding field V_S measurements. This observation is in good agreement with trends presented, for example, by Stokoe and Santamarina (2000), Stokoe et al. (2006), Stokoe (2008), and Stokoe (2011). In these studies, $V_{S,LAB}$ measurements on intact samples of dense soils are consistently lower than their corresponding $V_{S,FIELD}$ measurements. The ratio of $V_{S,LAB}$ to $V_{S,FIELD}$ presented by Stokoe (2008) for the approximate stiffness of the San Mateo is 0.4 to 0.8; this range was based on numerous sites studied for the ROSRINE Project in southern California. The samples of San Mateo sandstone are at the high end of this range, which should be expected given that the intact samples tested were the least disturbed of the samples recovered.

Using these parameters, the mean effective stress was estimated for the full depth of the San Mateo sandstone. Between the ground surface and elevation -600 ft, MLLW, the mean effective stress was back-calculated using the base case shear wave velocity and the estimated V_{S1} of 875 ft/s. Between elevation -600 ft, MLLW and the bottom of the San Mateo, the mean effective stress was calculated using the estimated vertical effective stress and K_O of 2.5. These estimates of mean effective stress were used to guide the assignment of modulus reduction and damping curves to layers in the free field profile as discussed in Section 4 below.

4.0 MODULUS REDUCTION AND DAMPING RATIO CURVES

4.1 Data Summary

The modulus reduction and damping ratio curves for the San Mateo Formation below the site free-field surface elevation (+30 ft, MLLW) were developed using laboratory test results from intact samples of the San Mateo sandstone collected during the current investigation from boreholes SC-1, SC-2, and SC-4. The laboratory testing program consisted of resonant column and cyclic torsional shear tests to measure soil properties in the low-strain (linear elastic) to moderately nonlinear (cyclic shear strain, $\gamma_c < 0.06$ %) range and cyclic and monotonic direct simple shear tests to measure soil properties in the high-strain (nonlinear with $\gamma_c > 0.1$ %) range; these direct simple shear tests were performed under constant volume conditions to approximate undrained behavior. The full set of data considered in modeling the modulus reduction and damping ratio curves for the San Mateo is shown on Figure 4-1; the data in this figure are binned by mean effective confining stress.

The low-strain behavior of the San Mateo sandstone is based on eight multi-stage resonant column and cyclic torsional shear (RCTS) tests. These tests evaluated stiffness and damping properties of the specimens over the linear to moderately nonlinear ranges of shear strains for six stages of confining pressure, with the final stage tested at the approximate stress and OCR conditions corresponding to a specific elevation within the free-field profile similar to the sample elevation. As discussed in Appendix F, two RCTS tests were not used due to specimen void ratio falling outside the appropriate range of in-situ sandstone (i.e., they were considered too disturbed).

The high-strain behavior of the San Mateo sandstone is based on twenty-eight strain-controlled cyclic direct simple shear (cDSS) tests and five monotonic direct simple shear (mDSS) tests on intact specimens. Each direct simple shear test specimen was consolidated past the estimate of in-situ vertical stress and unloaded to the estimated vertical effective stress in the free-field profile for the elevation corresponding to the sample elevation. The specimens were then tested under constant volume (i.e., undrained) loading conditions. This process attempted in a reasonable way to capture in the laboratory nonlinear soil behavior under the in-situ effective vertical stress and OCR conditions for specific elevations in the free-field profile using samples obtained from similar elevations. It is noted that the high horizontal stresses that likely exist in the field cannot be easily re-created in the laboratory setting using a standard NGI-type direct simple shear testing device. As such, to interpret the initial mean effective stress for each test, the horizontal stresses were estimated using a $K_{O,DSS}$ of 0.34 times the maximum vertical consolidation stress in the laboratory; this value of $K_{O,DSS}$ is based on a friction angle of 41° for the San Mateo sandstone, as reported in the UFSAR (SCE, 2003) and the theoretical relationship between K_O and friction angle (Jaky, 1944). As discussed below, the estimate of the mean effective stress for each set of tests was then used to match the high-strain data with the corresponding low-strain data for modeling the modulus reduction and damping curves for that particular mean effective stress.

Tests on intact specimens which had measured dry densities outside the range of in-situ field measurements (γ_d < 115 pcf) were not explicitly considered in the modeling of dynamic properties but were used to observe and evaluate trends related to the San Mateo in general. Additional tests on reconstituted specimens were performed to support the understanding of the dynamic soil properties of the San Mateo sandstone. All results from the laboratory testing program are presented in Appendix C; a detailed discussion of the development of the dynamic property models is included in Appendix F.

4.2 Model Development

4.2.1 Modulus Reduction Modeling

The model for the modulus reduction (G/G_{MAX}) curve for the San Mateo sandstone was developed within the framework of the current understanding of nonlinear soil behavior of granular materials. Work by Darendelli (2001), Menq (2003), and Stokoe (2011) was used as the basis for the G/G_{MAX} model. Specifically, the "hyperbolic model" was selected as the functional form for the San Mateo G/G_{MAX} model:

$$\frac{G(\gamma_c)}{G_{max}} = \frac{1}{1+\left(\frac{\gamma_c}{\gamma_r}\right)^{\alpha}}$$

(Equation 4-1)

where:

$G(\gamma_c)$ = shear modulus at a given cyclic shear strain

G_{max} = maximum shear modulus at very small shear strains

γ_c = cyclic shear strain amplitude in percent

γ_r = pseudo-reference strain in percent

α = coefficient of curvature

In the equation above, γ_r, pseudo-reference strain and coefficient of curvature, α effectively serve as curve fitting parameters for the hyperbolic model. The following considerations are pertinent in specifying the above equation:

- It has been observed by Darendelli (2001), Menq (2003), and Stokoe (2011) that mean effective stress, σ'_m, has a first order influence on γ_r and α for a given material.
- Work by Darendelli (2001) has shown that for fine-grained materials plasticity index (PI) and OCR may influence γ_r and α.
- Work by Menq (2003) and Stokoe (2011) have shown that factors such as initial void ratio, e_o, mean grain size, D_{50}, and coefficient of uniformity, C_U, have some influence on γ_r and α for granular materials.
- It is commonly observed that the hyperbolic model fit to low-strain data poorly captures stress-strain material behavior at strains higher than approximately 0.5% (Yee et al., 2011).
- Significant differences between field and laboratory small strain shear modulus, G_{MAX}, are commonly observed particularly in very dense or stiff soils and soft rock (e.g., Stokoe, 2008).

The methodology adopted to specify the parameters in Equation 4-1 is illustrated schematically on Figure 4-2. As shown in pane No. 1, γ_r and α are evaluated by least squares fit for each stage of RCTS testing in the low- to moderate-strain range, and γ_r and α are evaluated for each set of DSS tests under the same mean effective stress conditions in the high-strain range. As discussed below, the shear modulus data, G_S, from the DSS tests were normalized using inferred G_{MAX} values to fit the parameters γ_r and α. As shown in pane No. 2, γ_r and α are modeled with respect to σ'_m, OCR, e_o, D_{50}, and C_U; this resulted in equations to calculate low-strain and high-strain G/G_{MAX} relationships for any given set of stress conditions and material properties. Pane No. 3 illustrates the next step which implements a strain hybrid model that captures the G/G_{MAX} from the low-strain model at $\gamma_c < 0.05$ %, captures G/G_{MAX} from the high-strain model at $\gamma_c > 0.5$ %, and smoothly transitions in-between. The final step is shown in pane No. 4 where the preferred G/G_{MAX} model anchored to G_{MAX} at a given confining stress is compared to the high-strain model to evaluate whether the model appropriately represents the laboratory measured shear strength of the material in the nonlinear strain range.

As noted in section 3, the specimens tested in the laboratory had shear wave velocities that were lower than the shear wave velocities measured in the field under the same stress conditions. This is believed to be a result of sample disturbance from stress relief permanently changing the interparticle contacts within the sandstone. Because this disturbance has a strong influence on the low-strain shear wave velocity and shear modulus, the shape of the G/G_{MAX} curve was evaluated by normalizing the data to the lab measured G_{MAX}; the curve is then applied going forward using the G_{MAX} associated with the free-field shear wave velocity based on the following equation:

$$G_{MAX} = \rho \times V_S^2$$

(Equation 4-2)

where:

ρ= mass density of the San Mateo sandstone, = 4.22 lbm/ft^3

V_S = base case shear wave velocity

It is postulated that for the high quality samples with the pre-shear void ratio values being consistent with those in situ, once the shear strain exceeds 0.1% in the laboratory tests, the sample disturbance effects on stiffness and damping may become minor, and stress-strain behavior observed in the laboratory should be an appropriate representation of the likely material behavior in the field with increasing shear strains. As such, the high-strain model was developed using the DSS data normalized by G_{MAX} values that are representative of field conditions. As noted above, in order to carry this out, the pre-shear mean effective stress conditions in the specimens were estimated for each DSS test using the assumption that horizontal stresses were equal to 0.34 times the maximum vertical stress imposed on the sample prior to shearing. This value of $K_{O,DSS}$ is consistent with well known empirical relationships for the friction angle of the San Mateo sandstone of 41°, as reported in the UFSAR (SCE, 2003). Additionally, based on numerous DSS tests performed for the ROSRINE Project in southern California, it has been observed that very dense, highly over-consolidated sandy materials tested at vertical effective confining stresses less than their maximum past pressure, have $K_{O,DSS}$ of approximately 0.3 (Vucetic, 2013) which is in general agreement with the assumption stated above. The estimated in-situ mean effective stress conditions for layers deeper than 150 ft are so high that they exceed the capacity of the direct simple shear testing equipment. As such, the high-strain model curve fitting parameters are capped at the maximum values determined from the laboratory tests, 0.0282% and 0.75 for the reference strain and coefficient of curvature, respectively.

4.2.2 Damping Ratio Modeling

The modeling of damping ratio with respect to cyclic shear strain is also consistent with the current understanding of dynamic soil properties described by Darendelli (2001), Menq (2003), and Stokoe (2011). The basic principle for developing the damping ratio curve is based on Masing's rules; the resulting damping is then scaled using two parameters, D_{MIN}, to account for low-strain damping and *b*, to scale down high-strain damping. Because the parameter *b* specifically scales damping in the high-strain range, the damping based on the Masing rule for the San Mateo sandstone is calculated to be consistent with the γ_r and α from the low-strain G/G_{MAX} model. It has been observed by Menq (2003) and Stokoe (2012) that D_{MIN} is influenced by σ'_m, D_{50}, and C_U; in keeping with these observations, a specific model for D_{MIN} was developed using the results of the cyclic torsional shear test results in the tenth cycle at a loading frequency of approximately 1 Hz. With the damping based on the Masing rule and D_{MIN} evaluated, the scaling parameter *b* was modeled as a function of mean effective stress using a least squares fit approach and the cyclic direct simple shear damping in the tenth cycle at a loading frequency of 1 Hz for cyclic strain amplitudes less than 0.5%, the fifth cycle for cyclic strain amplitudes between 0.5% and 1.0%, the third cycle for cyclic strain amplitudes between 1.0% and 2.0% and the second cycle for cyclic strain amplitudes greater than 2.0%. These cycle number choices are based on judgment that it is unlikely to observe many cycles of larger shear strain levels even under high shaking levels associated with low probability events.

4.3 Base Case Dynamic Properties for Analysis

4.3.1 San Mateo Sandstone Modulus Reduction Model

As discussed above, the material-specific modulus reduction curve, referred to herein as the San Mateo sandstone model, is calculated for a given set of input parameters including σ'_m, OCR, e_o, D_{50}, and C_U; the development of the San Mateo model is detailed in Appendix F. For the San Mateo sandstone model in the free-field profile mean values of e_o, D_{50}, and C_U are assumed so high-strain and low-strain values of γ_r and α are calculated using depth specific estimates of σ'_m and OCR. For a given depth, the mean effective stress was estimated using the procedure described in section 3. OCR for a given depth was estimated using the best estimate of overburden thickness corresponding to 750 ft of San Mateo sandstone; buoyant unit weight was used in this estimate to account for the full deposit only existing below sea level. The simplified equations used to calculate the San Mateo Sandstone model for the free field profile are presented in Table 4-1 below:

Table 4-1 Equations for San Mateo Sandstone Modulus Reduction Model

STEP 1	Calculate Low-Strain Reference Strain, γ_r	$\gamma_r = c_1 \ln\left(\frac{\sigma'_m}{p_a}\right) + c_2\left(\frac{\sigma'_m}{p_a}\right)^{c_3} \times (OCR-1) + c_4$ $c_1 = 0.0037, c_2 = 0.0035, c_3 = 1.330, c_4 = 0.0312$
	Calculate Low-Strain Coefficient of Curvature, α	$\alpha = c_5 \ln\left(\frac{\sigma'_m}{p_a}\right) + c_6\left(\frac{\sigma'_m}{p_a}\right)^{c_7} \times (OCR-1) + c_8$ $c_5 = -0.0145, c_6 = -0.0242, c_7 = 1.0405, c_8 = 1.033$
	Determine Low-strain G/G$_{MAX}$	$\left(\frac{G(\gamma_c)}{G_{max}}\right)_{LS} = \frac{1}{1+\left(\frac{\gamma_c}{\gamma_r}\right)^{\alpha}}$
STEP 2	Calculate High-Strain Reference Strain, γ_r	$\gamma_r = c_9\left(\frac{\sigma'_m}{p_a}\right)^{c_{10}} \le 0.0282\%$ $c_9 = 0.0008, c_{10} = 1.867$
	Calculate High-Strain Coefficient of Curvature, α	$\alpha = c_{11}\left(\frac{\sigma'_m}{p_a}\right)^{c_{12}} \le 0.75$ $c_{11} = 0.4616, c_{12} = 0.2537$
	Determine High-Strain G/G$_{MAX}$	$\left(\frac{G(\gamma_c)}{G_{max}}\right)_{HS} = \frac{1}{1+\left(\frac{\gamma_c}{\gamma_r}\right)^{\alpha}}$
STEP 3	Determine Strain Hybrid G/G$_{MAX}$	$\left(\frac{G(\gamma_c)}{G_{max}}\right)_{SHM} = \left(\frac{G(\gamma_c)}{G_{max}}\right)_{HS} + \left[\left(\frac{G(\gamma_c)}{G_{max}}\right)_{LS} - \left(\frac{G(\gamma_c)}{G_{max}}\right)_{HS}\right] \times \frac{1}{1+\left(\frac{\gamma_c}{0.1}\right)^{1}}$

The G/G$_{MAX}$ curves for the low-strain model are plotted against the subset of the resonant column test data on Figure 4-3; the data on Figure 4-3 has been binned by effective confining stress and represent the first five stages of increasing confining stress in each RCTS test. The G/G$_{MAX}$ curves for the low-strain model are plotted against the resonant column test data from the unloaded sixth stage of each test on Figure 4-4; as noted in the figure, the best fit model for the unloaded data is significantly more linear than the best fit model from the initial loading stages under the same mean effective stress conditions. The G/G$_{MAX}$ curves for the high-strain model are plotted against the direct simple shear test data on Figure 4-5; as noted in the figure, the G$_{MAX}$ values for these curves were based on the parameters determined as discussed above. The G/G$_{MAX}$ curves for the high-strain model are plotted in stress-strain space on Figure 4-6; as expected the dilative behavior of the material is most prominently observed at the lower confining stresses.

Specific details on the functional form of the various components in the preferred model are discussed in detail in Appendix F. As discussed in Appendix F, the preferred model matches the laboratory data used in the regression analysis very well in G/G$_{MAX}$ space; calculated values are within 1.5% of the measured data, on average. The uncertainty and limitations of the San Mateo sandstone modulus reduction model are discussed in detail in Appendix F. The San Mateo sandstone modulus reduction curves are not meant to be used explicitly in the nonlinear analysis per se; cyclic and monotonic direct simple shear tests may be used directly to calibrate the soil models used in the nonlinear analysis as discussed in Appendix G.

4.3.2 San Mateo Sandstone Damping Ratio Model

The San Mateo sandstone damping ratio model is consistent with the approach proposed by Darendelli which uses the damping based on the Masing rule modified by scaling parameters D_{min} and *b*. In the San Mateo sandstone model, D_{min} and *b* are based on σ'_m (mean values of D_{50} and C_U are implicit in the model). The equations used to calculate the San Mateo Sandstone damping model are presented in Table 4-2 below:

Table 4-2 Equations for San Mateo Sandstone Damping Ratio Model

STEP 1	Calculate Masing damping for a coefficient of curvature, $\alpha = 1$	$D_{masing,\alpha=1}(\gamma) = \frac{100}{\pi}\left[4\frac{\gamma - \gamma_r ln\left(\frac{\gamma+\gamma_r}{\gamma_r}\right)}{\frac{\gamma^2}{\gamma+\gamma_r}} - 2\right]$ ***Uses γ_r calculated from the Low-Strain Model*
STEP 2	Adjust Masing damping for Low-Strain model coefficient of curvature, α	$D_{masing}(\gamma) = c_1 \times D_{m,\alpha=1}(\gamma) + c_2 \times \left(D_{m,\alpha=1}(\gamma)\right)^2 + c_3 \times \left(D_{m,\alpha=1}(\gamma)\right)^3$ $where\ c_1 = -1.1143\alpha^2 + 1.8618\alpha + 0.2523$ $c_2 = 0.0805\alpha^2 - 0.0710\alpha - 0.0095$ $c_3 = -0.0005\alpha^2 + 0.0002\alpha + 0.0003$ ***Uses α calculated from the Low-Strain Model*
STEP 3	Calculate D_{MIN}	$D_{MIN} = c_4 \ln\left(\frac{\sigma'_m}{p_a}\right) + c_5 \geq 0.10\%$ $c_4 = -0.3016, c_5 = 1.019$
	Calculate *b*	$b = c_6 \ln\left(\frac{\sigma'_m}{p_a}\right) + c_7$ $c_6 = 0.0255, c_7 = 0.4073$
STEP 4	Final San Mateo Sandstone Damping Ratio	$D_{SMS}(\gamma) = D_{MIN} + b \times D_{masing}(\gamma) \times \left(\frac{G(\gamma)}{G_{max}}\right)_{LS}^{0.1}$ ***Uses Low-Strain Model G/G_{MAX}*

The damping curves fit to the resonant column and torsional shear data in the low-strain range are shown on Figure 4-7; it is observed that D_{MIN} decreases with increasing confining stress. The damping ratio curves for the final model are plotted against the complete set of data considered on Figure 4-8.

The uncertainty and limitations of the San Mateo sandstone damping ratio model are discussed in detail in Appendix F. The San Mateo sandstone damping ratio curves are not meant to be used explicitly in the nonlinear analysis per se; cyclic and monotonic direct simple shear tests may be used directly to calibrate the soil models used in the nonlinear analysis as discussed in Appendix G.

5.0 SUMMARY AND CONCLUSIONS

The site characterization presented in this report provides material properties, body wave velocity profiles and dynamic properties for use in Probabilistic Seismic Hazard Analyses (PSHAs) and site response analyses (both equivalent linear and nonlinear) for SONGS. The free-field control point is defined as an assumed location at the site at final grade where no structures exist; for the purpose of this evaluation the site free-field control point surface elevation is specified at +30 ft, MLLW. The key foundation material of interest is the San Mateo sandstone which extends from the surface of the free-field to an elevation of -850 ft, MLLW. The San Mateo sandstone is very dense, predominantly composed of well-graded sand and homogeneous across the Unit 2 & 3 power block foundation laterally and with respect to elevation. Material properties of the San Mateo sandstone were defined based on a review of previous studies, supplemented with a current site exploration and laboratory testing program. The base case subsurface profile is presented on Figure 2-11.

Shear and pressure wave velocities were evaluated for the San Mateo sandstone using previous and current geophysical data collected at the site. The shear and compression wave velocities of the San Mateo sandstone are strongly influenced by mean effective confining pressure; as such, a model was developed to appropriately interpret the measured data to be applied to the free-field profile. The base case San Mateo sandstone shear wave velocity model is presented in Section 3.3.1, the San Mateo sandstone shear wave velocity profile with respect to elevation in the free-field is presented on Figure 3-8. The base case shear wave velocity profile for the free-field between the ground surface and the top of crystalline basement rock is shown on Figure 3-9

Modulus reduction and damping ratio were evaluated for the San Mateo sandstone using dynamic property laboratory test results from the current investigation. The modulus reduction and damping ratio for the San Mateo sandstone were found to be primarily influenced by mean effective confining pressure and OCR; gradational characteristics and void ratio were found to have some influence on the dynamic properties. The modulus reduction and damping ratio curves were based on the hyperbolic model with modifications to account for difference in low-strain and high-strain behavior as well as differences in field and laboratory measurements of stiffness. In the selected models, modulus reduction and damping curves for the free-field profile are calculated using estimated effective overburden pressures and OCR values. Base case San Mateo sandstone modulus reduction and damping ratio models are presented in Section 4.2.1 and 4.2.2, respectively, the resulting G/G_{MAX} and damping ratio curves for the base case model at twelve elevations within the free-field profile are shown on Figure 5-1. The stress-strain relationships implied by the G/G_{MAX} model at the same twelve elevations are shown on Figure 5-2.

6.0 ACKNOWLEDGEMENTS

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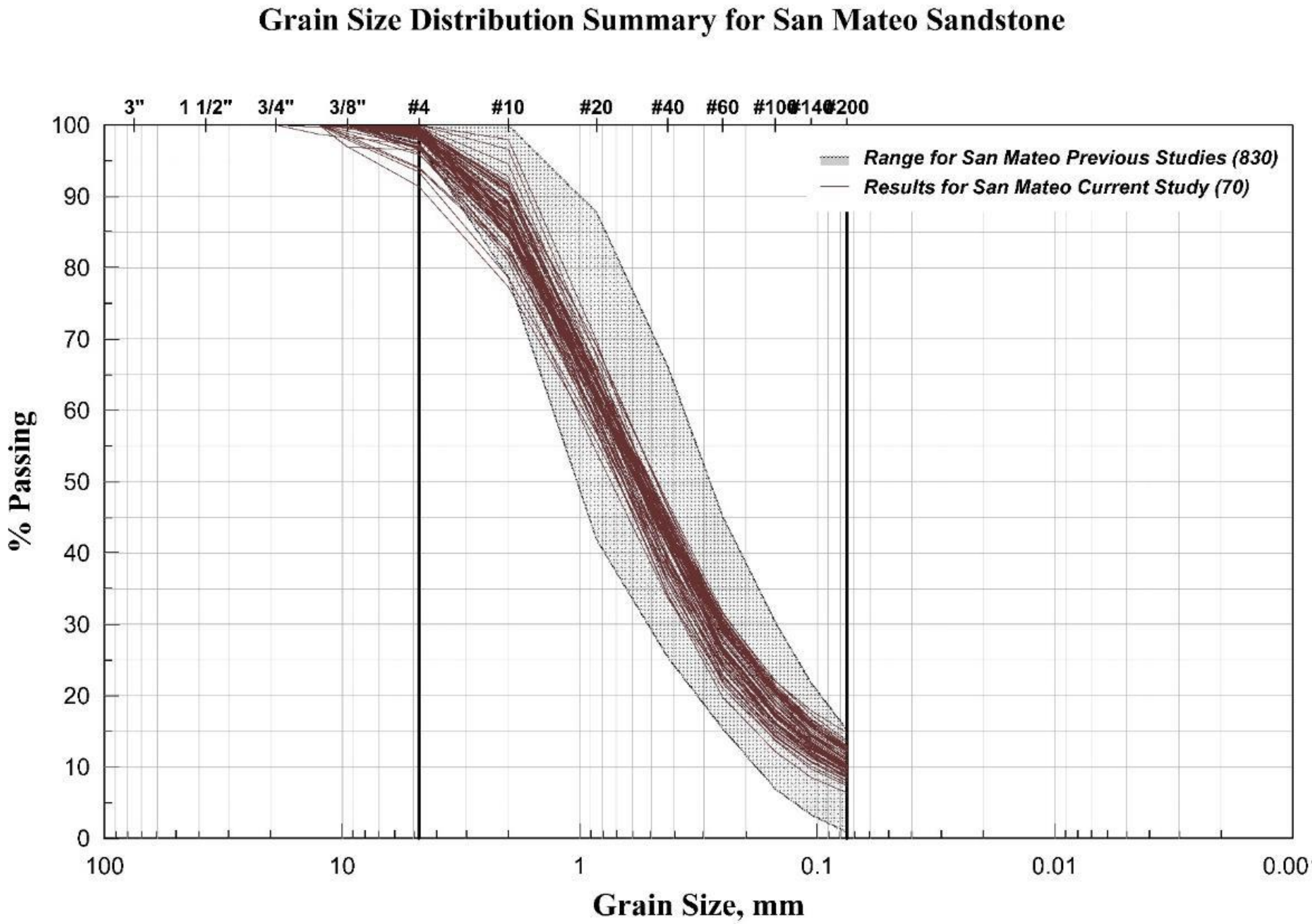
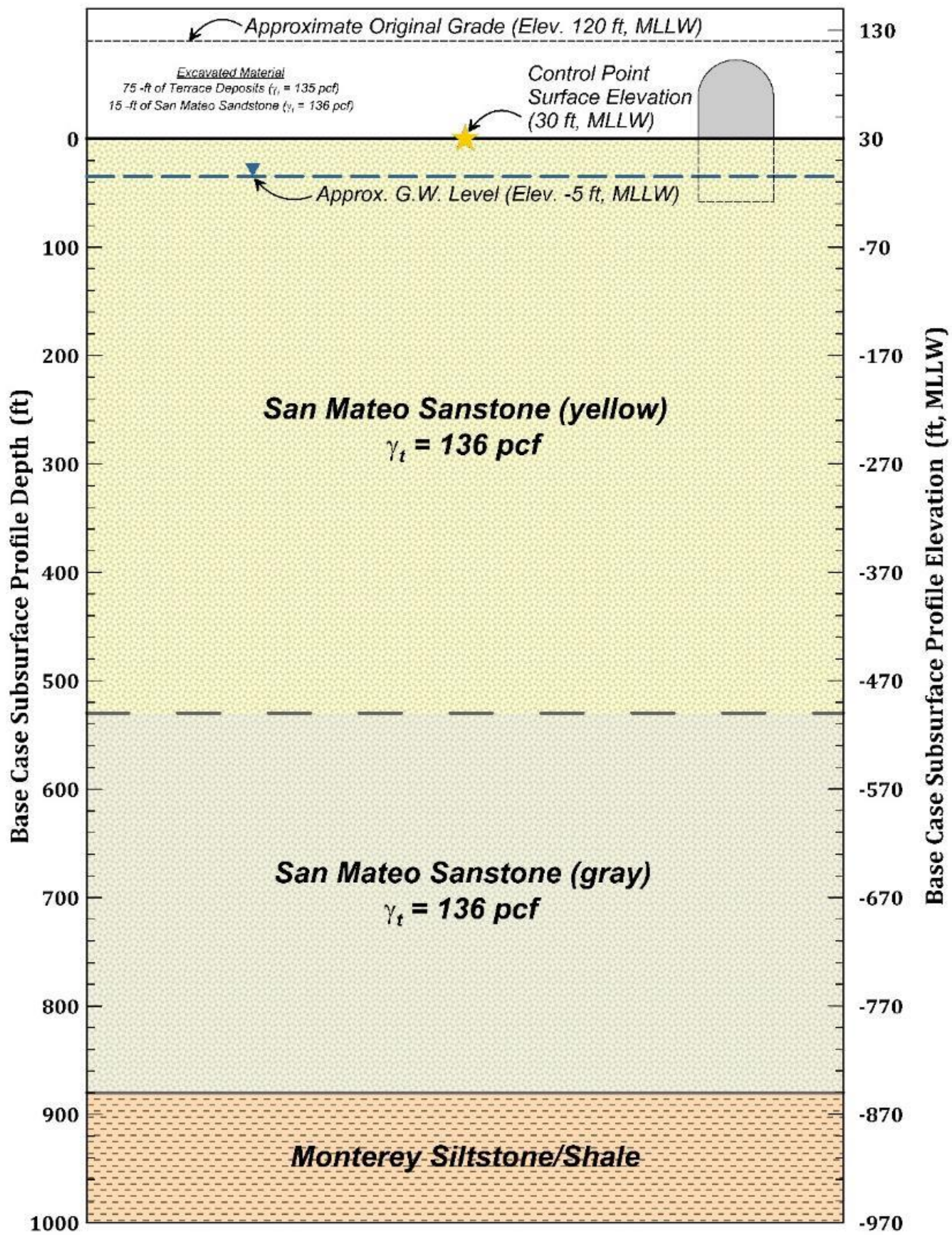


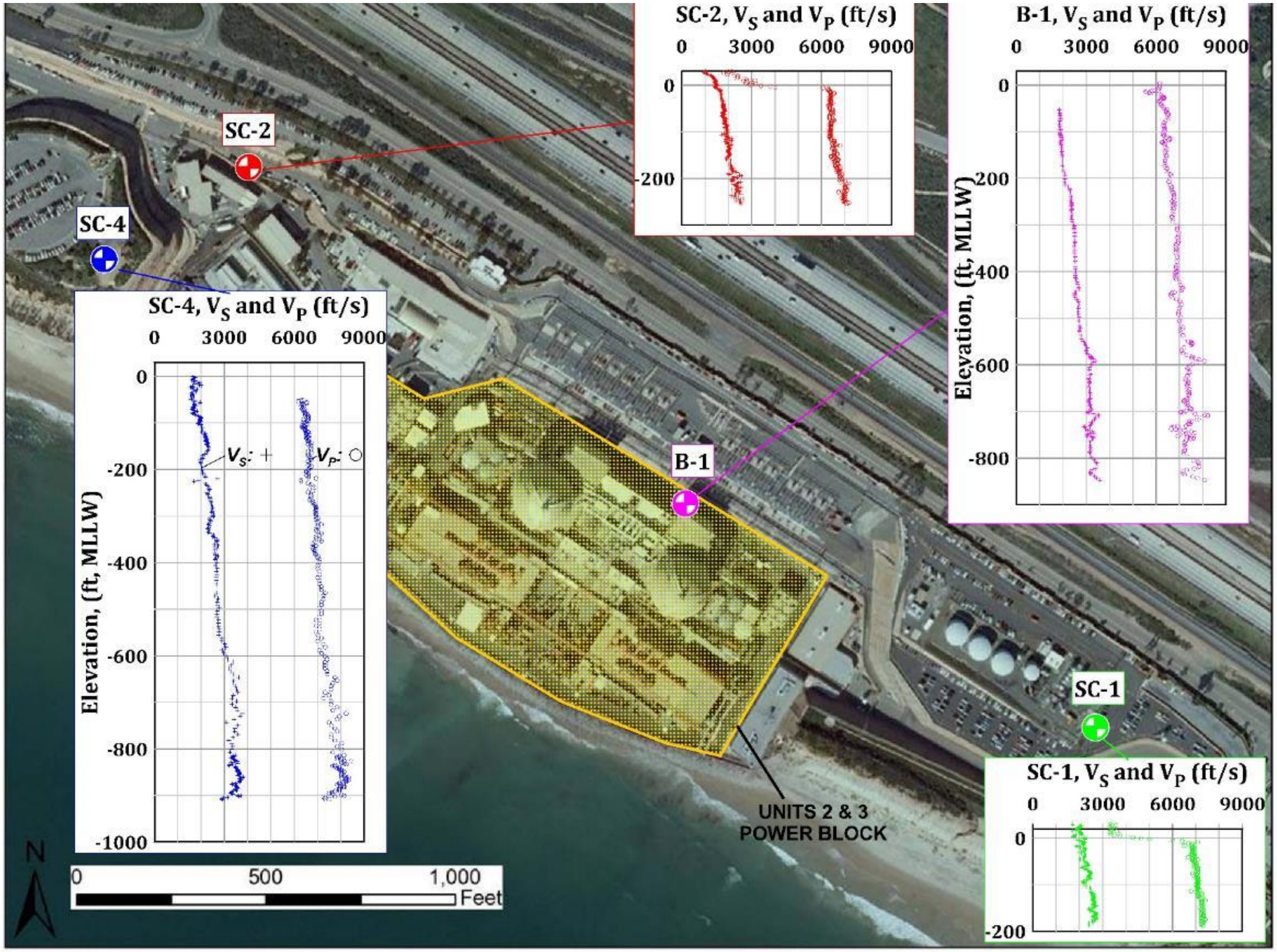
SAN MATEO SANDSTONE - GRAIN SIZE ANALYSIS RESULTS

Unit 2 &3 1-D Base Case Subsurface Profile

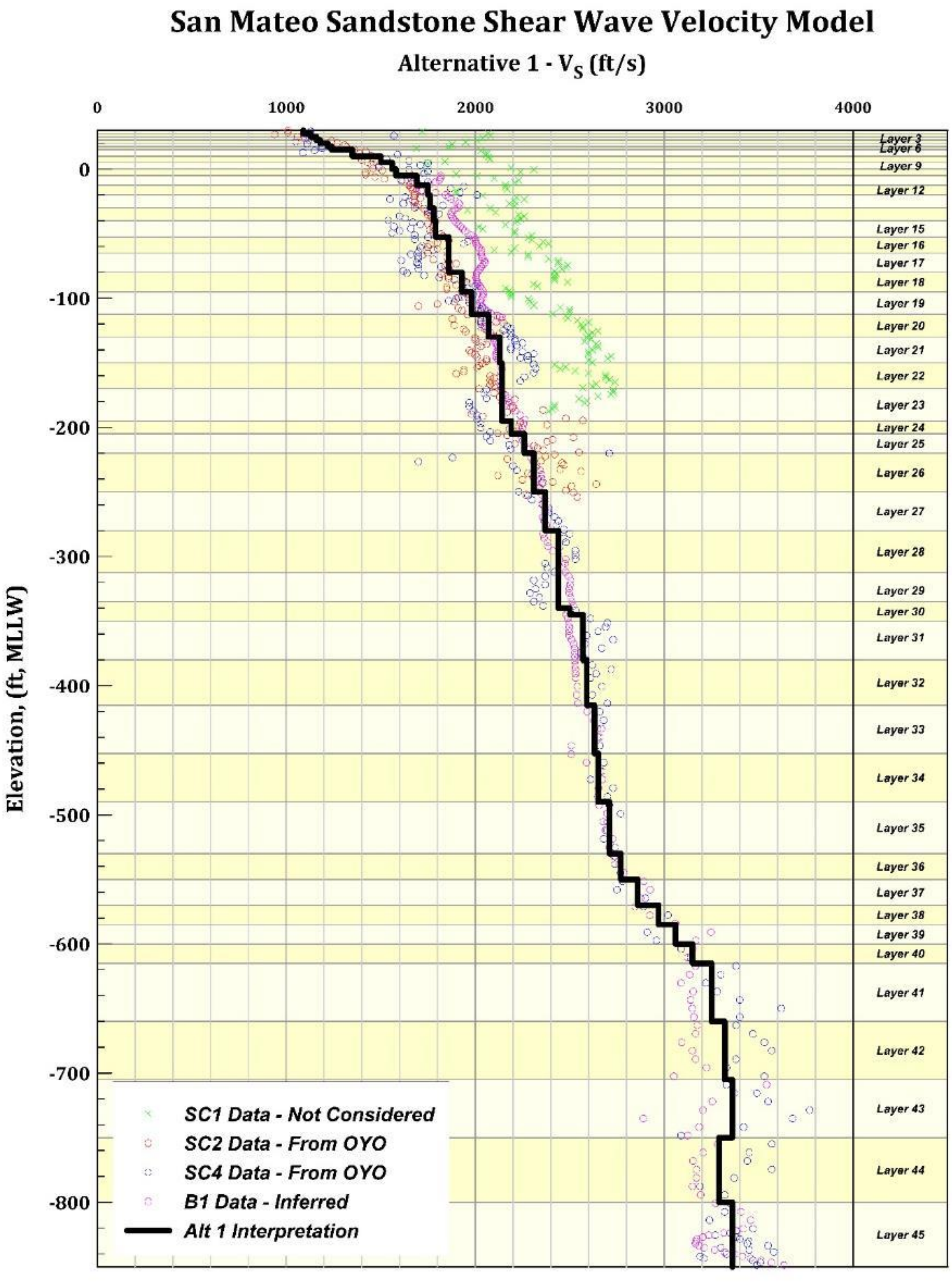


UNIT 2 & 3 1-D BASE CASE SUBSURFACE PROFILE

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-11

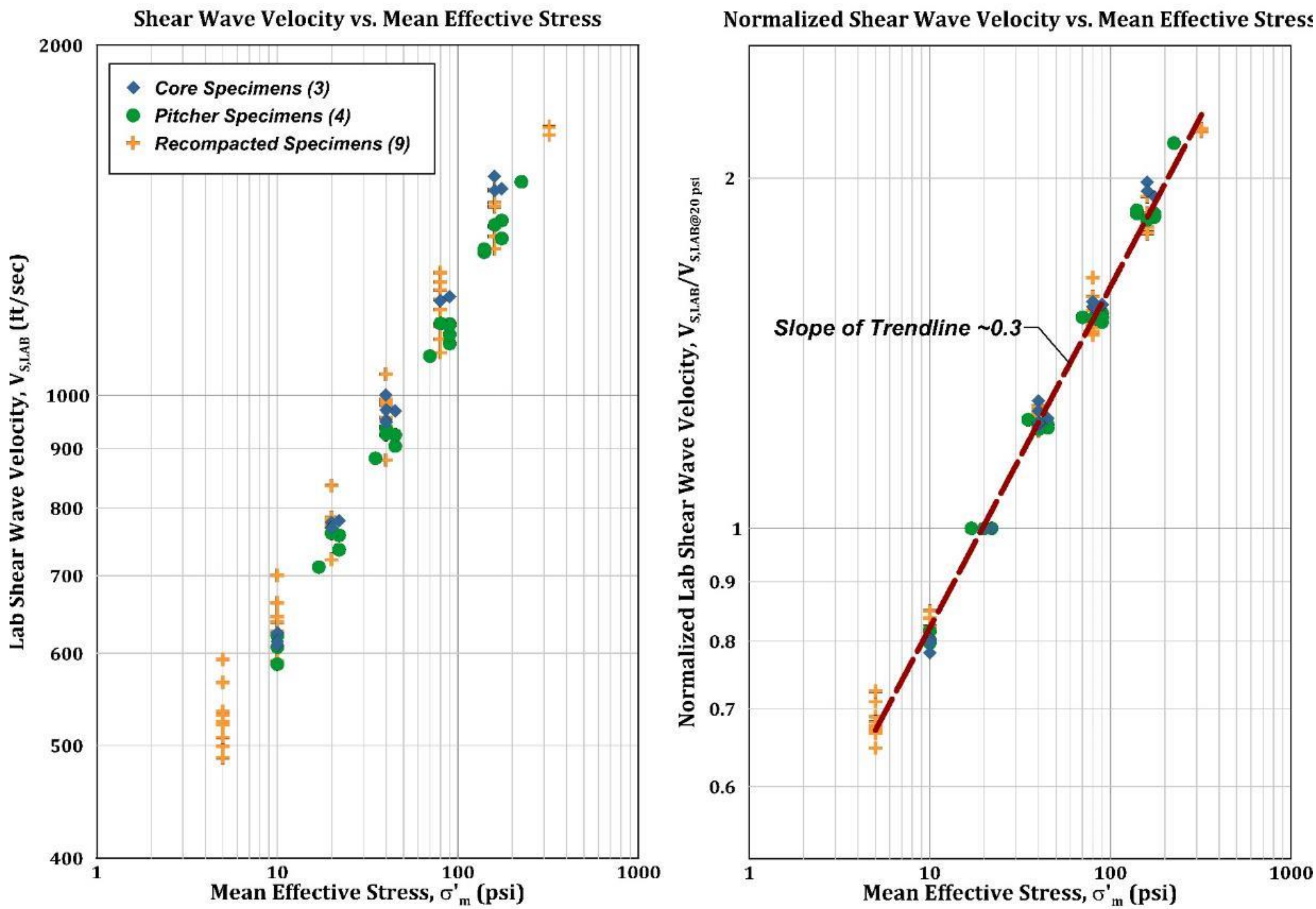


SUMMARY OF SHEAR AND PRESSURE WAVE VELOCITY DATA CONSIDERED IN ANALYSIS

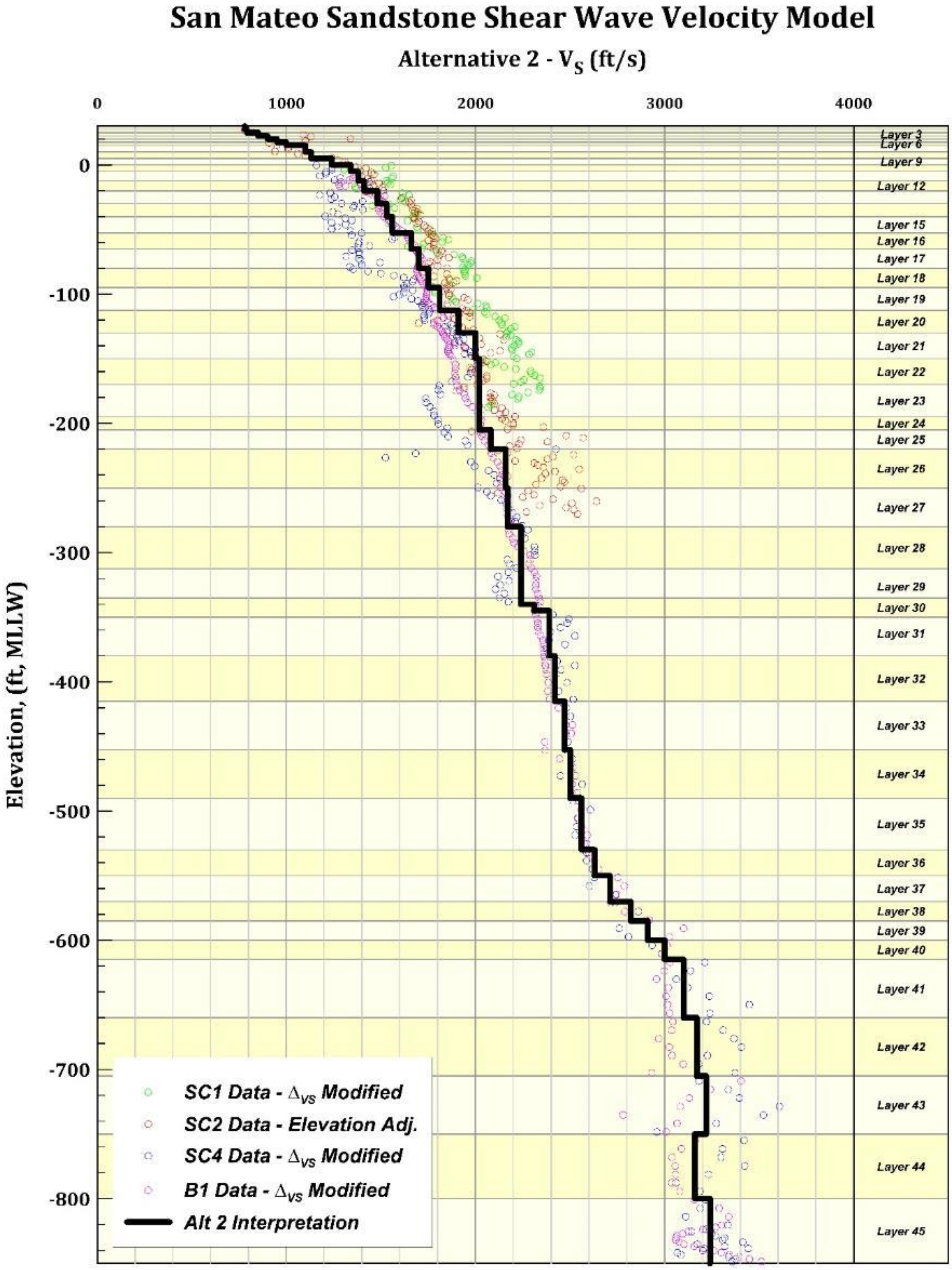


SAN MATEO SANDSTONE SHEAR WAVE VELOCITY PROFILE - ALT 1 INTERPRETATION

Project No.: 09024 | Project: SAN ONOFRE NUCLEAR GENERATING STATION | Date: OCT 2012 | Figure 3-2

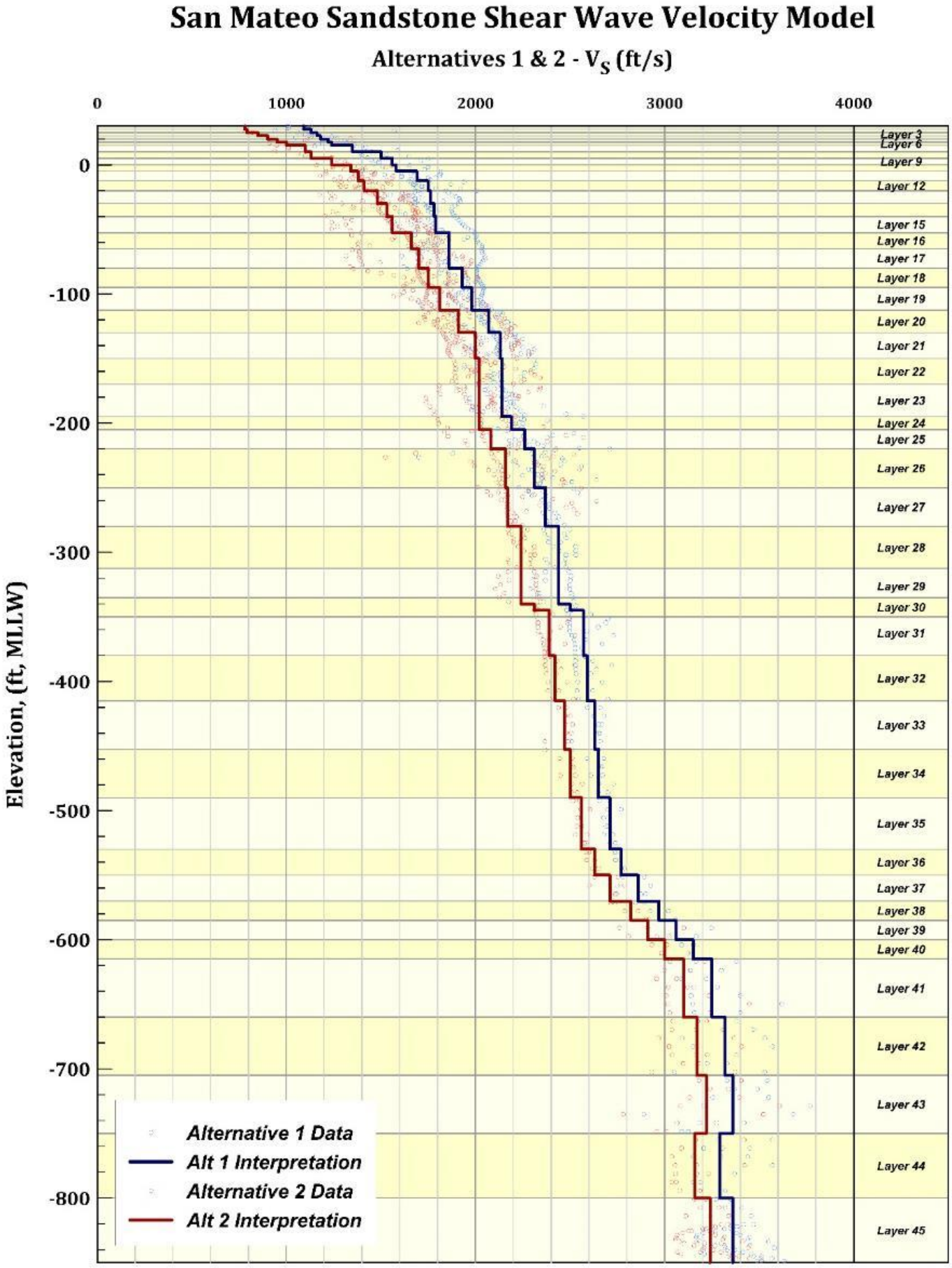


LABORATORY MEASURED SHEAR WAVE VELOCITY



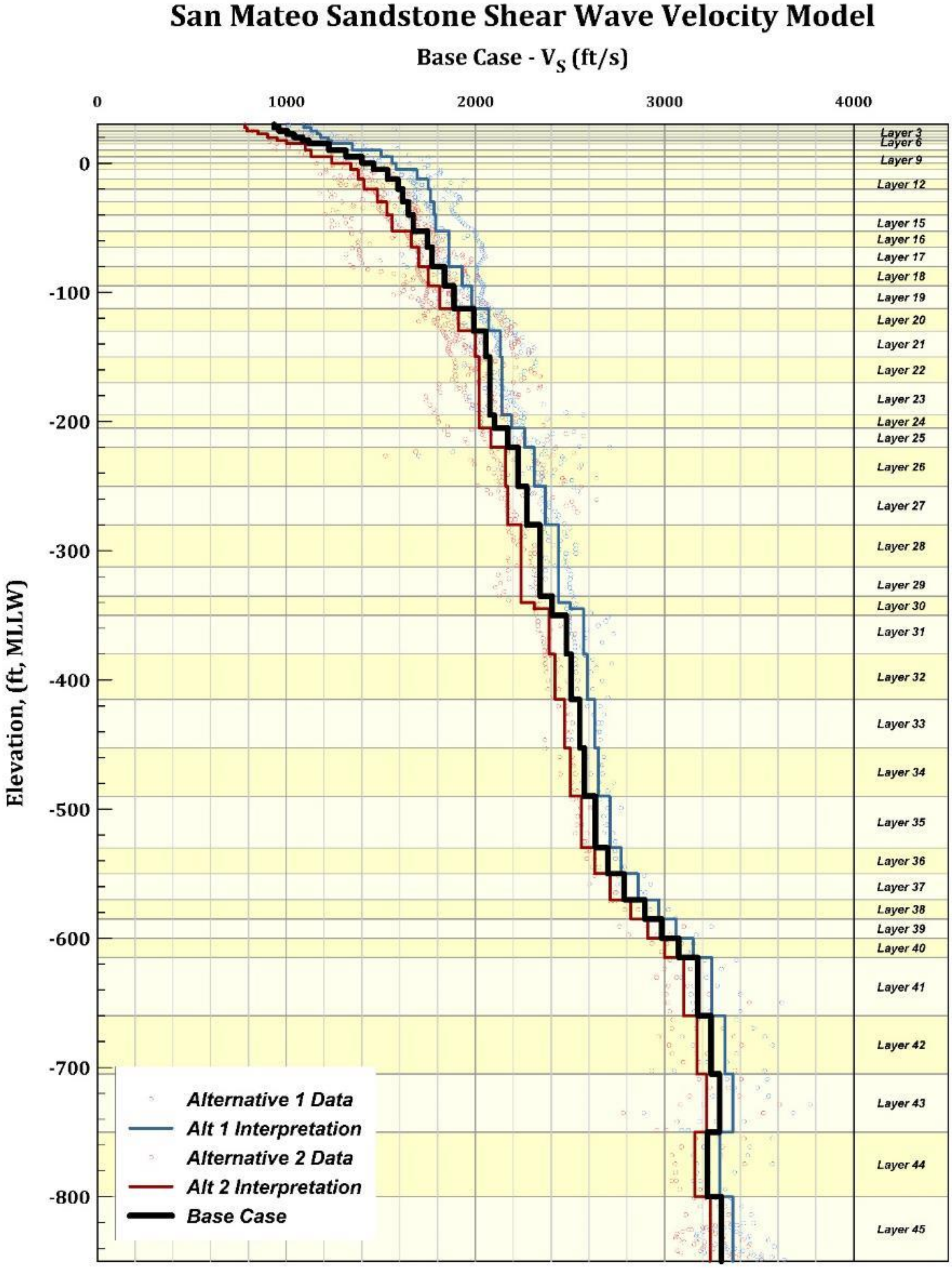
SAN MATEO SANDSTONE SHEAR WAVE VELOCITY PROFILE - ALT 2 INTERPRETATION

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 3-4



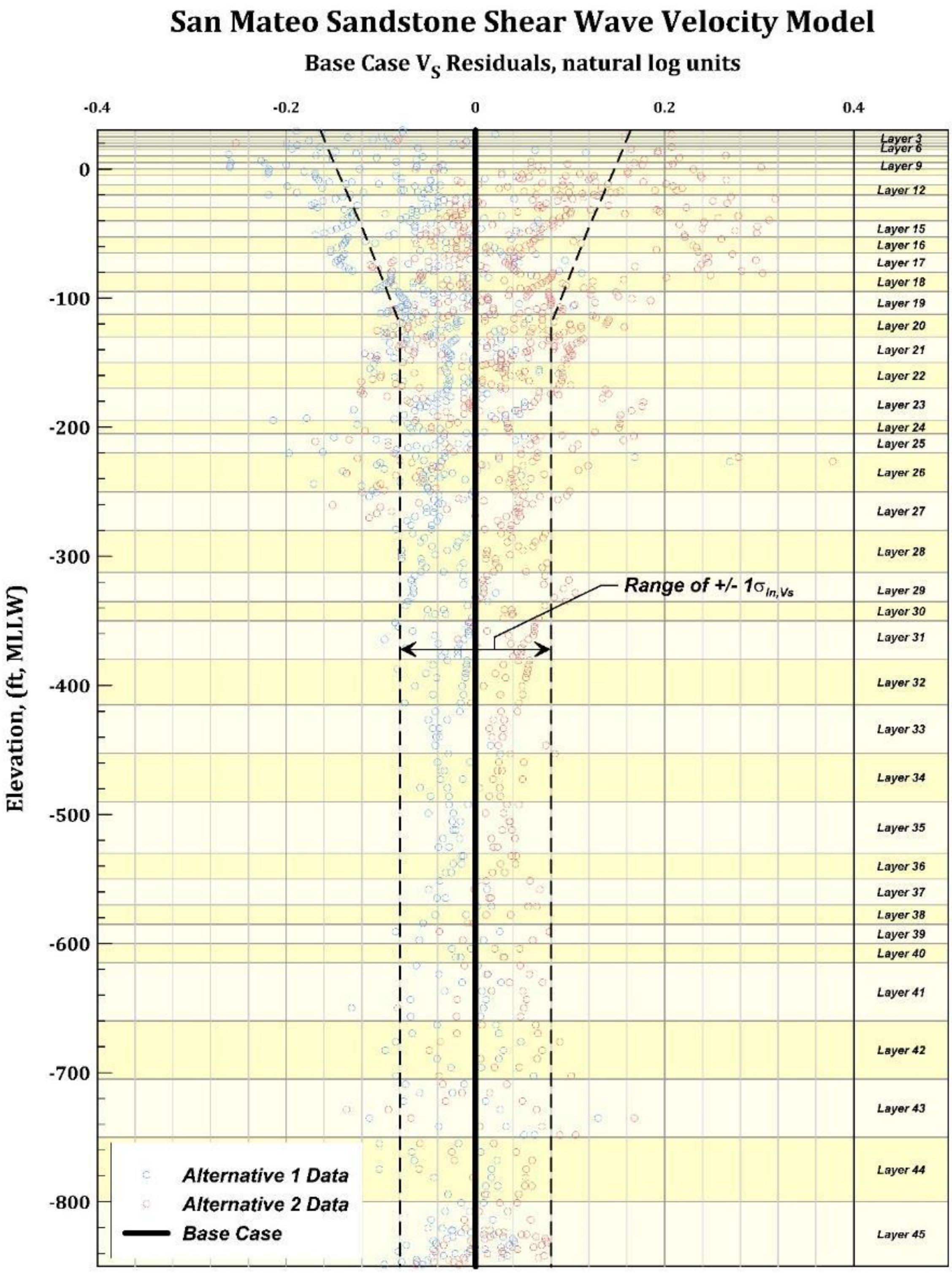
SAN MATEO SANDSTONE SHEAR WAVE VELOCITY PROFILE - ALTERNATIVE INTERPRETATIONS

Project No.: 09024 | Project: SAN ONOFRE NUCLEAR GENERATING STATION | Date: OCT 2012 | Figure 3-5



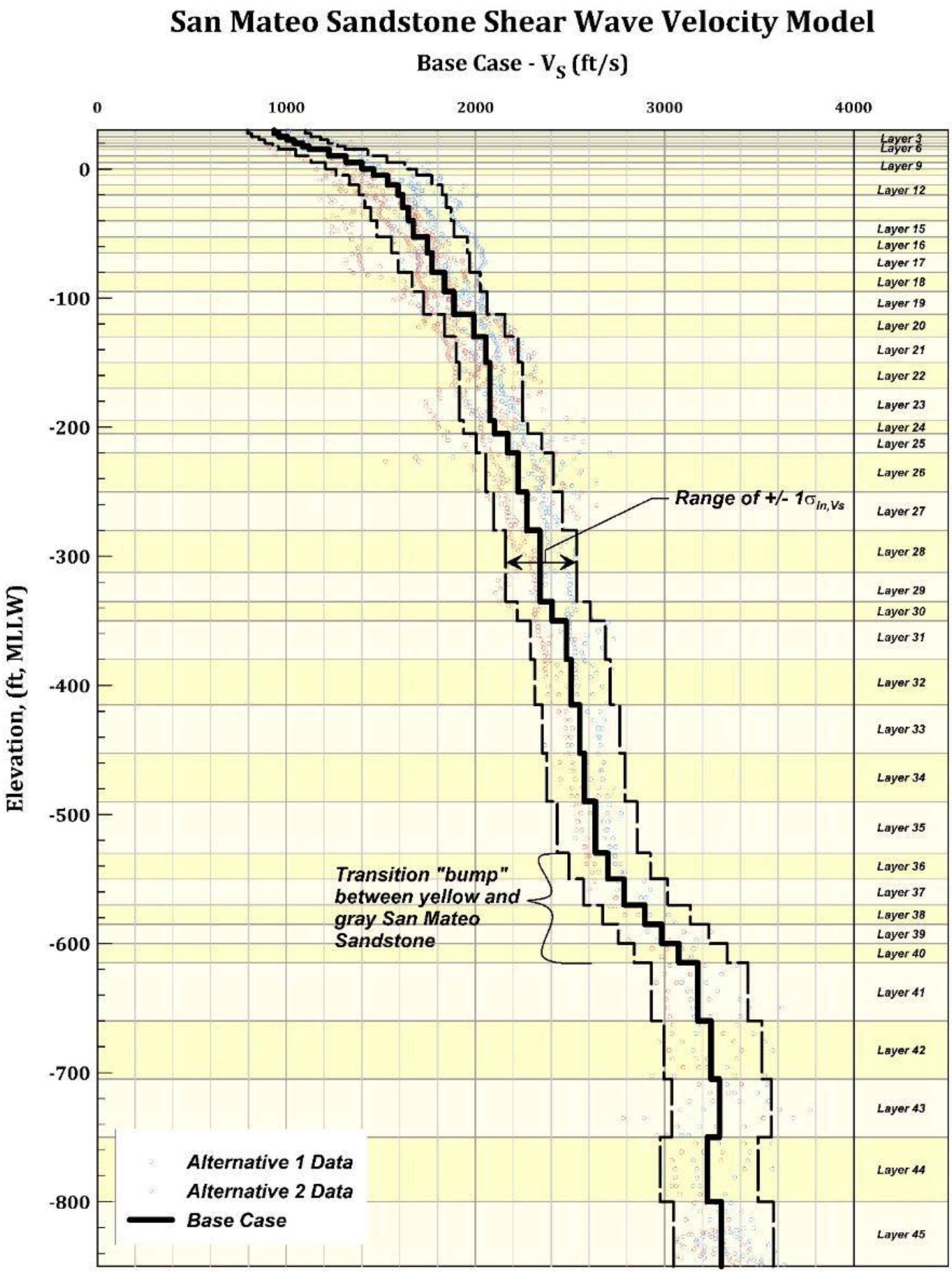
SAN MATEO SANDSTONE SHEAR WAVE VELOCITY PROFILE - BASE CASE

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 3-6



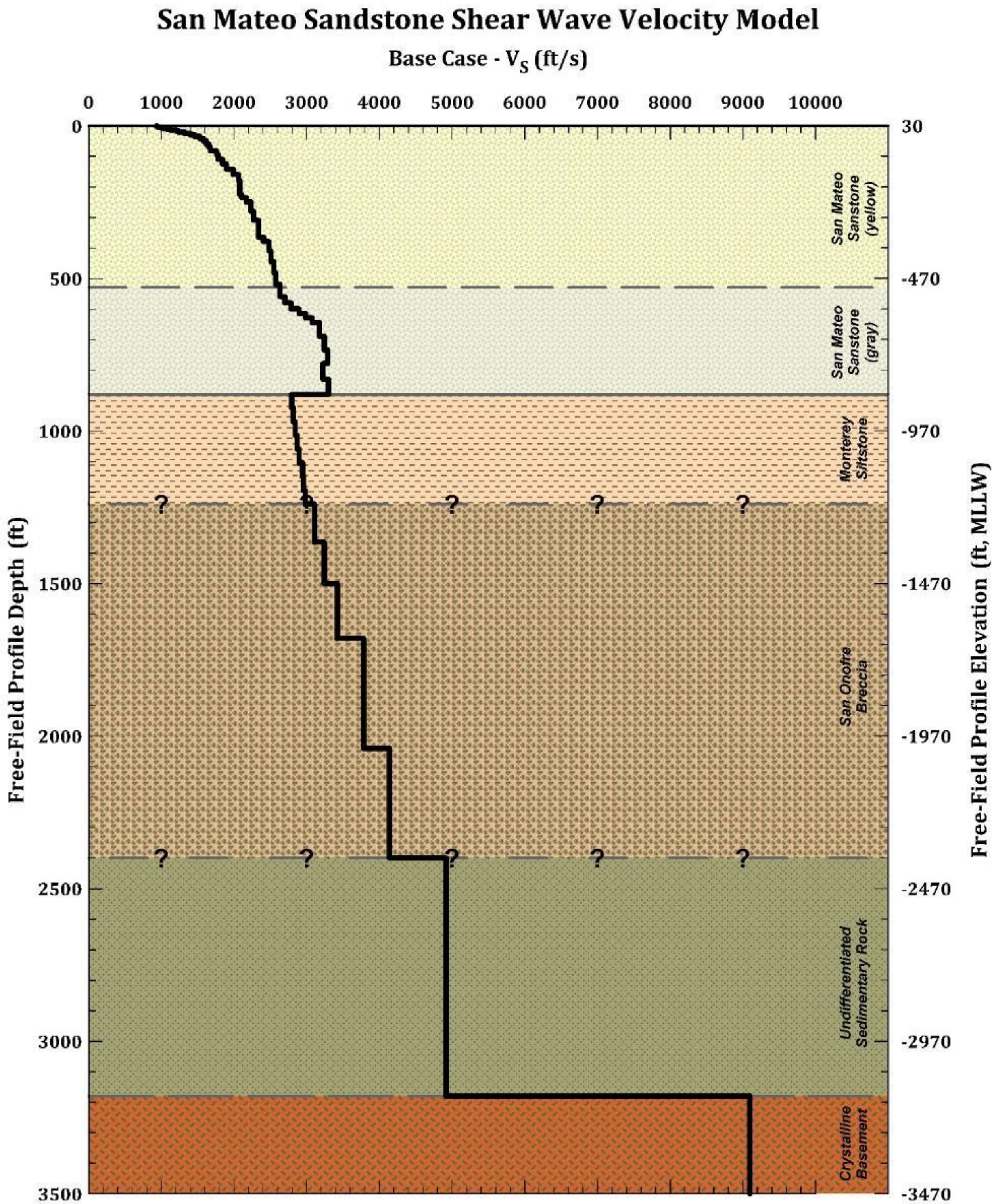
SAN MATEO SANDSTONE SHEAR WAVE VELOCITY PROFILE - BASE CASE

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 3-7



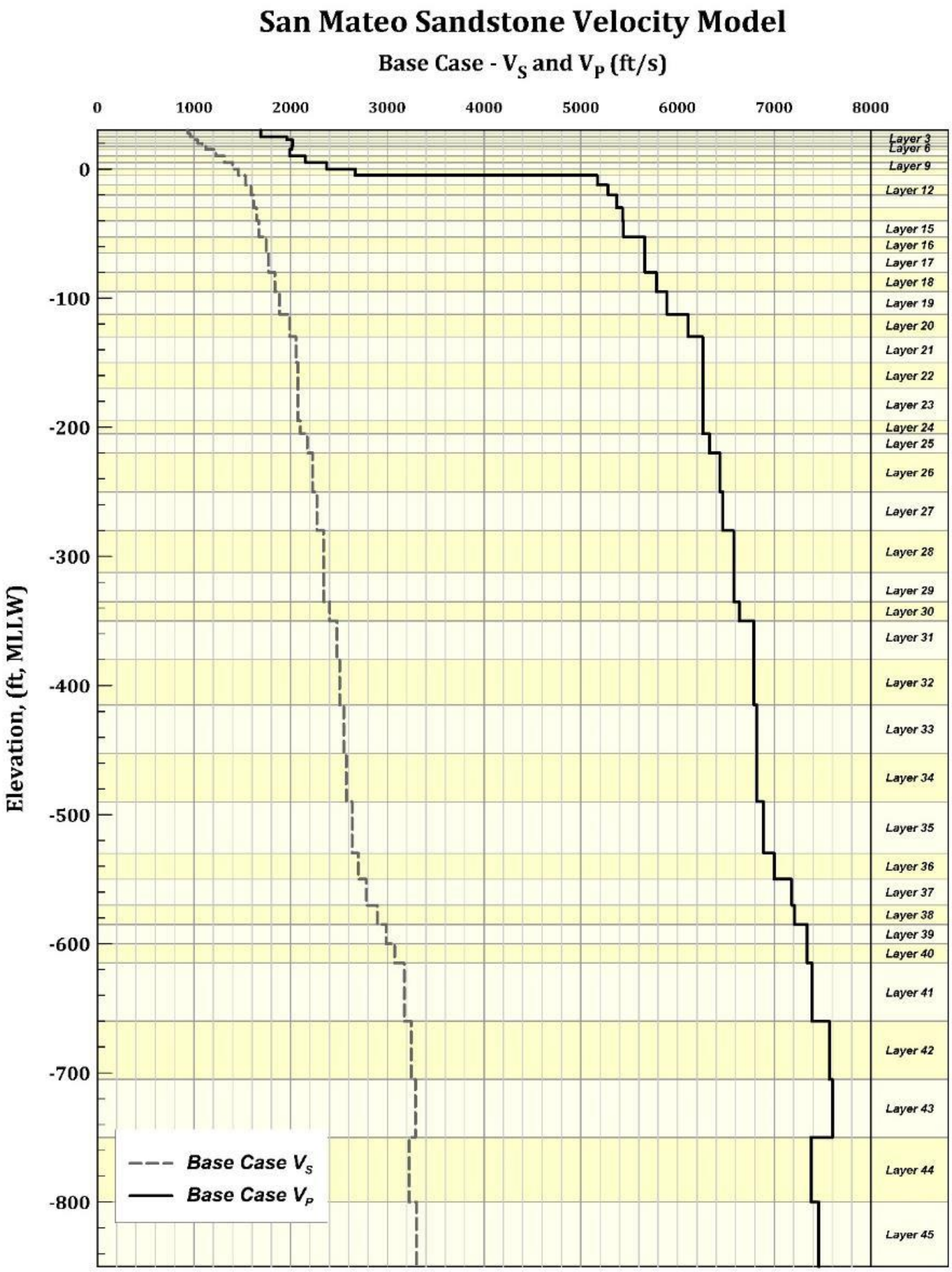
SAN MATEO SANDSTONE SHEAR WAVE VELOCITY PROFILE - BASE CASE

Project No.: 09024 | Project: SAN ONOFRE NUCLEAR GENERATING STATION | Date: OCT 2012 | Figure 3-8



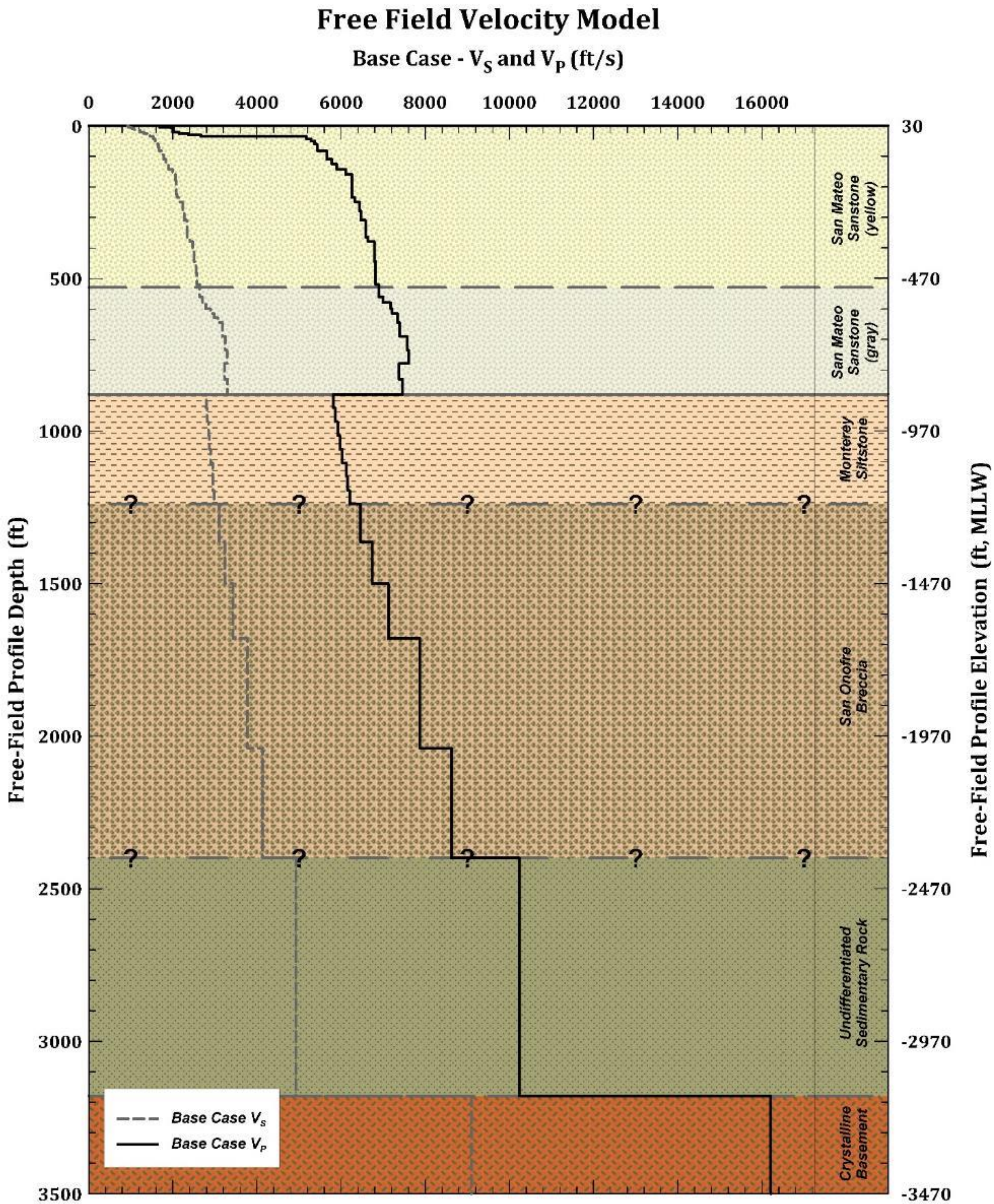
SAN MATEO SANDSTONE SHEAR WAVE VELOCITY PROFILE - ALT 2 INTERPRETATION

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: FEB 2013	Figure 3-9



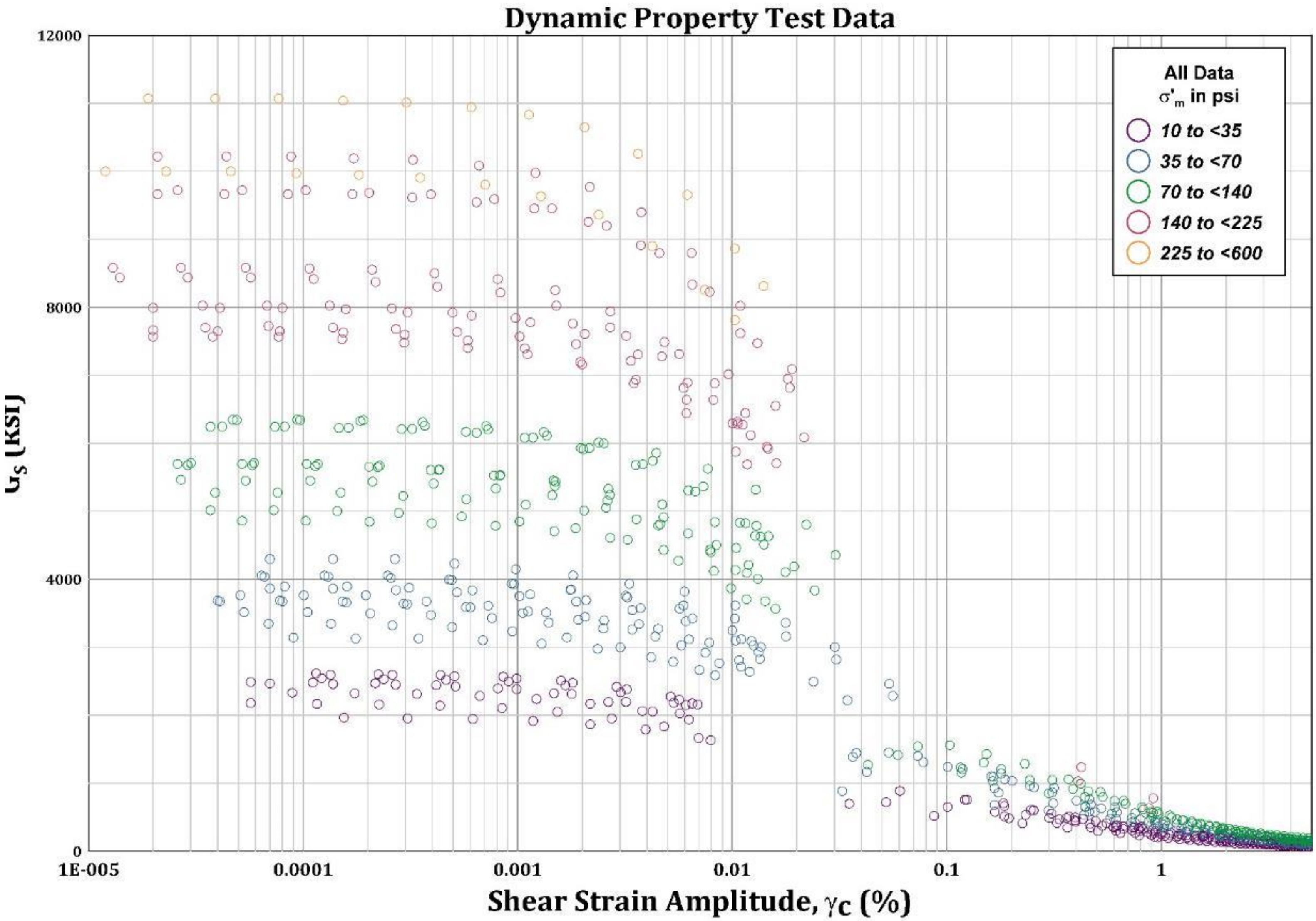
SAN MATEO SANDSTONE VELOCITY PROFILE - BASE CASE

Project No.: 09024 | Project: SAN ONOFRE NUCLEAR GENERATING STATION | Date: OCT 2012 | Figure 3-10

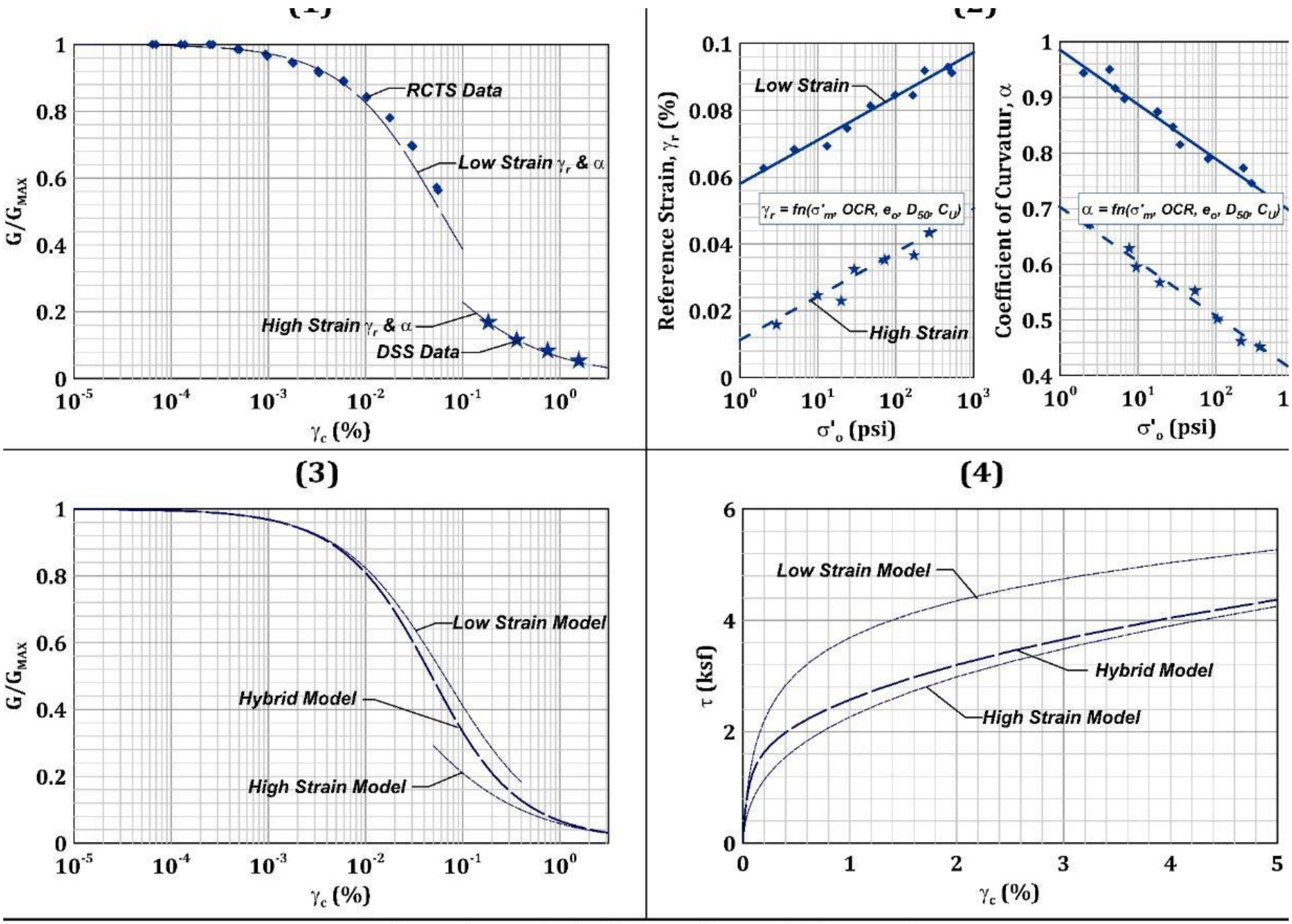


FREE FIELD VELOCITY PROFILE - BASE CASE

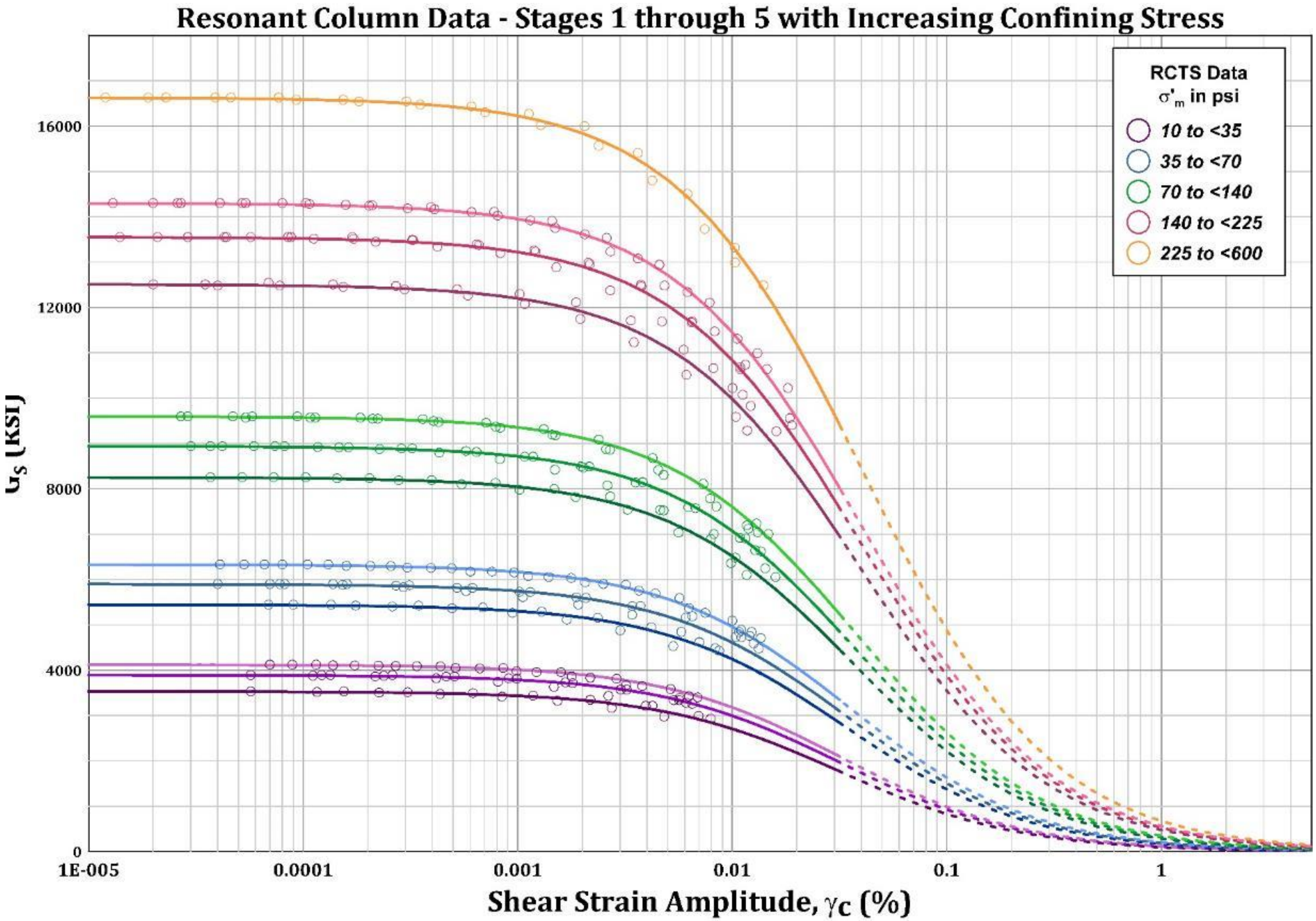
Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: FEB 2013	Figure 3-11



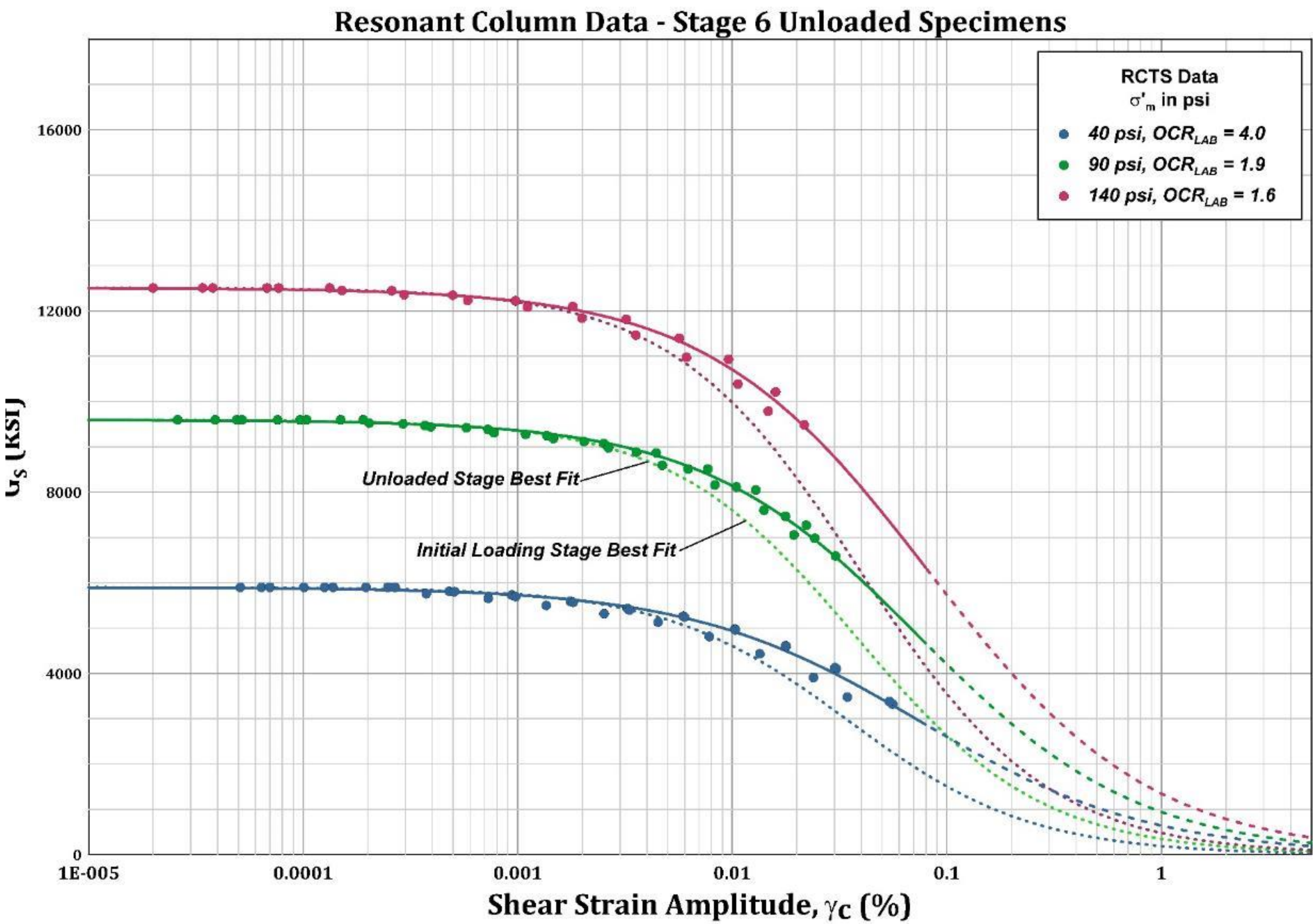
DYNAMIC PROPERTY TEST DATA



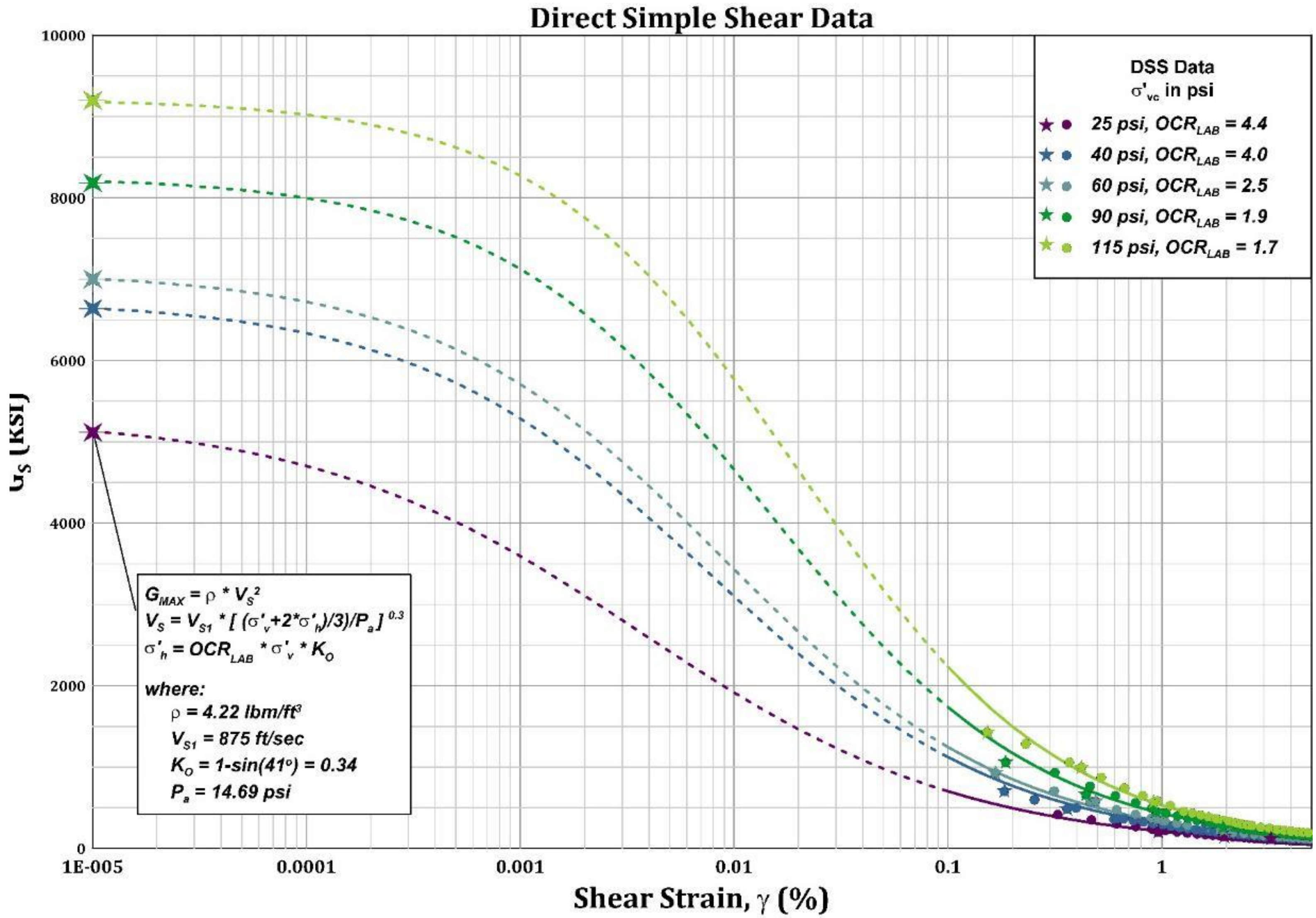
MODULUS REDUCTION CURVE MODELING SCHEMATIC



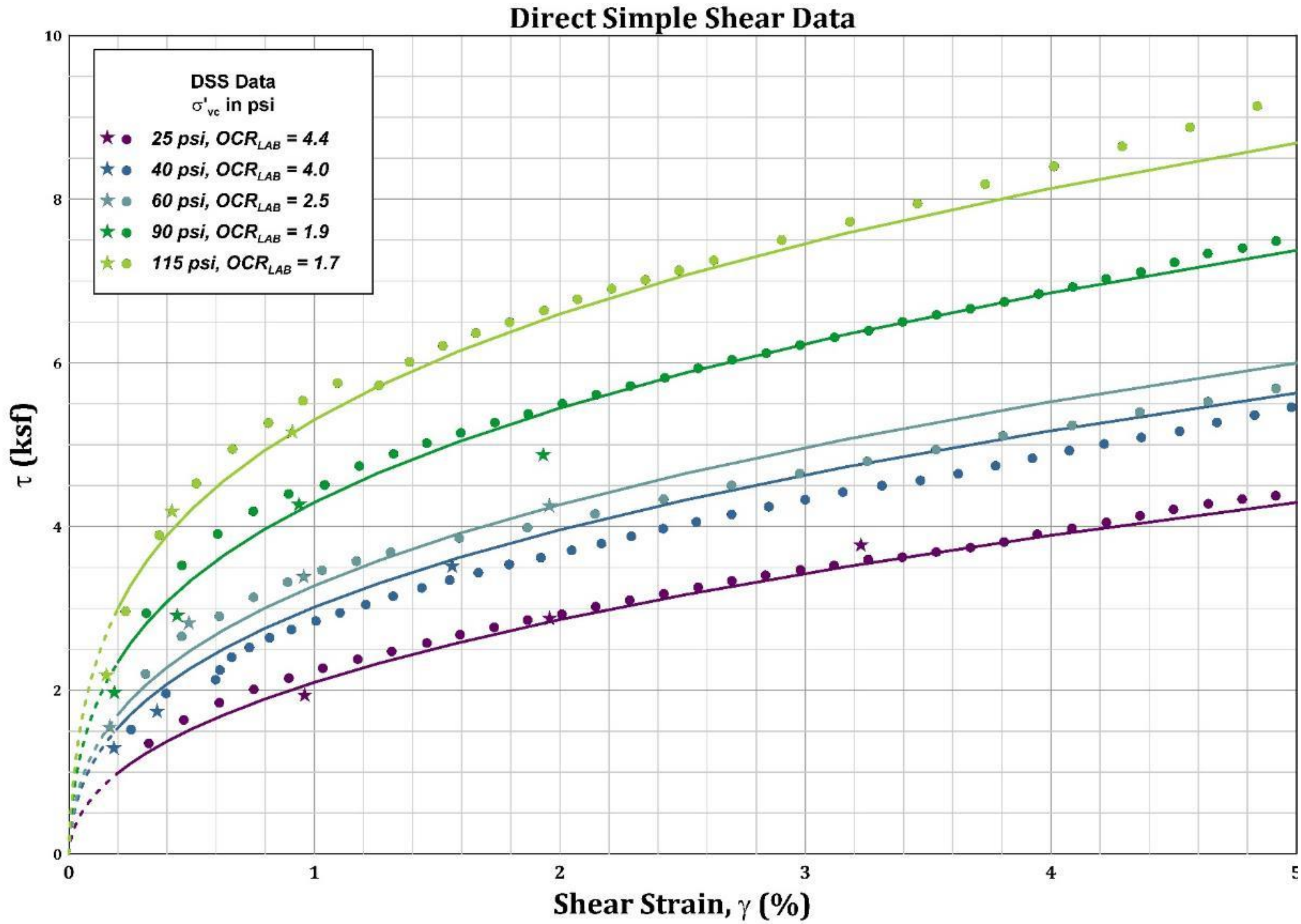
RESONANT COLUMN DATA WITH LOW STRAIN MODEL



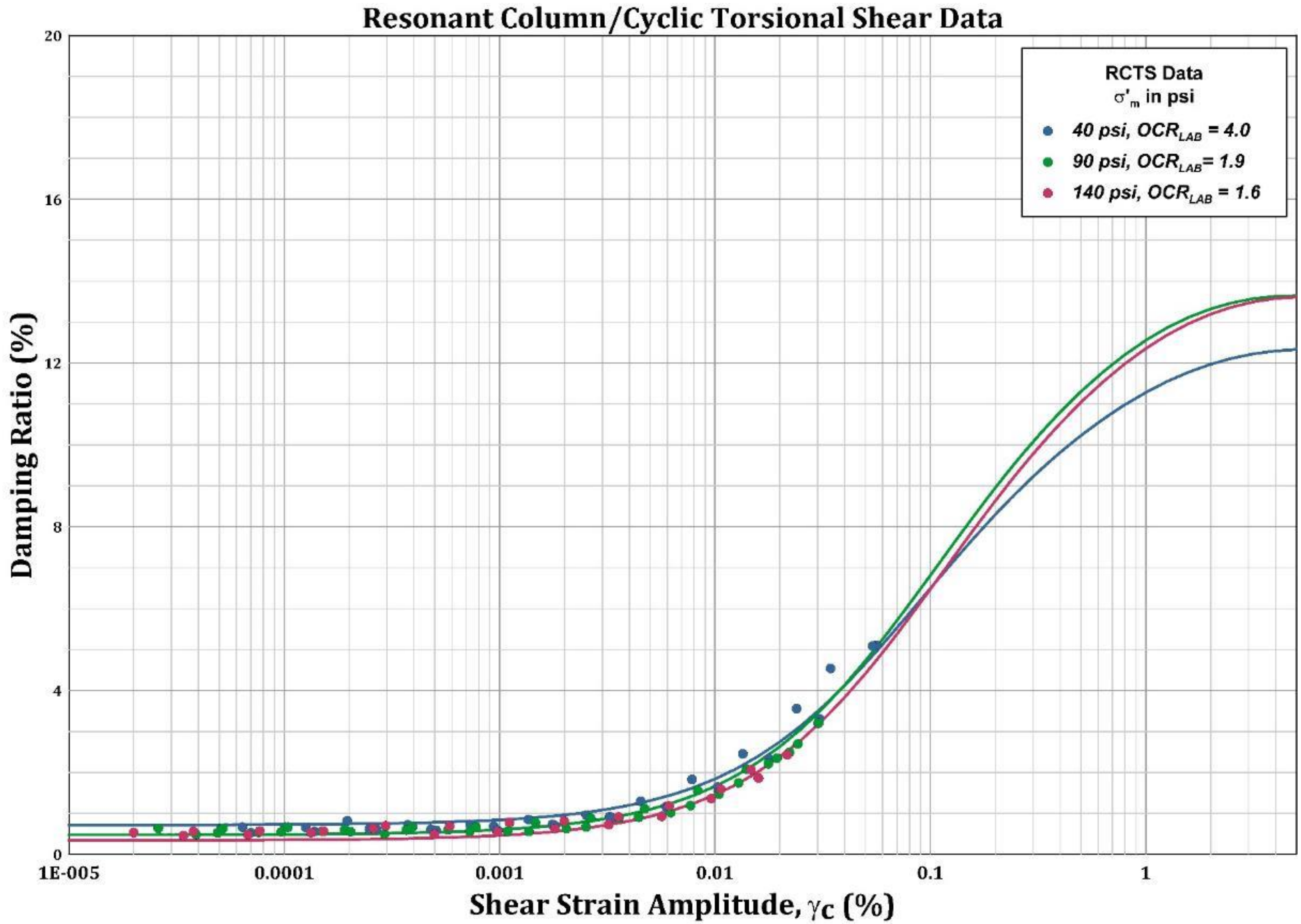
RESONANT COLUMN DATA WITH LOW STRAIN MODEL



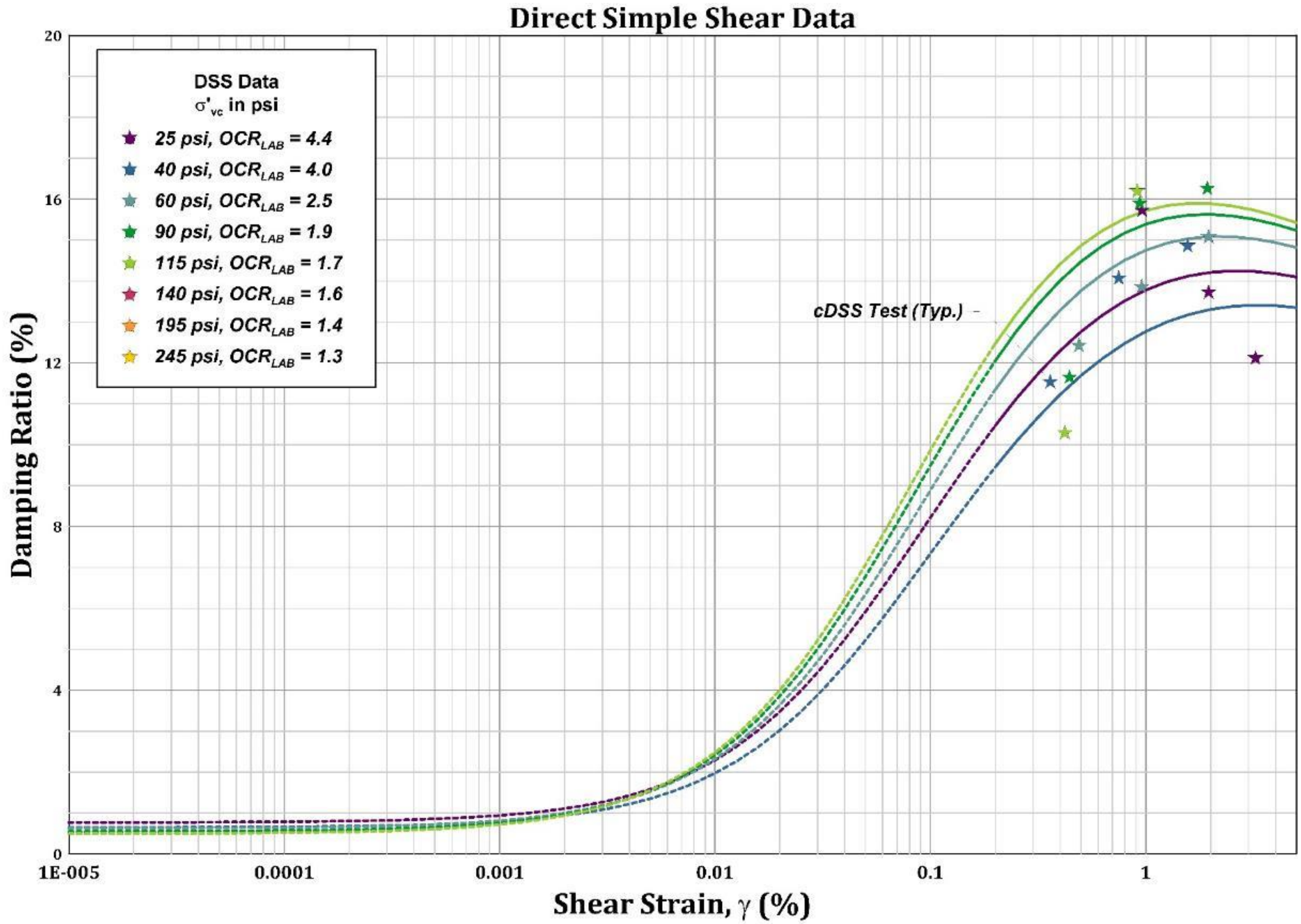
DIRECT SIMPLE SHEAR DATA WITH HIGH STRAIN MODEL



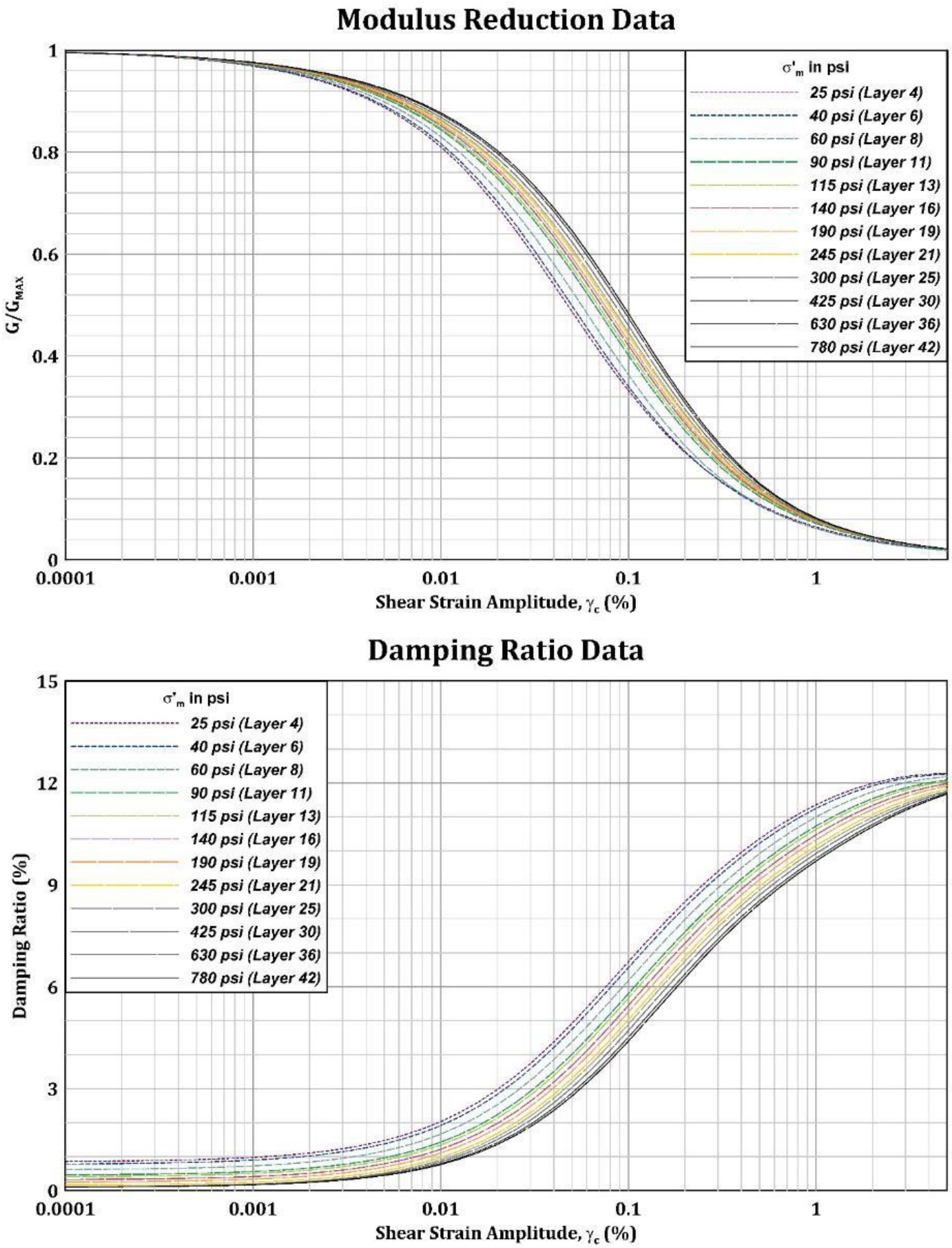
DIRECT SIMPLE SHEAR DATA WITH HIGH STRAIN MODEL



RC/cTS DATA WITH LOW STRAIN MODEL

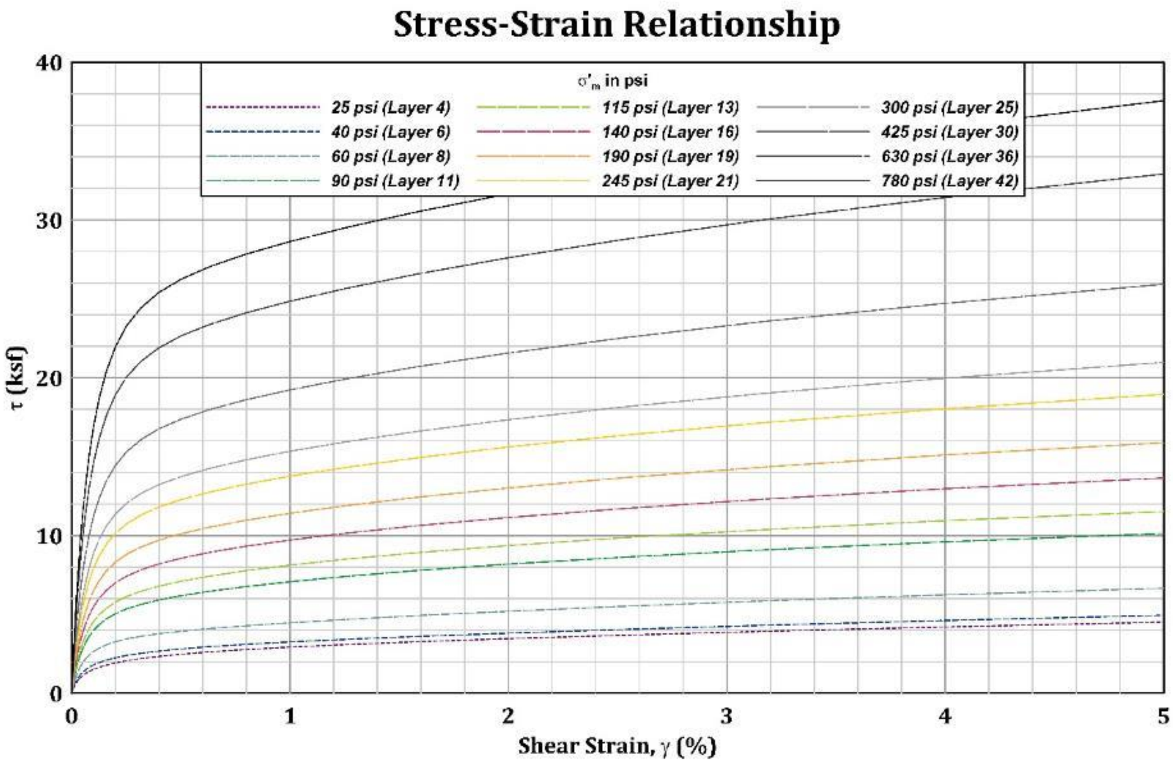


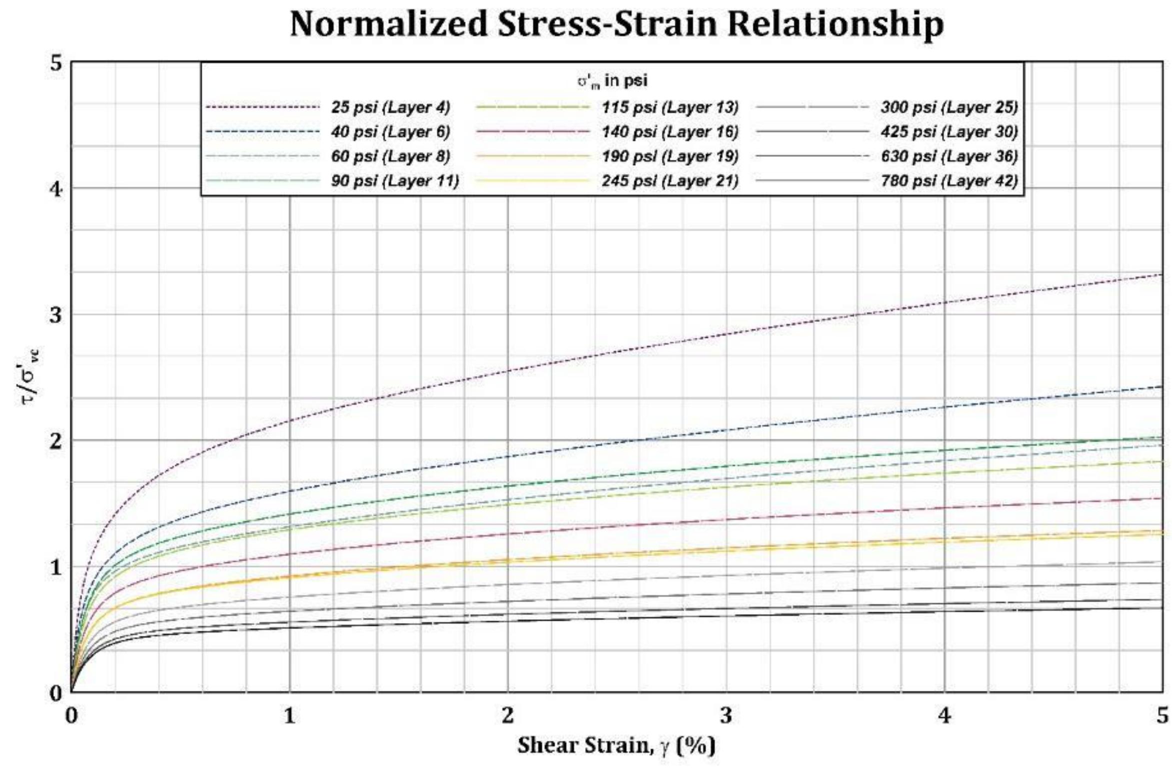
OVER-CONSOLIDATED DIRECT SIMPLE SHEAR DATA WITH DAMPING MODEL



SAN MATEO SANDSTONE MODEL G/G_{MAX} AND DAMPING RATIO CURVES

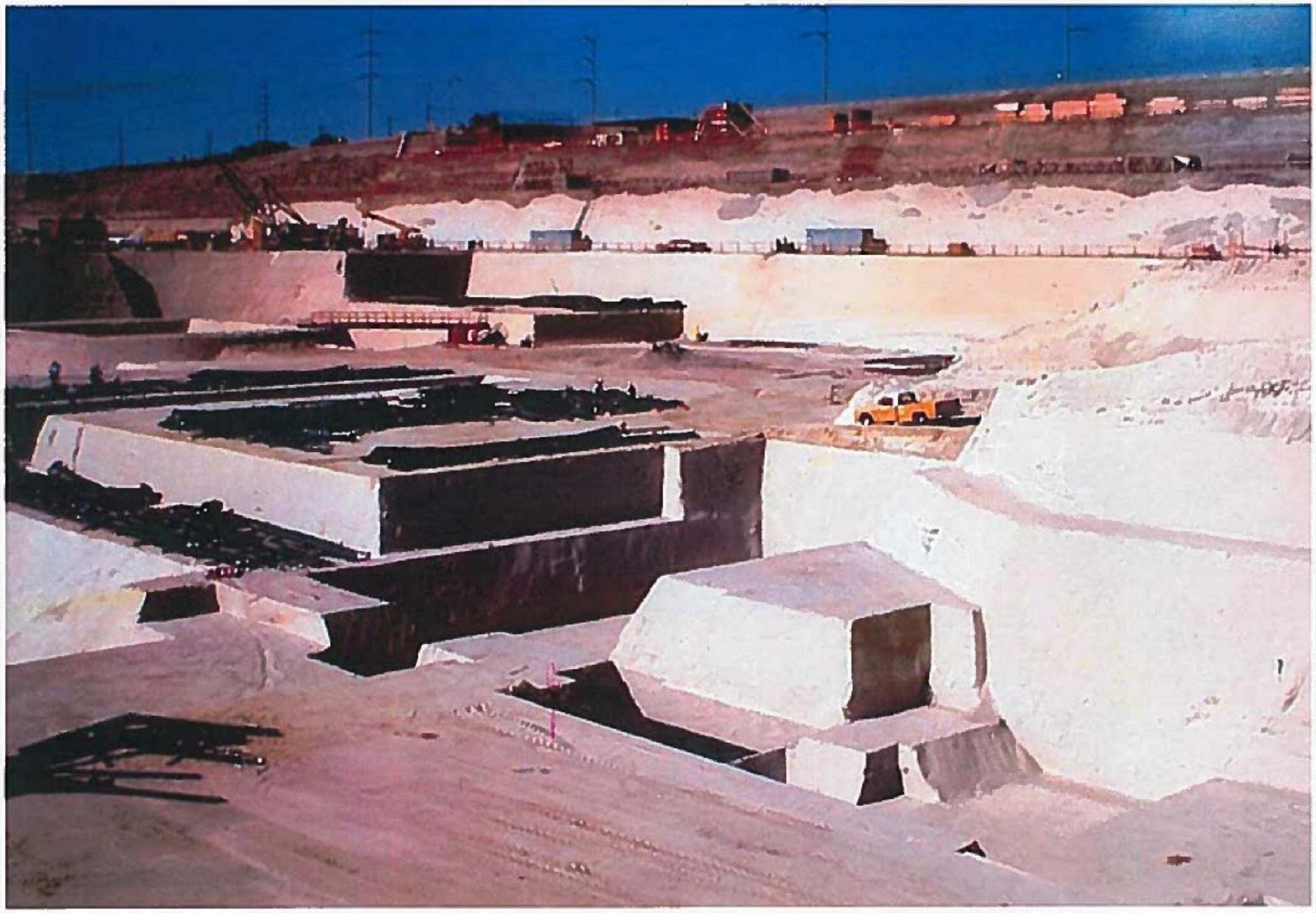
Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 5-1





SAN MATEO SANDSTONE MODEL STRESS-STRAIN RELATIONSHIPS

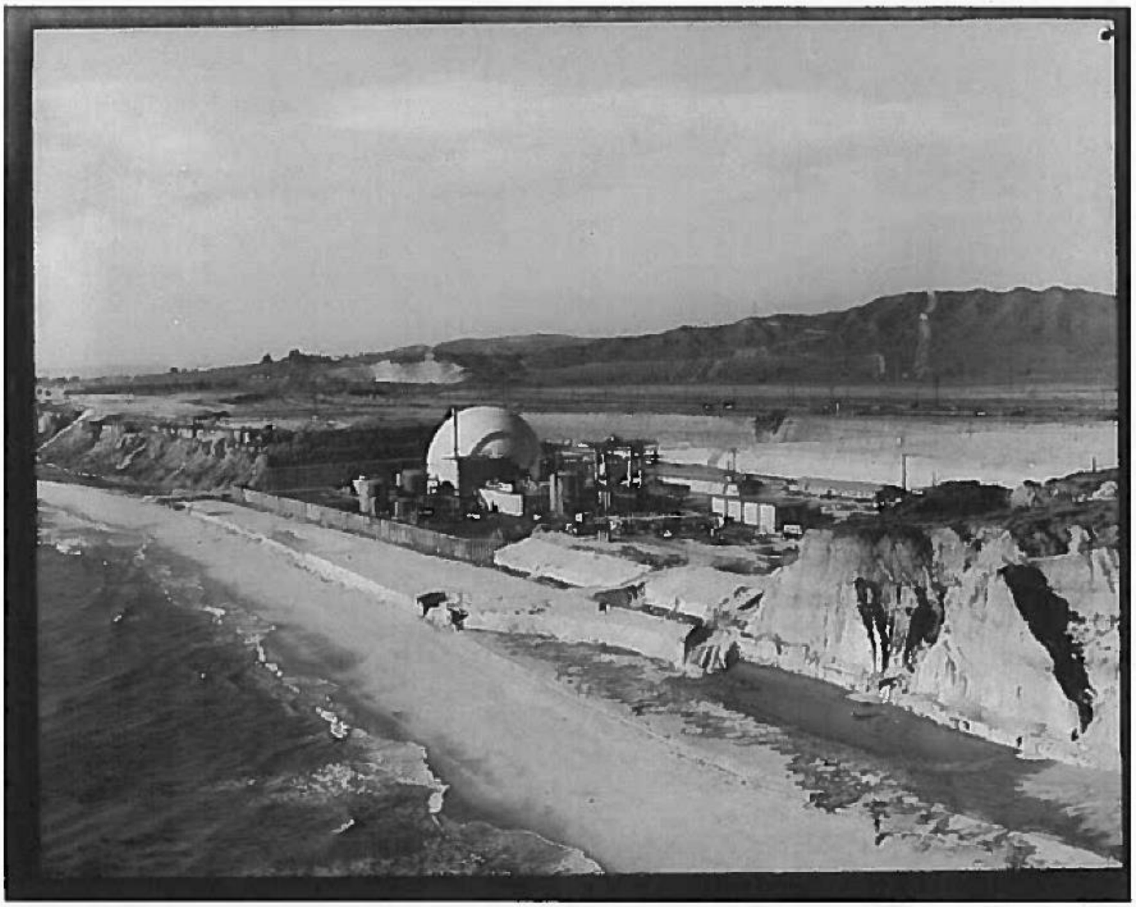
Project No.: 09024 | Project: SAN ONOFRE NUCLEAR GENERATING STATION | Date: OCT 2012 | Figure 5-2



SITE CONSTRUCTION FOUNDATION PHOTO (ca. 1970s)			
Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-4b

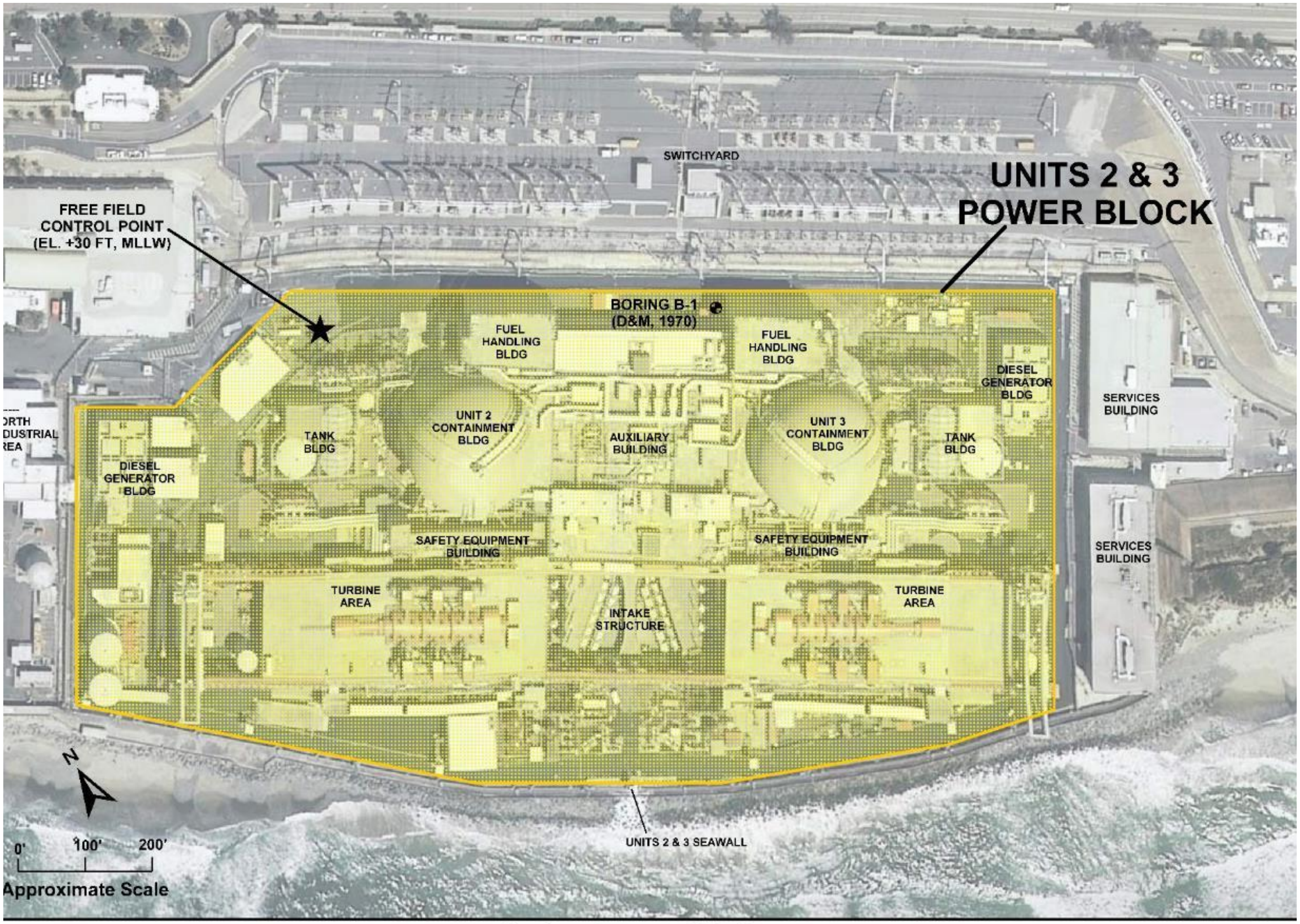
SITE CONSTRUCTION AERIAL PHOTO (ca. 1970s)			
Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-4a

Print this item: San Onofre Nuclear Generating Station aerial NE from ocean.

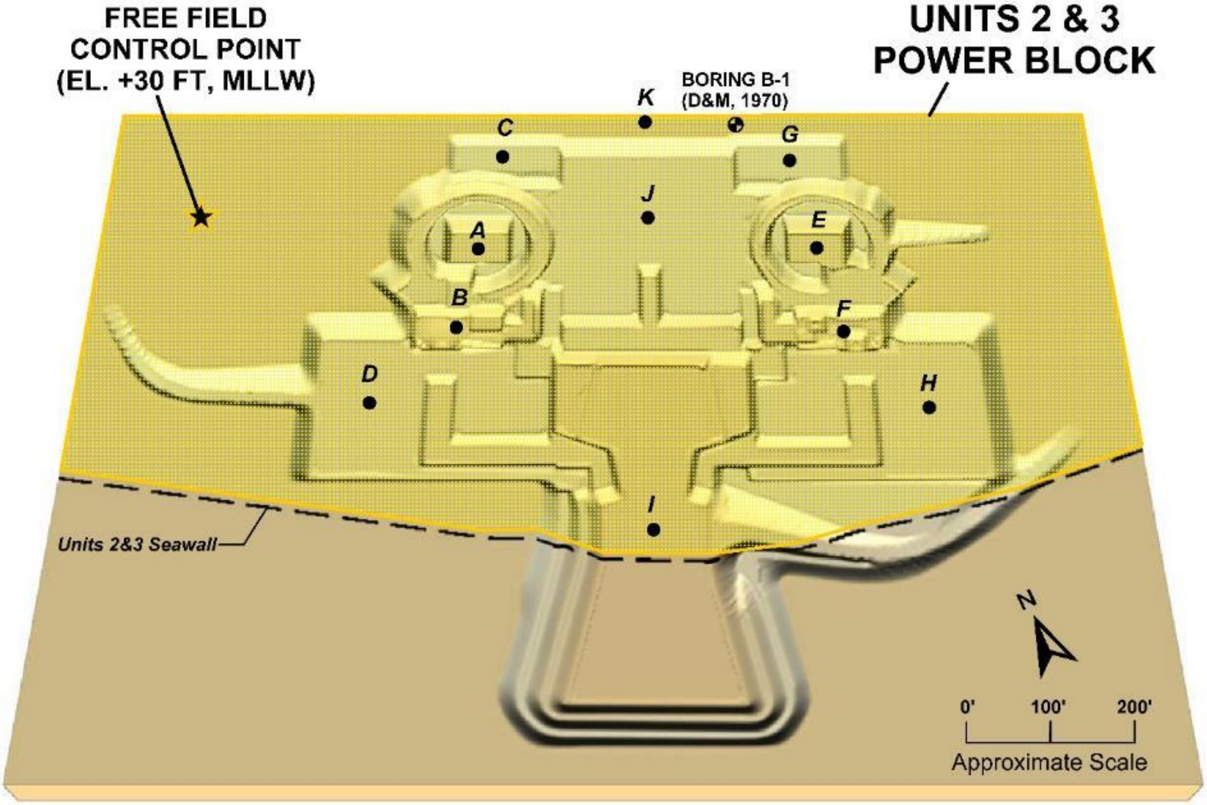


Unit 1 4/16/67

SITE LOCATION MAP AND APPROXIMATE STATION LAYOUT



UNITS 2 & 3 POWER BLOCK SITE PLAN



Units 2 &3 Power Block Foundation Key

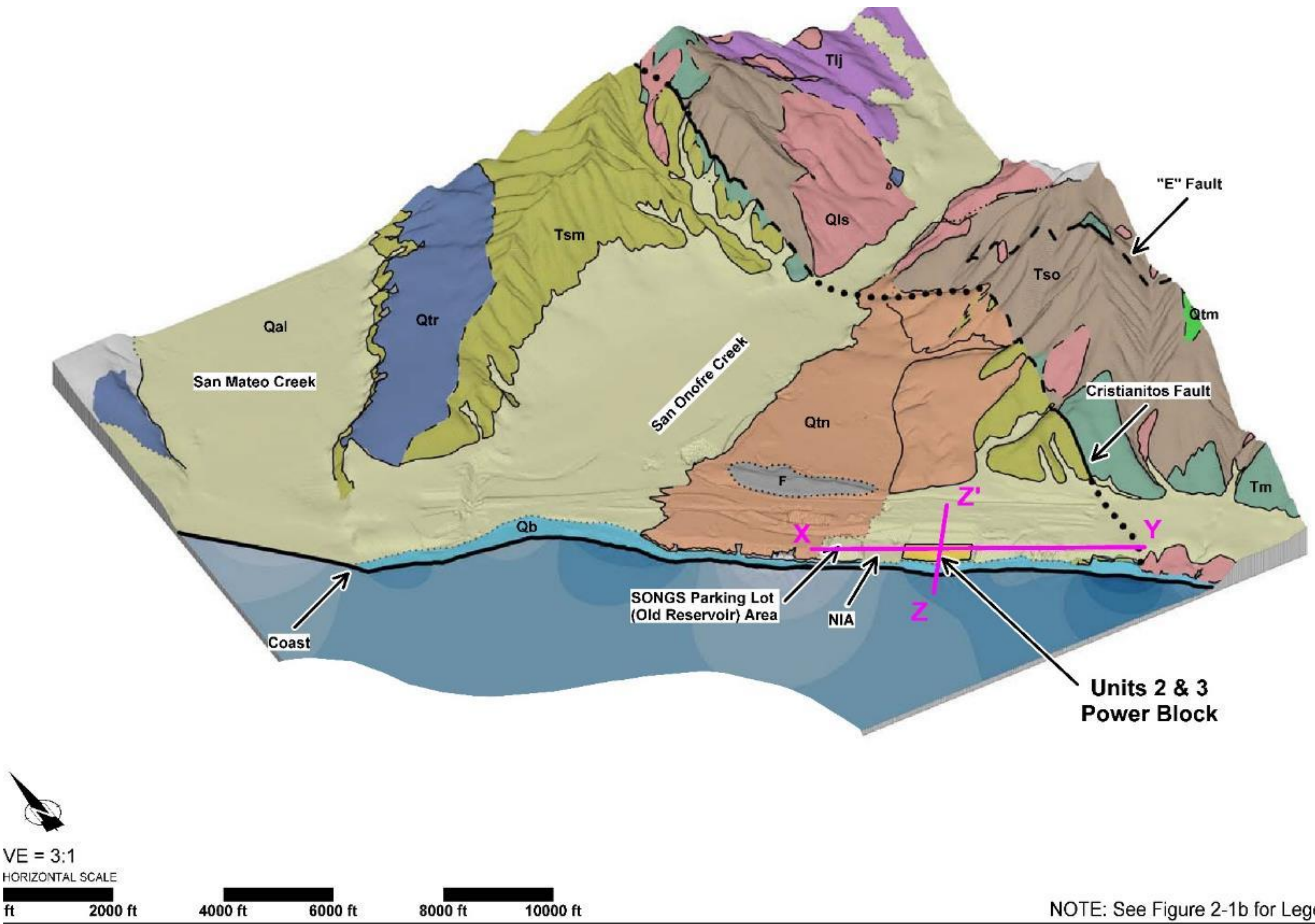
ID	Structure Foundation	Approx. Elevation[1]
A	Unit 2 Containment Pit	-20
B	Unit 2 Safety Equipment Building	-20 to +0
C	Unit 2 Fuel Handling Building	-5
D	Unit 2 Turbine Area	-17 to -9
E	Unit 3 Containment Pit	-20
F	Unit 3 Safety Equipment Building	-20 to +0
G	Unit 3 Fuel Handling Building	-5
H	Unit 3 Turbine Area	-17 to -9
I	Intake Structure	-35 to -17
J	Auxilary Building	-7
K	Toe of Switchyard Slope	+30

[1]Datum: Elevation 0.00-ft, MLLW

UNITS 2 & 3 POWER BLOCK FOUNDATION MAP

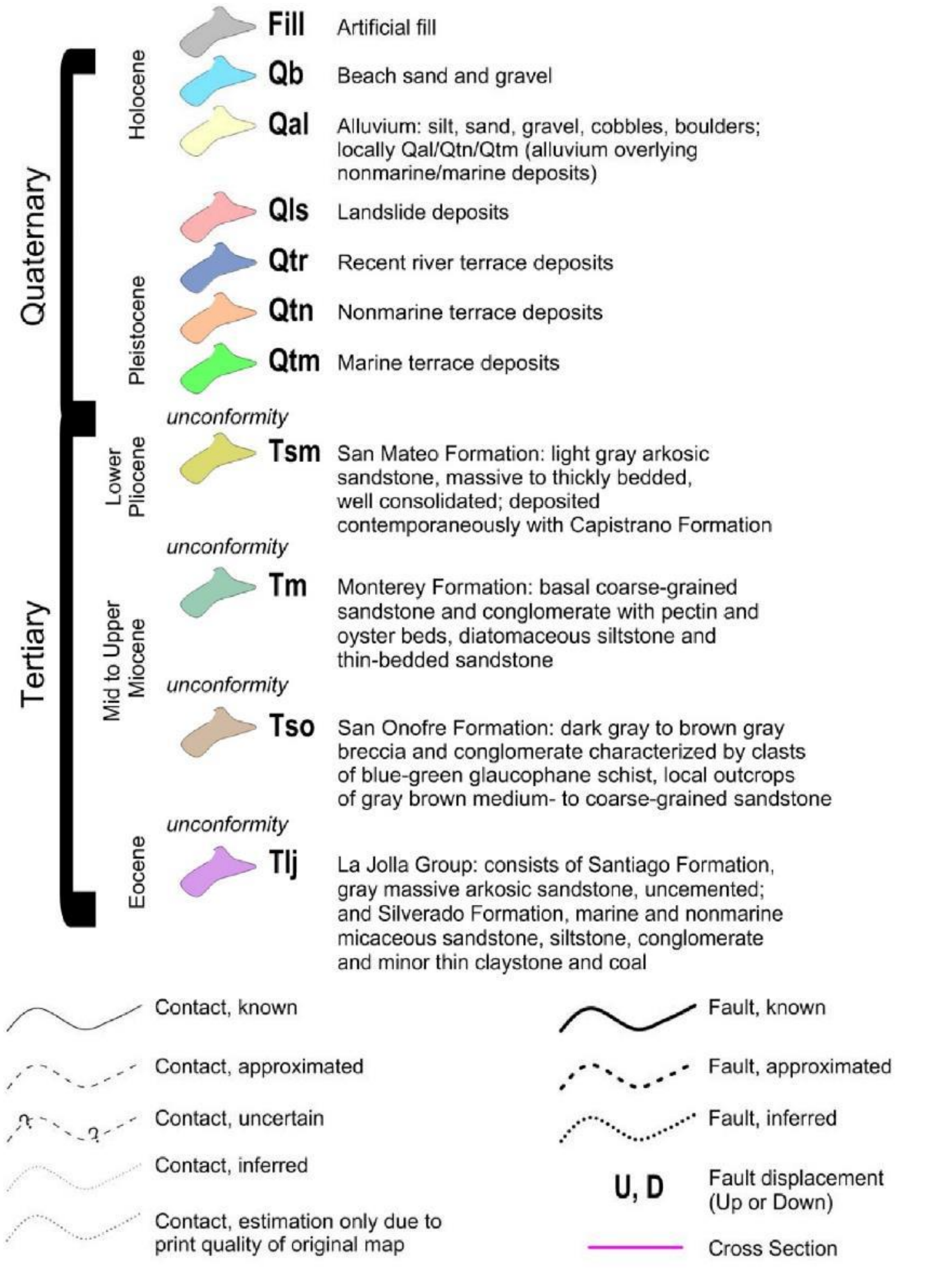
Project No.: 09024 | Project: SAN ONOFRE NUCLEAR GENERATING STATION | Date: OCT 2012 | Figure 1- 3

EXPLORATORY BORINGS LOCATION MAP			
roject No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 1-4



3D DEPICTION OF REGIONAL GEOLOGIC MAP (BASED ON EHLIG, 1977)

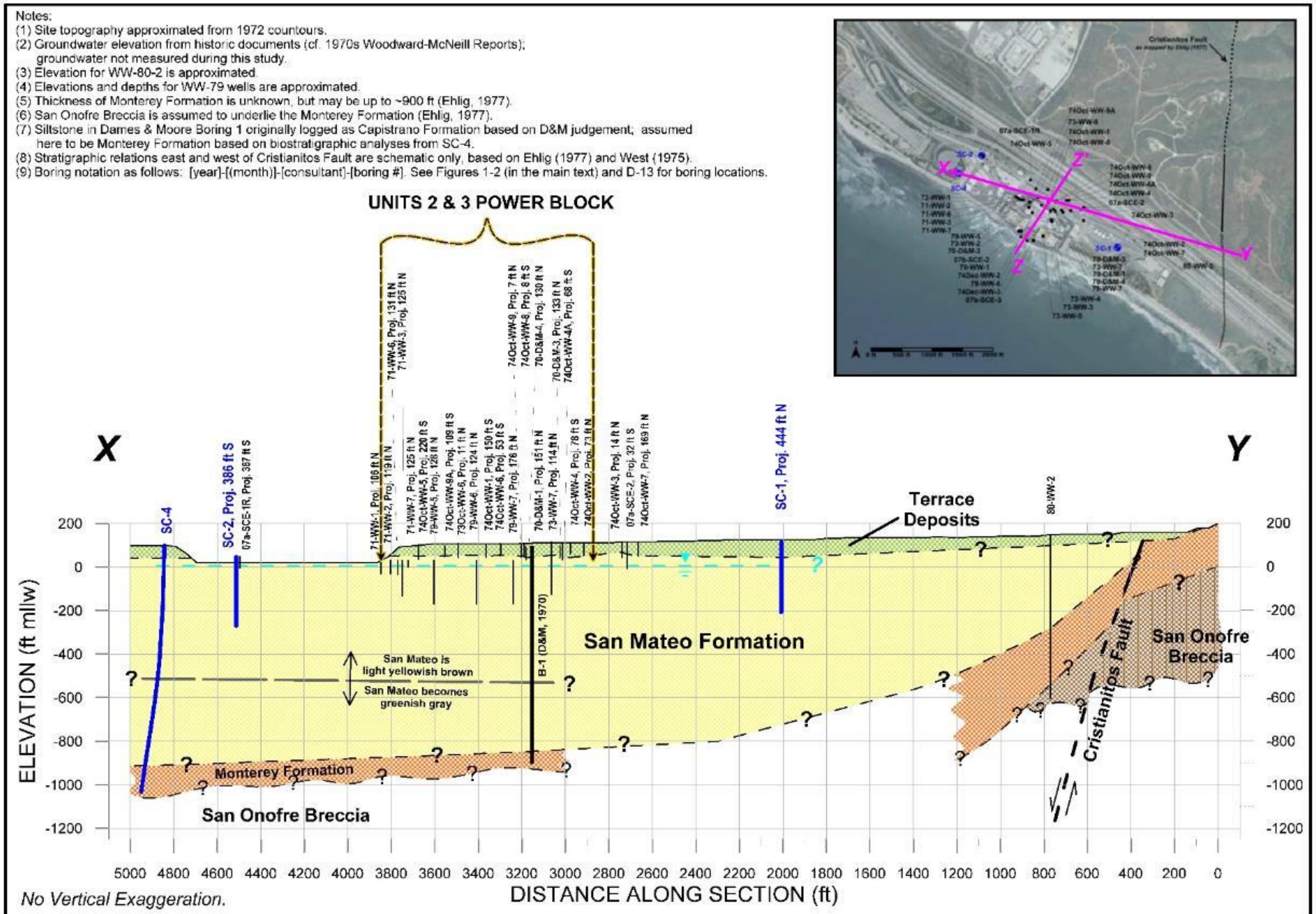
roject No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: MAY 2012	Figure 2-1a



NOTE: See Figure 2-1a for Map

3D DEPICTION OF REGIONAL GEOLOGIC MAP LEGEND (BASED ON EHLIG, 1977)

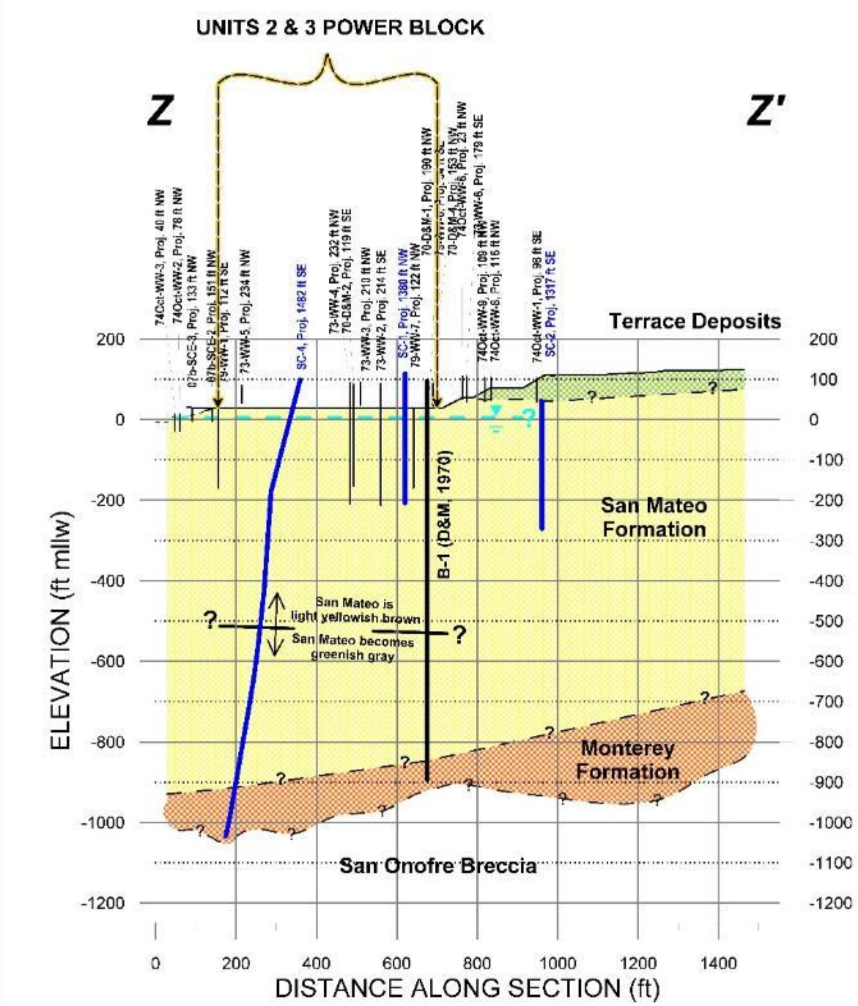
Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-1b



GEOLOGIC CROSS SECTION X-Y

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-2a

GeoPentech

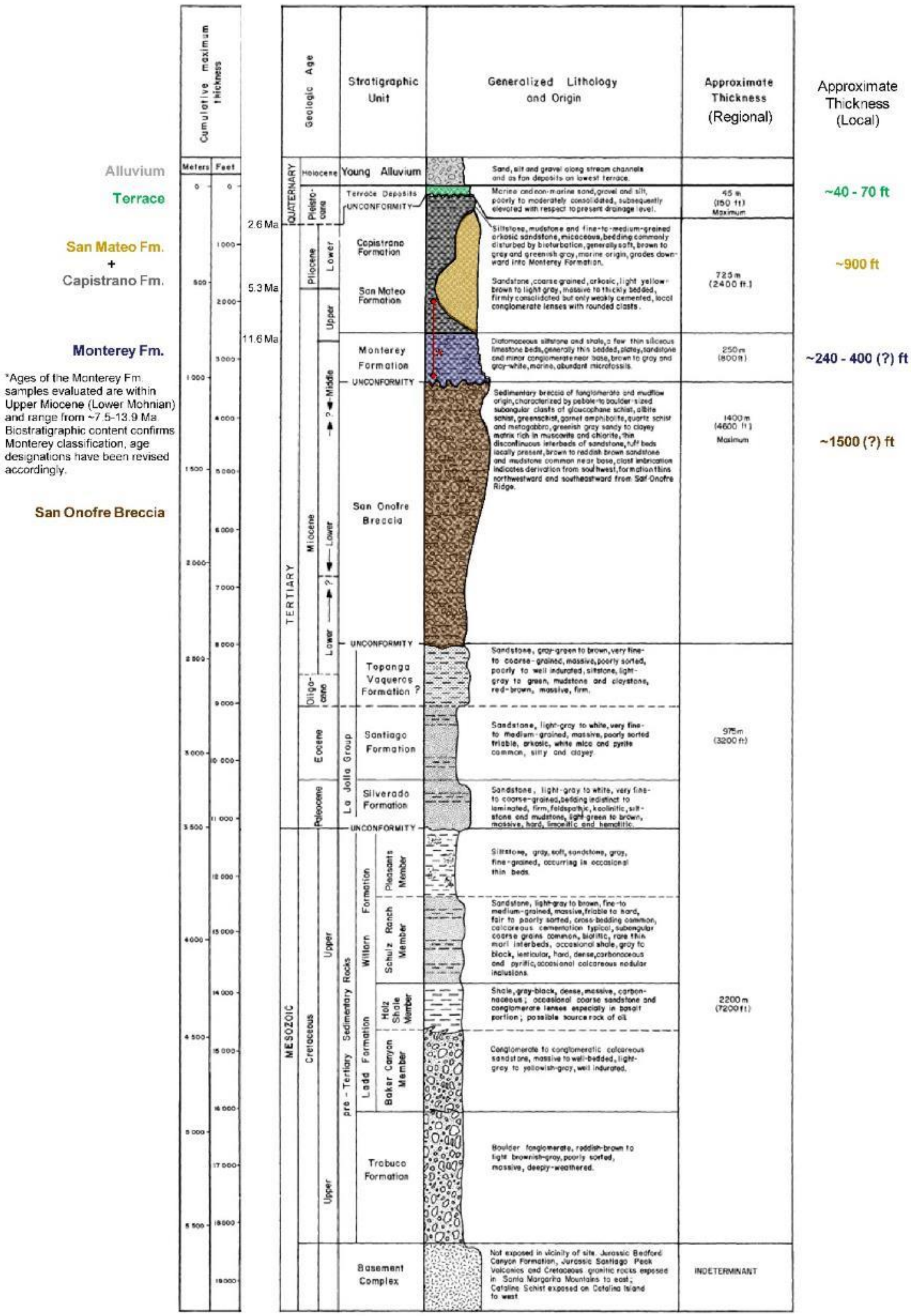


No Vertical Exaggeration.

Notes:
(1) Site topography approximated from 1972 countours.
(2) Groundwater elevation from historic documents (cf. 1970s Woodward-McNeill Reports); groundwater not measured during this study.
(3) Elevation for WW-80-2 is approximated.
(4) Elevations and depths for WW-79 wells are approximated.
(5) Thickness of Monterey Formation is unknown, but may be up to ~900 ft (Ehlig, 1977).
(6) San Onofre Breccia is assumed to underlie the Monterey Formation (Ehlig, 1977).
(7) Siltstone in Dames & Moore Boring 1 originally logged as Capistrano Formation based on D&M judgement; assumed here to be Monterey Formation based on biostratigraphic analyses from SC-4.
(8) Stratigraphic relations east and west of Cristianitos Fault are schematic only, based on Ehlig (1977) and West (1975).
(9) Boring notation as follows: [year]-[(month)]-[consultant]-[boring #]. See Figures 1-4 (in the main text) and D-13 for boring locations.

GEOLOGIC CROSS SECTION Z-Z'			
Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-2b

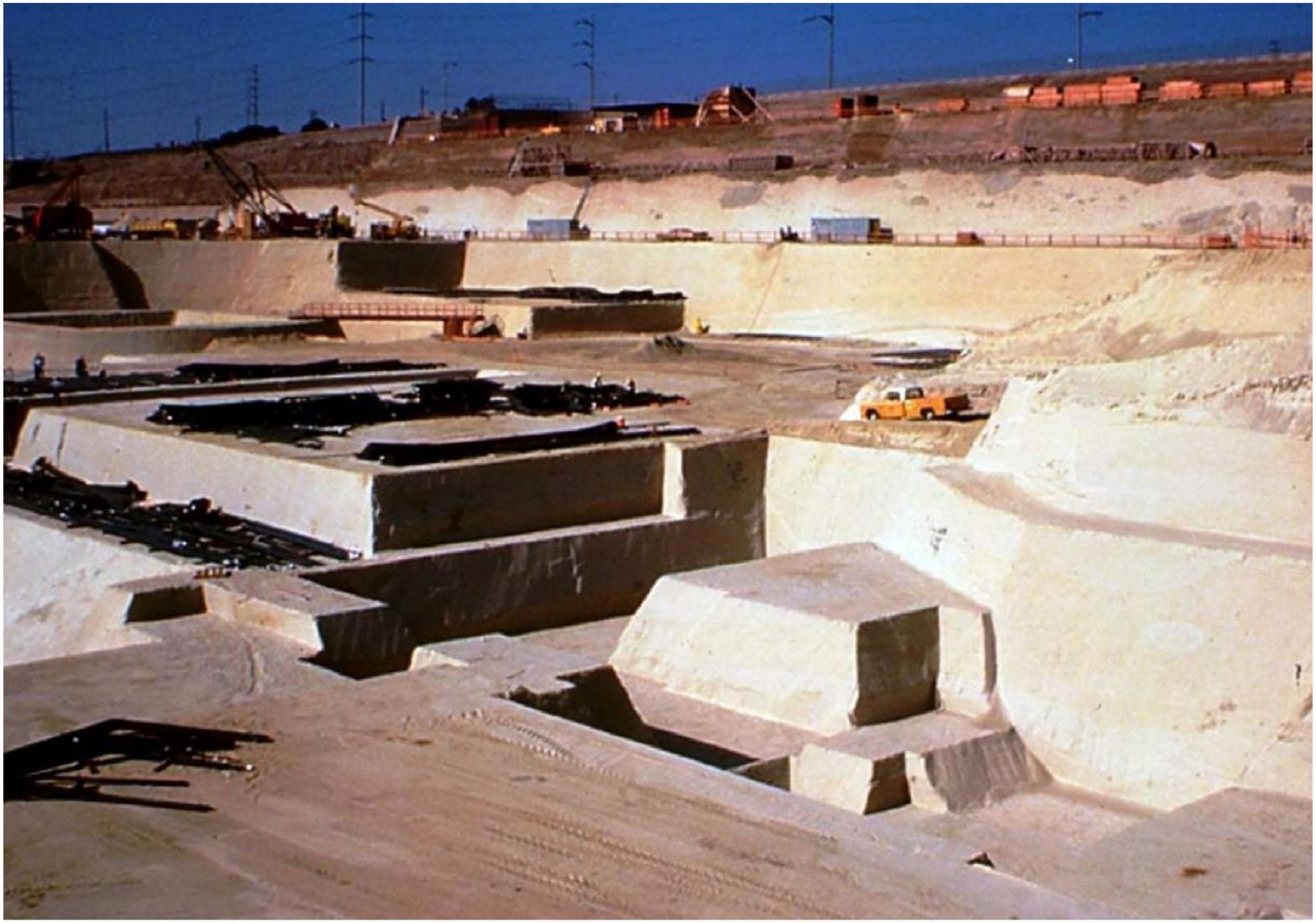
GeoPentech



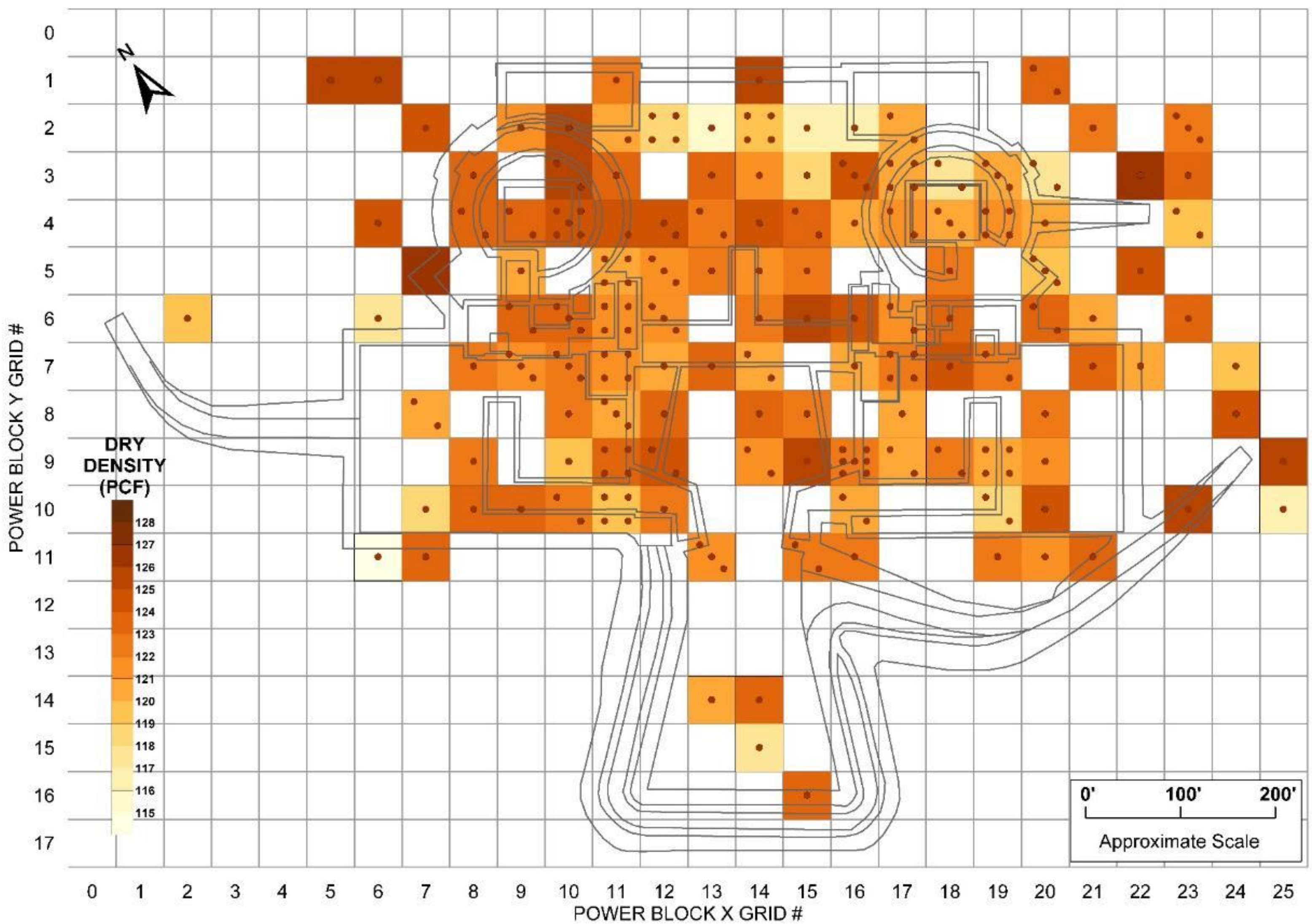
STRATIGRAPHIC COLUMN MODIFIED FROM EHLIG (1977)

Project No.: 09024 | Project: SAN ONOFRE NUCLEAR GENERATING STATION | Date: OCT 2012 | Figure 2-3

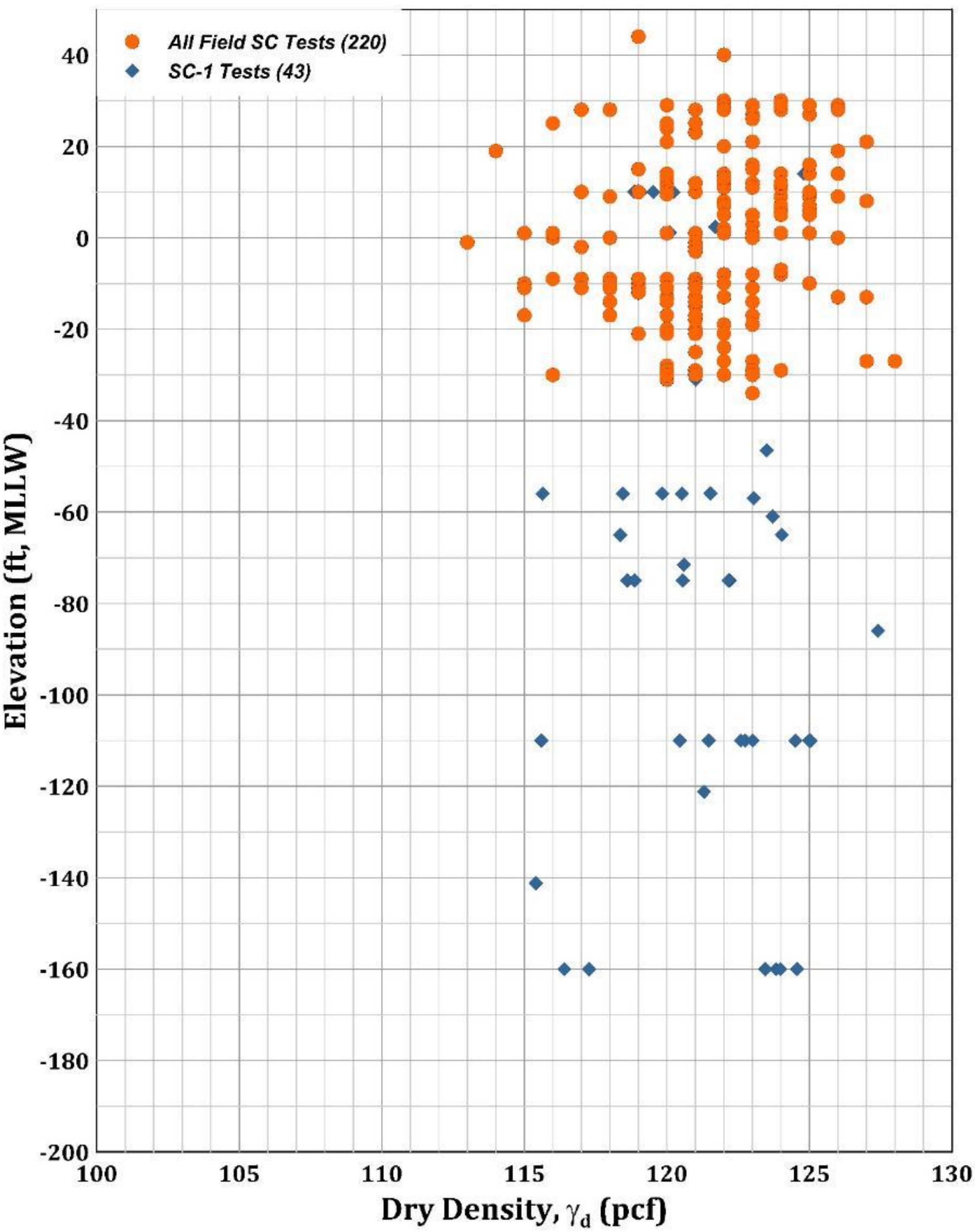
SITE CONSTRUCTION AERIAL PHOTO (ca. 1970s)



SITE CONSTRUCTION FOUNDATION PHOTO (ca. 1970s)

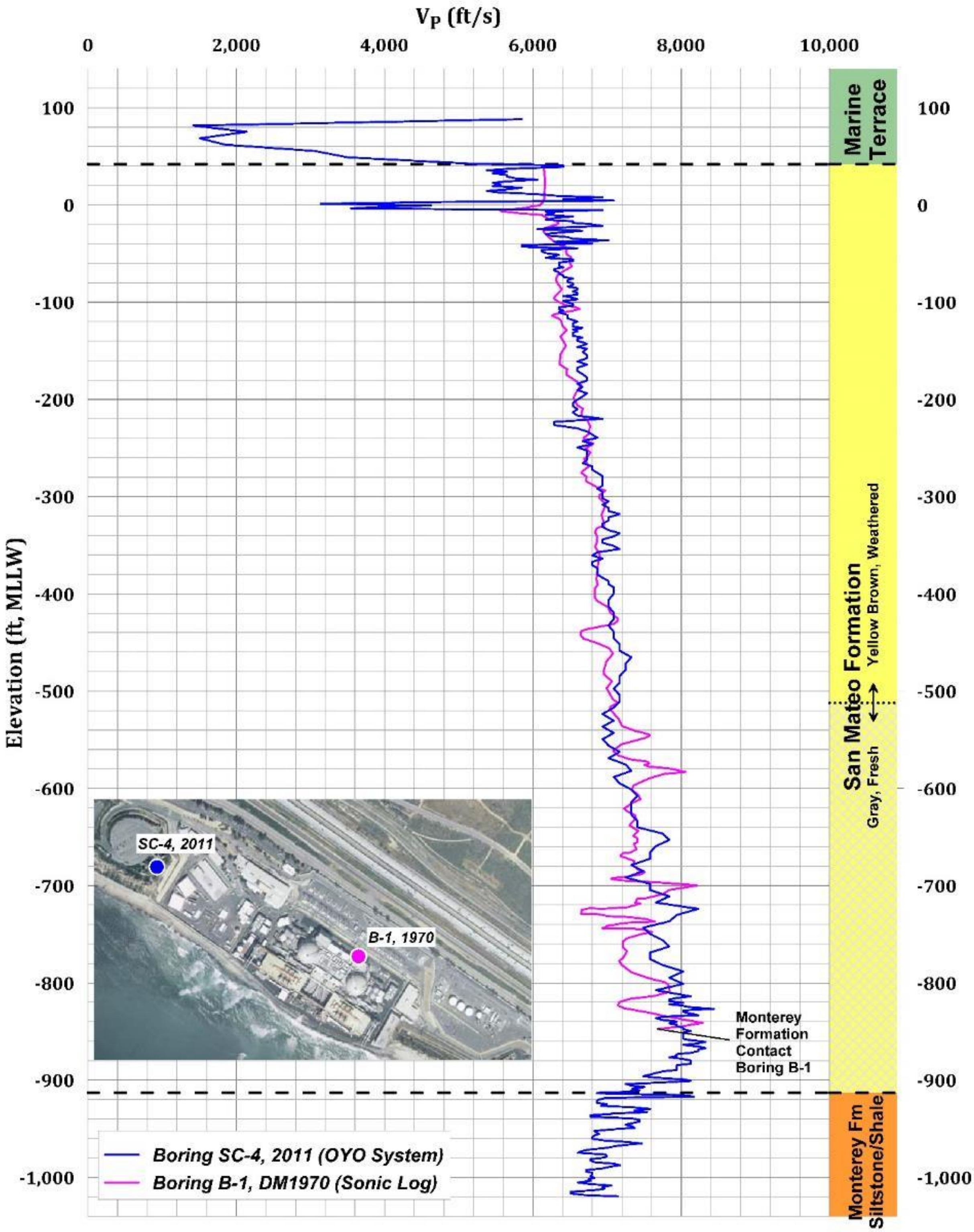


LATERAL DISTRIBUTION OF DRY DENSITY



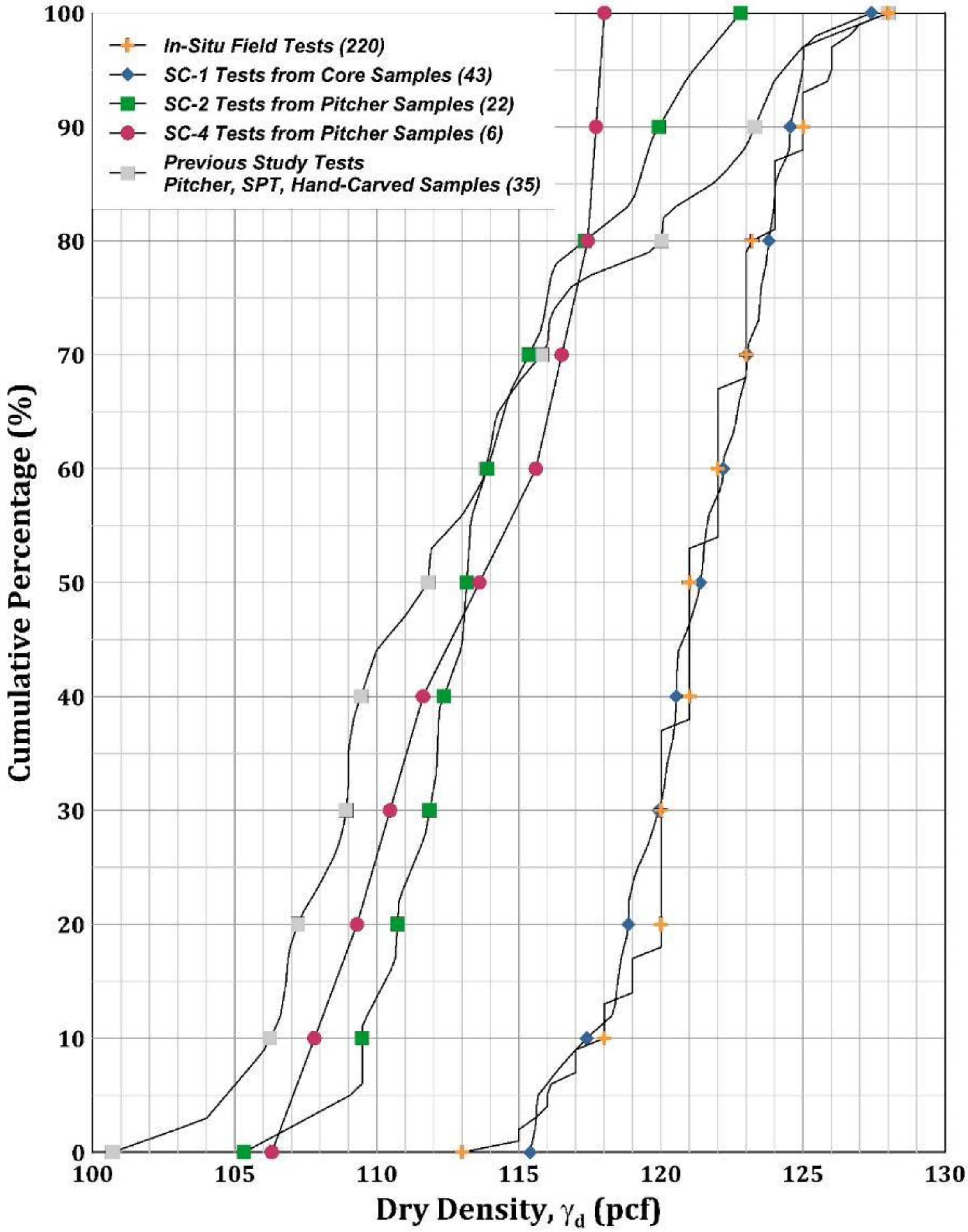
SAN MATEO SANDSTONE - DRY DENSITY VS ELEVATION

Project No.: 09024 | Project: SAN ONOFRE NUCLEAR GENERATING STATION | Date: OCT 2012 | Figure 2-6



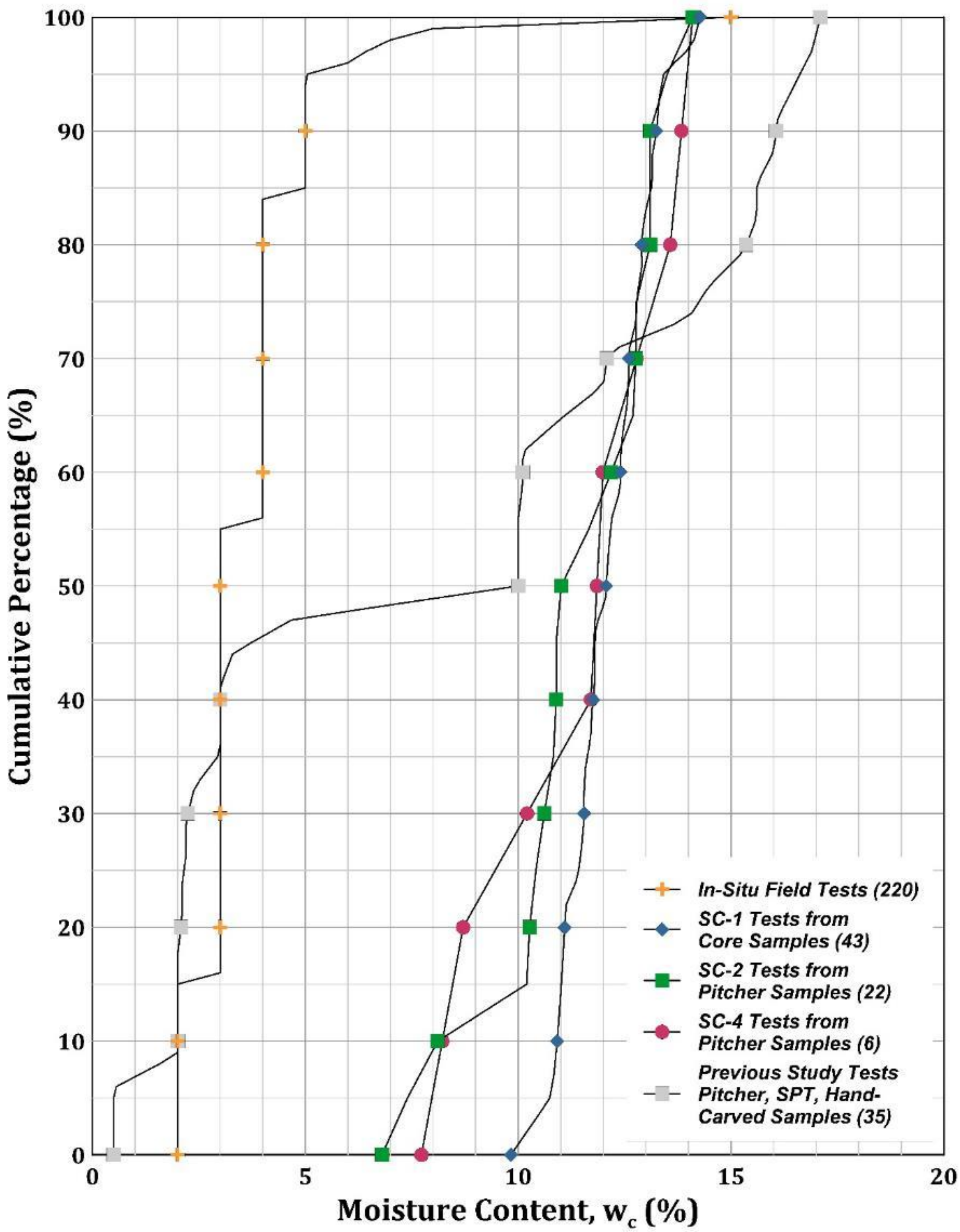
DEEP PRESSURE WAVE VELOCITY PROFILES

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-7



SAN MATEO SANDSTONE - CUMULATIVE DISTRIBUTION OF DRY DENSITY

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-8

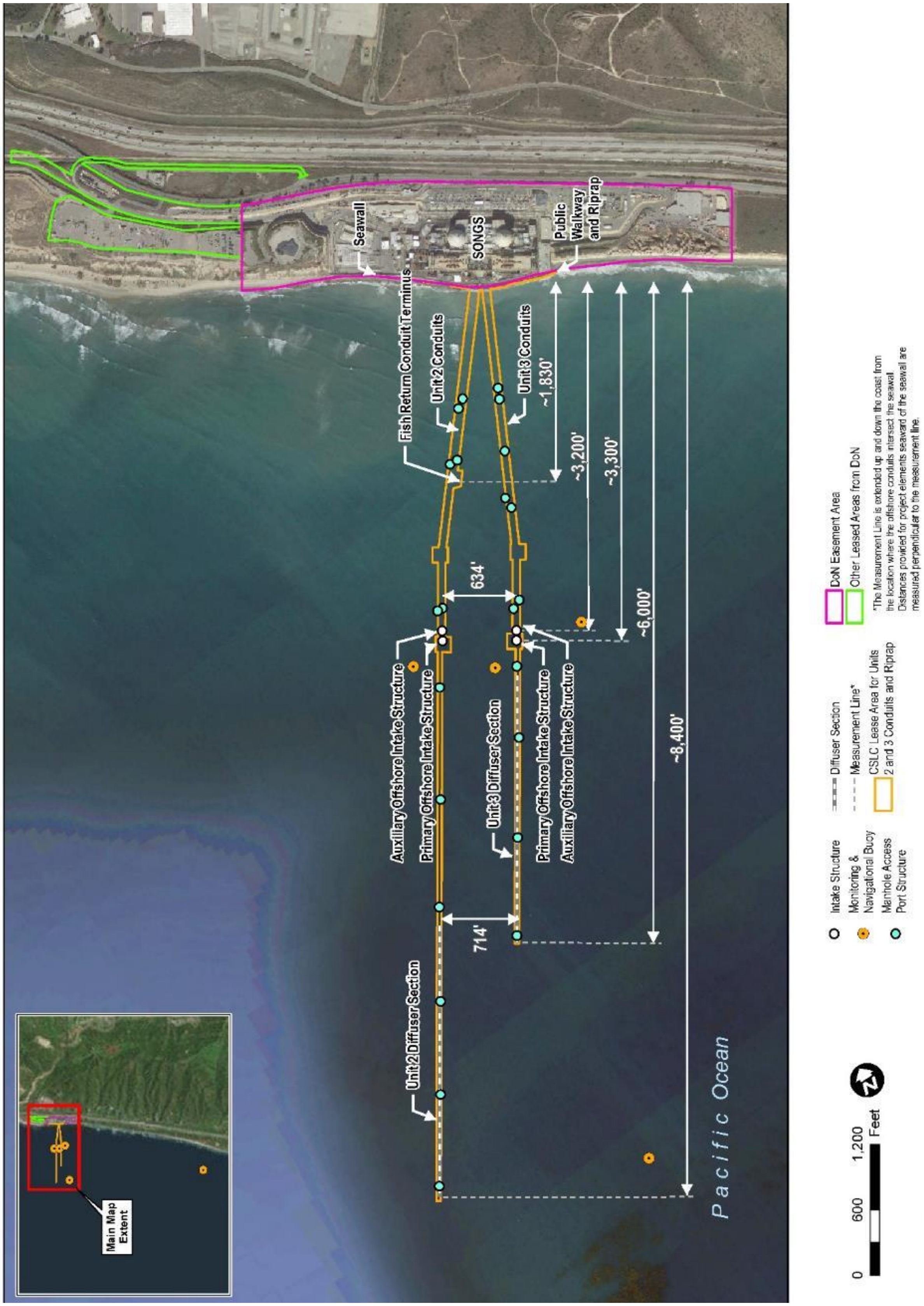


SAN MATEO SANDSTONE - CUMULATIVE DISTRIBUTION OF MOISTURE CONTENT

Project No.: 09024	Project: SAN ONOFRE NUCLEAR GENERATING STATION	Date: OCT 2012	Figure 2-9

Attachment G

Figure 1-2. DoN / CSLC Lease Easement Areas



Source: SCE.

Attachment H

SUMMARY OF SETTLEMENT AGREEMENT

A *Settlement Agreement Regarding Coastal Development Permit for Storage of San Onofre Spent Nuclear Fuel* ("Settlement Agreement") has been reached between Southern California Edison ("SCE") and Citizens Oversight, Inc. and Patricia Borchmann (collectively, "Plaintiffs"). The Settlement Agreement results in SCE using its efforts to relocate the spent nuclear fuel off site and the dismissal of the lawsuit filed by Plaintiffs in 2015. The San Diego Superior Court retains jurisdiction to enforce the settlement terms.

Relevant Background

- In 2000, the California Coastal Commission ("Commission") issued a coastal development permit ("CDP") authorizing the construction of a dry storage facility (known as an Independent Spent Fuel Storage Installation ("ISFSI")) at the San Onofre Nuclear Generating Station ("SONGS") to store Unit 1 spent nuclear fuel.
- In 2001, the Commission approved an expansion of this ISFSI to store spent fuel from Units 2 and 3.
- Upon retirement of SONGS in 2013, approximately two-thirds of the spent fuel from Units 2 and 3 remained in "wet" storage pools.
- On October 6, 2015, the Commission approved a CDP ("2015 CDP") authorizing the construction of an additional on-site ISFSI to accommodate the transfer of all spent fuel to dry cask storage.
- On November 3, 2015, Plaintiffs filed a legal action in San Diego Superior Court challenging the Commission's approval of the 2015 CDP.

Interests Driving Settlement

- SCE believes the long-term, permanent storage and disposal of the SONGS spent nuclear fuel ("Spent Fuel") is the legal responsibility of the U.S. Department of Energy ("DOE"). However, the DOE has yet to discharge its responsibility and take possession of the Spent Fuel.
    - Until it is transferred to the DOE or under contract to an NRC-licensed third party, SCE will continue to maintain ownership of the Spent Fuel.
- Plaintiffs desire to expedite the transfer of the Spent Fuel to an inland location because they believe that will benefit the local community.
- Plaintiffs and SCE have a shared interest in relocating the Spent Fuel to an offsite, NRC-licensed facility operated by either the federal government or a third party (an "Offsite Storage Facility"). It is this shared interest that forms the basis of the Settlement Agreement.

Key Terms

- Pending development of a permanent DOE repository for the Spent Fuel, SCE shall use "Commercially Reasonable" efforts to relocate the Spent Fuel to an Offsite Storage Facility.
    - The "Commercial Reasonableness" standard ensures that any actions taken under the Settlement Agreement are prudent and take into account a number of factors including technical feasibility, costs, and utility customer interests.
- To facilitate SCE's efforts to relocate the Spent Fuel offsite, SCE shall spend up to $4,000,000 on the following "SCE Commitments":
    - Maintain an "Experts Team" to advise SCE on any proposed relocation of Spent Fuel;

  - Develop a conceptual plan for the offsite transportation of Spent Fuel;
  - Develop a strategic plan ("Strategic Plan") to support the development of a Commercially Reasonable Offsite Storage Facility;
  - Make a formal, written request to the owners of Palo Verde regarding the development of an expanded ISFSI to store Spent Fuel;
  - Develop the Inspection and Maintenance Program for the 2015-approved ISFSI by October 6, 2020; and
  - Develop a written plan addressing contingencies for damaged or cracked canisters consistent with NRC regulations and requirements by October 6, 2020.
- To keep the Plaintiffs and other stakeholders apprised of SCE's progress, the Settlement Agreement also calls for SCE to:
  - Provide Plaintiffs with a report regarding its progress in fulfilling the SCE Commitments, then reporting at prescribed intervals thereafter until completed; and
  - Provide Plaintiffs with a monthly progress report on the transfer of Spent Fuel from the "wet" pools to the ISFSI.
- SCE will implement actions or recommendations identified in the Strategic Plan subject to certain conditions, such as California Public Utilities Commission ("CPUC") approval of the costs associated with transfer of the Spent Fuel to a Commercially Reasonable Offsite Storage Facility.
- SCE's obligations under the Settlement Agreement expire when/if:
  - The SCE Commitments are satisfied and neither an Offsite Storage Facility or implementation of the Strategic Plan are Commercially Reasonable; or
  - Laws prohibit relocation of the Spent Fuel; or
  - An NRC-licensed, Offsite Storage Facility agrees to accept the Spent Fuel on Commercially Reasonable terms; or
  - A permanent DOE facility is NRC-licensed to store the Spent Fuel; or
  - The initial term of the 2015 CDP expires in 2035.
- In exchange for SCE's Commitments, Plaintiffs shall dismiss their legal challenge with prejudice. This allows for SCE to complete the ISFSI and to transfer all Spent Fuel to dry storage pending the availability of an Offsite Storage Facility. Plaintiffs also commit to supporting the Settlement Agreement in current and future proceedings.

Attachment I

JACOBS

Memorandum

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Subject	**Technical Memo Discussing Marine Biological Impacts for the SONGS Decommissioning Project**
Project Name	SONGS Units 2 and 3 Decommissioning
Attention	Anne McAulay/Southern California Edison
From	David Rasmussen/Jacobs
Date	August 27, 2018

1. Introduction and Purpose

This memorandum sets forth input and comments from Jacobs' marine biology group on the Draft Environmental Impact Report (EIR) for the San Onofre Nuclear Generation Station (SONGS) Units 2 and 3 Decommissioning Project (Proposed Project). The information herein also sets forth suggested revisions to the EIR to clarify the scope of potential impacts to marine biological resources as a result of the Proposed Project. Jacobs' input falls into two categories, which will be discussed independently of one another. The first category is impacts to Habitat Areas of Particular Concern (HAPCs) identified in the Pacific Coast Groundfish Fishery Management Plan (FMP), and potential impacts to these species themselves, including ratfish (*Hydrolagus colliei*) and sablefish (*Anoplopoma fimbria*). The second category is the potential release of hydrogen sulfide (H_2S) gas and associated impacts.

2. Impacts to HAPCs in the Pacific Coast Groundfish Fishery Management Plan and Species Managed under this Plan

Within the offshore portions of the Proposed Project area there is documented occurrence of seagrass and canopy kelp, both HAPCs within the Pacific Coast Groundfish FMP, and the presence of fish managed under the Pacific Coast Groundfish FMP. Seagrass in the Proposed Project area is likely the surfgrass species, *Phyllospadix torreyi*, based on the description of the plant in the Draft EIR, and habitat requirements for this species. The seagrass HAPC includes those waters, substrate, and other biogenic features associated with seagrass. The HAPC for canopy kelp is associated with canopy-forming kelp species (*Macrocystis* sp. and *Nereocystis* sp.) and not with lower growing/non-canopy-forming kelp species. The canopy kelp HAPC includes those waters, substrate, and other biogenic habitats associated with canopy-forming kelp species.

2.1 Seagrass HAPC

The seagrass HAPC is discussed throughout the Draft EIR along with statements about potential impacts to surfgrass. However, a depth limit for this species is not discussed. Incorporation of a depth limit is an important addition to the Draft EIR as it places an expected boundary, above which surfgrass may occur, but below that limit it would not occur. Impacts to areas that are below the depth limit for surfgrass would not result in a direct impact to this surfgrass or the seagrass HAPC.

Detailed information about the depth range for *Phyllospadix torreyi* in San Diego County identifies a lower depth limit for the species of 20 feet below Mean Lower Low Water (MLLW) (Stewart, 1991). This correlates well with the information presented on Figure 4.4-7 of the Draft EIR and reinforces why surfgrass was not found below this depth limit and why surveys were not completed at greater depths.

Based on this depth limit, the only Proposed Project activity that may result in direct impact to the surfgrass HAPC is the removal of the Manhole Access Ports (MAPs), eight of which are located in waters shallower than 20 feet below MLLW. Removal of other MAPs, the Primary Offshore Intake Structure (POIS), Auxiliary Offshore Intake Structure (AOIS), fish return conduit opening, and diffusers on the discharge conduits are all located in areas which are deeper than the depth limit for surfgrass, so removal of these structures will not result in direct impacts to surfgrass or the seagrass HAPC.

At the MAPs that are in waters less than 20 feet MLLW, there is potential for direct impacts to surfgrass through the removal of the structures, and potential sidecasting of excavated sediments. Based on results of sediment sampling referenced in the Draft EIR, all of the sediments in waters less than 20 feet deep around the conduits are fine- or coarse-grained sands; no finer grained sediments like silts or clays are present. Sand settles out of the water column quickly after being disturbed and is not held in the water column for prolonged periods of time like finer grained sediments. Based on the Proposed Project description, the MAPs in shallow waters do not have stone blankets, so impacts at each shallow MAP will be approximately 0.06 acre with approximately 60 cubic yards of sediment removed. This material will either be suction dredged or sidecast within 15 to 20 feet of the excavation area. If dredged soils were sidecast onto surfgrass, it would result in a direct impact, however for the Proposed Project, this would occur in a small spatial area relative to the larger amount of surfgrass in the vicinity.

The Draft EIR also states that dredging may cause an indirect impact to surfgrass due to increased turbidity and reduced light levels. While this may occur, it would be over a very short period of time and this species is adapted to survive in highly dynamic nearshore environments and is adapted to increased levels of turbidity. Only one MAP would be worked on at a time, and even if all of the 60 cubic yards of sediments were released into the water column the majority would settle out within minutes due to the large grain size. Even if these sediments remained in the water column for a prolonged period of time the stated cross shore current in the Draft EIR of 1 to 2 feet per second would quickly disperse this limited dredge volume across a broad area. For reference, at a current speed of 2 feet per second, a sand grain could potentially travel a distance of 7,200 feet from the source in one hour. Spreading 60 cubic yards of sediments over a much smaller area than this would still not result in a measurable increase in turbidity. Combine this with the expected settlement rates of sand sediments, and the potential impacts to surfgrass and seagrass HAPC due to turbidity would not be significant.

Settlement of dredged sediments on surfgrass is another potential impact to the seagrass HAPC which is discussed in the Draft EIR. Studies on a congener, *Phyllospadix scouleri*, showed that sediment burial increased the potential for mortality and reduced growth of surfgrass, but only at burial depths of greater than 0.8 foot (Craig et al., 2008). The only way sand displaced by Proposed Project work could reach a depth of 0.8 foot would be if all sand were to settle out within a circle that has a radius of 8.5 meters, and even then, only if all material is sidecast. This is a very limited spatial area for impacts and would be entirely contained within the 0.06-acre impact area identified for each MAP. Given this, and that surfgrass is adapted to live in highly dynamic areas with shifting sediments, any potential impacts associated with sedimentation on seagrass HAPC will be highly localized, and are expected to be similar to naturally occurring impacts associated with storm events and large swells.

Anchor placement also has the potential to impact surfgrass and seagrass HAPCs. However, as discussed previously, the only activities in the vicinity of surfgrass are the removal of the eight MAPs that are located in waters shallower than 20 feet below MLLW. The larger impact areas associated with the removal of the POIS and AOIS are in deeper waters that are well offshore, out of the surfgrass depth limit, so impacts to seagrass HAPCs are not expected to occur for these and other offshore structures. Impacts at the shallow water MAPs are expected to be minimal given the short duration of work at these structures and the planned construction techniques.

Given that these impacts to surfgrass and seagrass HAPCs are limited to a highly localized area and that impacts are only temporary and will not result in a permanent conversion of habitat, they are not expected to be significant, and any impacted surfgrass would be expected to recover quickly. Impacts are expected to be similar to what would occur during storm events and large swells.

2.2 Canopy Kelp HAPC

The canopy kelp HAPC is discussed in the Draft EIR, along with similar impacts to those discussed above for the seagrass HAPC. The canopy kelp HAPC is only associated with canopy forming kelp species, and would not be associated with all algal species that are present in the Proposed Project area. To result in an impact to this HAPC the Proposed Project would need to impact canopy kelp. Figure 4.4-8 in the Draft EIR includes the approximate footprint of all of the major persistent kelp beds with canopy-forming kelp in the vicinity of SONGS. Based on this information, the impact areas for the POIS, AOIS, the MAPs on the intake conduits, and the majority of the MAPs and diffusers on the discharge conduits are at distances greater than 0.125 mile from the major persistent kelp beds, so impacts to canopy kelp HAPCs are not expected for the majority of these Proposed Project activities.

2.3 Fish Managed under the Pacific Coast Groundfish FMP

None of the fish listed in Appendix F of the Draft EIR that are expected to occur within the Proposed Project area are listed under the federal Endangered Species Act or California Endangered Species Act, or considered rare. Therefore, behavioral changes due to increased turbidity and take of individual fish including those managed under the Pacific Coast Groundfish FMP would not be considered a significant impact.

As discussed in Section 2.1, temporary increases in turbidity are expected to decrease quickly and sediments would settle out in proximity to the dredging areas. Fish species in the vicinity of the Proposed Project area are highly mobile and are adapted to living in highly dynamic areas that are regularly subject to increased turbidity. Fish would be expected to temporarily vacate areas if they encounter levels of turbidity that may cause irritation or damage to gills as any temporary increases in turbidity would be highly localized. The settlement of sediments out of the water column would be in areas adjacent to the dredging locations, and this may result in a highly localized and short-term reduction in habitat quality for groundfish, but these impacts are expected to be similar to natural events and would be less than significant.

Given the limited amount of habitat that will be disturbed relative to adjacent areas, and that surrounding areas are not HAPCs with the exception of surfgrass and canopy forming kelp, this would not be a significant impact to groundfish species or their local populations. Similarly, as potential impacts would be highly localized, temporary, and occur over a short timeframe, there would be no potential indirect effects to commercial or recreational fishing, this impact is overstated.

2.3.1 Ratfish and Sablefish

Ratfish and sablefish are both species that are managed under the Pacific Coast Groundfish FMP, and are discussed as having a high likelihood of occurrence in Table 4.4-2 in the Draft EIR. Given habitat preferences of these species, they would be expected to have a low potential for occurrence. While ratfish may occur in shallow nearshore waters such as those in the Proposed Project area, their preferred habitat is outer continental shelf and upper slope of the continental shelf off of California, and prefers depths between 164 to 1,640 feet (Barnett et al., 2012). Sablefish also prefer depths that are greater than those found in the Proposed Project area, and generally occur at depths between 492 and 4,920 feet (Kimura et al., 1998). Both species are considered to be deeper water fish, and only occasionally are considered to be present in shallow nearshore waters. Due to this, both species would be expected to have a low potential for occurrence in the Proposed Project area.

3. Impacts Associated with the Release of H_2S Gas

The potential impact and associated need for mitigation for the release of H_2S gas is overstated in the document. H_2S gas typically only forms in truly anaerobic environments such as in sediments in wetlands, embayments, and other stagnant areas where there is no oxygen present; however, as currently configured, none of the discharge conduits, POIS, AOIS, MAPs, or diffuser ports will be completely blocked off from water circulation. Given the large interior diameter of the conduits (18 feet for the intake and discharge conduits and 4 feet for the fish return conduit) and multiple structures that allow flow into the conduits (POIS, AOIS, diffuser ports), these areas would not be expected to be truly anaerobic as tidal action, wave action, currents, and other water circulation would result in some water turnover within the conduits.

Concentration of H_2S gas in water is largely dictated by the pH of the water, and ocean water has a pH around 8.1 or 8.2, and at this level, most H_2S would be dissolved into the water, instead of present as a gas. If any H_2S gas formed in the system, it would rise to high points in the conduits. These high points could include the MAPs, POISs, AOISs, diffuser ports, and the onshore termination of the conduits. If H_2S gas collects at the POIS, AOIS, diffuser ports, or end of the fish return conduit it would quickly diffuse into the water column as it is formed, and not result in a large release as these areas are not sealed and are open to ocean circulation. While the MAPs are covered, they do not have a complete gas-free seal around them. So, similar to the other structures, any gases that collect in the MAPs would escape through the gaps around the cover and into the water column. Therefore, if H_2S gas collects in any of the vertical risers, it would quickly diffuse into the water column as it is formed, and would not result in a large release.

Removal of the MAPs may result in increased circulation of water within the intake conduits which could allow some water to exit the conduit. Water within the vicinity of the MAPs would be expected to slowly turnover with surrounding ocean water due to local ocean circulation, and any gases or low oxygen water in the conduits would slowly diffuse into the water column and be quickly diluted given the highly dynamic environment. This would not cause immediate mortality of organisms that come into contact with the water as stated in the Draft EIR, given the slow release and turnover of water. Also, any organisms in the vicinity of the MAPs would be expected to be mobile and able to move away from any impacts, and would also likely be temporarily driven away by dredging activities. As mentioned previously, the POIS, AOIS, diffusers, and fish return conduit are currently open to water circulation, so removal of these structures would not result in a water release or potential release of H_2S gas, as they are already open to water circulation.

Given this, the impact related to H_2S gas accumulation and release is overstated, and it is recommended that this potential impact be removed from the Draft EIR.

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David Rasmussen

Senior Marine Biologist and Project Manager

Education

M.S., Biological Sciences, California Polytechnic State University
Focus in Marine and Freshwater Fisheries Biology

B.S., Ecology and Systematic Biology, California Polytechnic State University
Minor, Environmental Studies
Minor, Biotechnology

Distinguishing Qualifications

- Strong background and experience as a marine and fisheries biologist.
- Global Coastal and Offshore Community of Practice Leader for Jacobs.
- In-depth experience conducting habitat assessment surveys and focused surveys for special-status marine, freshwater, and terrestrial species and wildlife, rare plants, and nesting birds.
- Regulatory Specialist proficient in preparation of a wide variety of permits from State and Federal resource agencies, and proven negotiation skills with the resource agencies to speed permit approval.
- Scientific Collecting Permit (SCP #8870) for the handling and relocation of aquatic species including salmonids, approved by resource agencies for the handling of other aquatic and terrestrial special-status species.

Relevant Experience

David Rasmussen is an experienced marine and fisheries biologist who is well versed in habitat assessments, aquatic and terrestrial species identification, restoration techniques, development of constraints analyses and environmental project strategy reports, resource agency permitting and negotiations, and evaluation of impacts to special-status species and sensitive resources.

Currently, Mr. Rasmussen's job responsibilities include being a lead biologist and subject matter expert for a variety of Pacific Gas & Electric Company's (PG&E's) projects including gas and electrical transmission and distribution projects, several confidential clients pursuing offshore work on the west and east coasts of the US, various Caltrans and PG&E projects which involve demolition of structures and fish relocation and monitoring in creeks and other waterways, and fisheries sampling projects for Union Pacific Railroad, the EPA, and the Navy. Mr. Rasmussen is also the project manager and lead wildlife and aquatic species biologist for two large scale electrical transmission projects that are currently being permitted through the California Environmental Quality Act.

Responsibilities on these projects and programs include preparation and review of permitting strategy reports, CEQA and NEPA documents, resource agency permit applications and leading negotiations with resource agencies, managing sub-consultants, conducting biological surveys, and preparation of a variety of biological technical reports. He also conducts aquatic habitat assessments and mapping for special-status species, fish relocation and rescue, toxicology testing and sampling of freshwater, estuarine, and marine invertebrates and vertebrates, electrofishing, and producing environmental documents, permits, and reports dealing with aquatic species.

Representative Projects and Dates of Involvement

Market Segment Projects

Operations Leader/Talent Supervisor; Jacobs. Mr. Rasmussen is the Talent Supervisor for 22 biologists and environmental scientists within the Jacobs ATEN Business Group. These individuals are located between Denver in the east, Alaska in the north, Hawaii in the west and the US/Mexico border to the south. They focus on a variety of clients throughout this area. Mr. Rasmussen leads staffing and hiring for the biologists and environmental scientists within this region, assists with distributing workload between staff, and with other Talent Supervisors throughout North America, and other typical supervisory tasks.

David Rasmussen

Coastal and Offshore Community of Practice Leader; Jacobs; 2015-Current. Mr. Rasmussen is the leader for the global Jacobs Coastal and Offshore Community of Practice. This Community of Practice focuses around environmental and biological issues associated with work in the coastal zone and offshore. Responsibilities include leading monthly meetings with Jacobs employees from around the globe that are working in or are interested in coastal and offshore issues, keeping up to date on relevant environmental issues and regulator updates in the coastal and offshore arenas and providing information to the Community of Practice, assisting with staffing of projects, and advising on permitting strategy and issues on coastal and offshore projects.

Lead Fisheries and Benthic Resources Author; Confidential Client. 2017-Current. Mr. Rasmussen is the lead author for the Fisheries, Essential Fish Habitat, and Benthic Resources chapters of a Construction and Operations Plan for a proposed offshore wind farm located on the East Coast of the United States. Work included conducting literature reviews, research on species that may occur in the project area, determining potential impacts associated with the project including impacts to marine habitats, sound propagation, behavioral shifts, expected restoration timeframes post impact, and development of appropriate mitigation measures. Mr. Rasmussen also advised on impacts to marine mammals, turtles, and other special-status marine organisms.

Lead Marine Biologist; San Diego Gas and Electric; San Diego Bay. 2018-Current. Mr. Rasmussen is the lead marine biologist for a project that is in San Diego Bay near Coronado Island. The project involves installation of concrete mattresses to protect a portion of gas pipeline. Work includes conducting database and literature reviews to determine the habitats present at the site, and species that may occur, looking at historic extent of eelgrass beds within San Diego Bay, and coordinating with subconsultants who conducted eelgrass surveys of the project area. This work also included the review of resource agency permit applications, and the eelgrass survey reports, and will transition into identifying mitigation sites for impacts to eelgrass beds and essential fish habitats in late 2018.

Lead Consultant Marine Biologist; California Wave Energy Test Center (CalWave); Vandenberg Air Force Base, California. 2017. Mr. Rasmussen was the lead consultant marine biologist for the CalWave project which was proposed for the areas off Vandenberg Air Force Base. This project involved developing a proposal and plan for several offshore sites to serve as a West Coast test center for several wave and offshore wind energy technologies. This project would have been the first West Coast wave energy center that was connected to the power grid. Mr. Rasmussen provided support in identifying potential special-status species and other constraints that may be present in the action area of the project. This included species covered under multiple fisheries management plans, essential fish habitat, migratory corridors for marine mammals, commercial and recreational fisheries impacts, benthic habitat types, and identification of impacts related to the various proposed technologies. These data were used to inform the principal investigators about the constraints of the project, develop planned survey needs and appropriate timing for surveys, and to prepare the Fish and Aquatic Resources section of the Preliminary Application Document to the Department of Energy.

Lead Biologist; Confidential Client; Los Angeles, Orange, and San Diego Counties, California; 2014-2016. Mr. Rasmussen provided lead biologist and survey support for the development of an environmental project strategy report for a 180-mile electrical transmission line which included both onshore and offshore locations and connected to a number of coastal and inland power generation facilities, including the San Onofre Nuclear Generating Station (SONGS). This included leading site walk downs, constraints reporting, and detailed desktop reviews of offshore and onshore resources including habitat types and expected presence of wildlife to help determine routing and how to avoid environmental constraints. Supported the preparation of the CAISO filing.

Lead Fisheries Biologist; Navy; San Gabriel and Morris Reservoirs, California; 2015. Mr. Rasmussen led the planning, permitting, and implementation for a fish tissue toxicology project on the San Gabriel River, identified sampling locations, and suitable reference sites. He provided guidance on sampling methodologies for maximizing catch of target fish species, handling techniques, species identification, and toxicity sampling. Mr. Rasmussen sampled fish in compliance with his Scientific Collecting Permit. Identified all captured fish, took morphological data, and collected appropriate samples. Upon receipt of the laboratory reports for the tissue samples, Mr.

David Rasmussen

Rasmussen prepared reporting to document levels of multiple toxins within the target site and compared to reference sites, and appropriate other information obtained from similar sampling at nearby reference sites.

Lead Fisheries Biologist; San Mateo Wastewater Treatment Plant Upgrade; San Mateo, California. 2017-Current. Mr. Rasmussen was the lead fisheries biologist and author for the Biological Assessment for aquatic species for the upgrade and expansion of the San Mateo Wastewater Treatment Plant. Work involved conducting literature reviews on project impacts, research on species that may occur in the project area, and preparation of Biological Assessments for species under the jurisdiction of USFWS and NOAA Fisheries. Mr. Rasmussen also met with regulators from the RWQCB and NOAA Fisheries to discuss the project and to speed the permit approval process.

Project Manager and Lead Biologist; PG&E Oakland J to East Shore 115 kV Reconductoring Project; Oakland, California. Mr. Rasmussen is the Jacobs Project Manager and lead biologist for the PG&E Oakland J to East Shore 115 kV Reconducting Project, which involves reconductoring and structural upgrades for a transmission line that runs along the shoreline of the San Francisco Bay, and within adjacent salt marsh and aquatic areas. In addition to typical project management tasks, Mr. Rasmussen leads the field surveys and the preparation of California Environmental Quality Act documents, and developed the permitting strategy for the project. Mr. Rasmussen is also leading a group of subject matter experts and QA/QCing their work in the preparation of the California Environmental Quality Act documents. Through working closely with the project management team and construction management team, Mr. Rasmussen was able to guide the selection of work areas so that they avoid all areas jurisdictional under the Clean Water Act and California Fish and Game Code, and impact durations to minimize the potential for take of special-status species, thus avoiding the need to permit the project with federal and state agencies. This allowed for the schedule for the project to be accelerated by 1 year which resulted in a significant cost savings to the client.

Project Manager and Lead Biologist; PG&E Bay Towers Program; San Francisco Bay Area, California. Mr. Rasmussen is the Jacobs Project Manager and lead biologist for the PG&E Bay Towers Program, which involves the assessment of various power line and transmission line structures throughout the San Francisco Bay, and subsequent permitting to perform maintenance on or replace those structures. In addition to typical project management tasks, Mr. Rasmussen leads the biological field surveys and works directly with the engineering and construction management teams to design work areas to minimize environmental impacts. This will transition into the permitting of the project through various federal, state, and local agencies, including the preparation of California Environmental Quality Act documents, and potential National Environmental Policy Act documents depending on the project impacts.

Lead Fisheries and Aquatic Biologist; Numerous Caltrans Scour Repair and Bridge Replacement Projects; Northern and Central California, California. 2013-Current. Mr. Rasmussen led the permitting efforts for multiple scour repair, bridge repair, and bridge replacement projects throughout Northern and Central California. Permit applications prepared and obtained include RWQCB Water Quality Certifications, USACE Nationwide and Individual Permits, USFWS and NOAA Fisheries Biological Assessments and Letters of Concurrence, NOAA Incidental Harassment Authorization, CDFW Incidental Take Permits and Lake and Streambed Alteration Agreements, Coastal Development Permits from the Coastal Commission, BCDC Minor and Major Permits, and CEQA documents. Following the successful permitting of these projects, Mr. Rasmussen led the fish and aquatic species relocation during implementation of these projects, this included monitoring and advising on the installation of coffer dams, creek diversion systems, and during dewatering of multiple creeks, sloughs, and intertidal areas. Mr. Rasmussen was approved by the resource agencies to conduct assessments for special-status species and to lead the handling and relocation efforts for multiple special-status aquatic species including steelhead, Chinook salmon, coho salmon, tidewater goby, eulachon, and longfin smelt. Experienced with a variety of assessment and relocation techniques including snorkeling surveys, pedestrian surveys, remote monitoring, passive relocation, and active relocation through the use of seines, dipnets, hand nets, electrofishing, trapping, and funnel nets.

Lead Fisheries Biologist and Regulatory Specialist; Embarcadero-Potrero 230 kV Transmission Project; PG&E; San Francisco, California. 2013-2018. Prepared the biological section of the Proponents Environmental Assessment and

David Rasmussen

Initial Study/Mitigated Negative Declaration and resource agency permit applications for this PG&E submarine transmission cable project which was installed in the San Francisco Bay. Led and participated in negotiations with resource agencies including the USACE, RWQCB, USFWS, NOAA and NOAA Fisheries, CDFW, and BCDC. This included discussions with NOAA regarding Incidental Harassment Authorizations for marine mammals and ways to avoid this permitting. Successfully navigated the permitting for this project and developed seasonal work windows for the project which avoided impacts special-status species, and avoiding sensitive habitats identified in benthic habitat mapping. Led the monitoring effort during installation of the submarine cable, this included monitoring of screen intakes on pumps, surveys for herring spawning, and regular coordination with the regulators to update them on project status.

Lead Biologist and Safety Coordinator; Union Pacific Railroad Blair Landfill Intertidal Species Sampling Project; Richmond, California. January 2016- 2017. Mr. Rasmussen was the lead biologist and safety coordinator for this project which involved preparation of a sampling and analysis plan, coordinating with the United States Fish and Wildlife Service, California Department of Fish and Wildlife, and the California Department of Toxic Substances Control to gain approval for collection of intertidal species that are known prey sources for California Ridgway's Rail, a Federal and State protected species. Mr. Rasmussen led the sample collection and species identification effort and coordinated with the analytical laboratory to process the samples.

Marine Biologist; Confidential Client; Central and Northern, California. January 2017- 2018. Mr. Rasmussen assisted with the planning, sampling design, and identification of suitable reference sites for a sampling project to determine the concentration of heavy metals and other contaminants within mussels, algae, and other marine species in tidepools and nearshore habitats off of Central and Northern California. This included site visits, species counts and density determinations, identification of suitable sampling species that were present across all sampling and reference sites, and conducting water quality analyses within the field to ensure sample sites and reference sites were as consistent as possible.

Field Team Lead Fisheries Biologist and Safety Coordinator; Upper Columbia River Fish Tissue Investigation Project; Lake Roosevelt, Washington. 2016. Mr. Rasmussen was the field team lead fisheries biologist and safety coordinator for this project which was overseen by the EPA. He coordinated the collection and preparation of white sturgeon tissue samples from two Native American tribes that actively fish in Lake Roosevelt on the Upper Columbia River.

Lead Fisheries Biologist; EPA; Richmond Inner Harbor, California; June 2012 - 2014. Mr. Rasmussen assisted with the planning, preparation, and implementation for a fisheries monitoring project in the San Francisco Bay. He provided guidance on community involvement fishing programs, recapture methodology for fish species, methodologies for maximizing catch of target fish species, and toxicity sampling. Mr. Rasmussen sampled fish in compliance with his Scientific Collecting Permit. Identified all captured fish, took morphological data, and collected appropriate samples. Fish that were not covered under the Scientific Collecting Permit were released.

Experience Prior to Jacobs

Lead Fisheries Biologist; Nearshore Marine Fish and Invertebrate Monitoring Project, San Luis Obispo Science and Ecosystem Alliance (SLOSEA), San Luis Obispo, Monterey and San Mateo Counties, California (2006-2010). Mr. Rasmussen planned and implemented the first in-depth mark and recapture study of shallow and deep nearshore marine fish inside and outside of Marine Protected Areas (MPAs) off of central California, this included waters directly offshore of Diablo Canyon Power Plant. As Lead Fisheries Biologist he supervised a team of individuals, and trained research assistants. More than 6,500 live fish traps were set; the team captured over 4,000 fish and 8,000 invertebrates, tagged all non-pelagic fish, and identified and collected morphological data on all vertebrate and invertebrate species. Mr. Rasmussen personally handled and tagged over 2,500 fish during this project. Under Mr. Rasmussen's management, sampling costs were reduced by 33 percent over the course of the project while maintaining the same quality and quantity of available data.

Mr. Rasmussen provided data and information at regular meetings with NOAA Fisheries, CDFW, stakeholder groups, and academic experts. He also conducted population estimates and managed and analyzed all collected

David Rasmussen

data, performed home range assessments, homing ability and translocation experiments, and population estimates on nearshore marine fish species.

Lead Fisheries Biologist; Commercial Passenger Fishing Vessel Marine Reserve Project, SLOSEA, San Luis Obispo, Monterey and Santa Barbara Counties (2006-2010). As Lead Fisheries Biologist, Mr. Rasmussen assisted with the planning and implementation of a hook-and-line, mark and recapture study of nearshore fish populations inside and outside of MPAs off of central California including waters directly offshore of Diablo Canyon Power Plant. He coordinated with contracted fishermen, CDFG, NOAA Fisheries, and volunteers to effectively sample the deep nearshore environment. He monitored a maximum of fifteen volunteer fishermen, and handled, identified, tagged, and collected morphological data on all species and released all species. Mr. Rasmussen trained research assistants in how to properly identify captured species, collect morphological data, and identify and mitigate for barotraumas in captured fish. He conducted gut content analyses, fecundity estimates, and assessed breeding condition, fat content, and age of sacrificed individuals. He provided tissue samples and fin clippings to research institutes for work on genetic analyses of various fish species.

Fisheries Biologist and Boat Operator; Morro Bay Estuary and Avila Beach Monitoring Project, SLOSEA and Vantuna Research Group, San Luis Obispo County, California (2006-2010). Mr. Rasmussen operated small boats and conducted trawling, entrapment netting, and seining surveys on the vertebrate and invertebrate communities of Morro Bay Estuary and the freshwater tributaries that flow into it, and waters offshore of Avila Beach.

Assistant Lead Fisheries Biologist; Standard Monitoring Unit for Recruitment of Fish (SMURF) Project, SLOSEA, San Luis Obispo County, California (2005-2010). Mr. Rasmussen constructed SMURF traps and buoys and set them in 50-100 feet of water outside of kelp forests for the purpose of collecting larval and freshly recruited fish including waters directly off of the outflow for the Diablo Canyon Power Plant. He operated small boats and free-dove to collect buoys in nets, and then extracted and identified all organisms from the buoys and collected morphological data on all fish. Fish that could not be identified in the field were returned to the laboratory for further analysis and identification. Mr. Rasmussen collected data to determine seasonal trends in recruitment and cross-referenced recruitment data with measures of catch per unit effort to assess how prior recruitment episodes affected catch in later years.

Lead Fisheries Biologist; Mark and Recapture Program, SLOSEA, San Luis Obispo, Monterey and Santa Barbara Counties, California (2005-2010). Mr. Rasmussen led a mark and recapture program where commercial and recreational fishermen would return tagged fish and latitude/longitude of capture location for a reward. These data were used to track movement patterns, homing ability, growth rate, mortality, and population size of cabezon and other marine fish. Half of the captured fish were sacrificed to determine sex, breeding condition, fat content, and age using otoliths. Eggs in female fish were fixed and sampled to determine fecundity rates. Living and healthy fish were released from a known location to assess homing abilities. Mr. Rasmussen managed the budget for the project and coordinated with commercial and recreational fishermen, CDFG, NOAA Fisheries, and the Coast Guard. He provided environmental awareness training to commercial fishermen and regularly presented research findings to various stakeholder and local interest groups.

Biologist; Algal Cover Trampling Project, SLOSEA, San Luis Obispo County, California (2006-2009). Mr. Rasmussen participated in a field survey of the effects of trampling on algal cover and invertebrate density in intertidal areas. Survey work was conducted on PG&E land approximately ½ mile north of the Diablo Canyon Power Plant. Work was conducted to assess the number of individuals that could visit an intertidal area on a daily basis without adverse effects on biomass and diversity. Mr. Rasmussen conducted simulated trampling and pre- and post-sampling surveys of algal cover and invertebrate numbers, and coordinated with PG&E and Tenera Environmental Biologists.

Publications and Presentations

Rasmussen, D. E. 2010. *Comparisons of Fish Species Inside and Outside of Marine Protected Areas off the South Central Coast of California*. California Polytechnic State University.

David Rasmussen

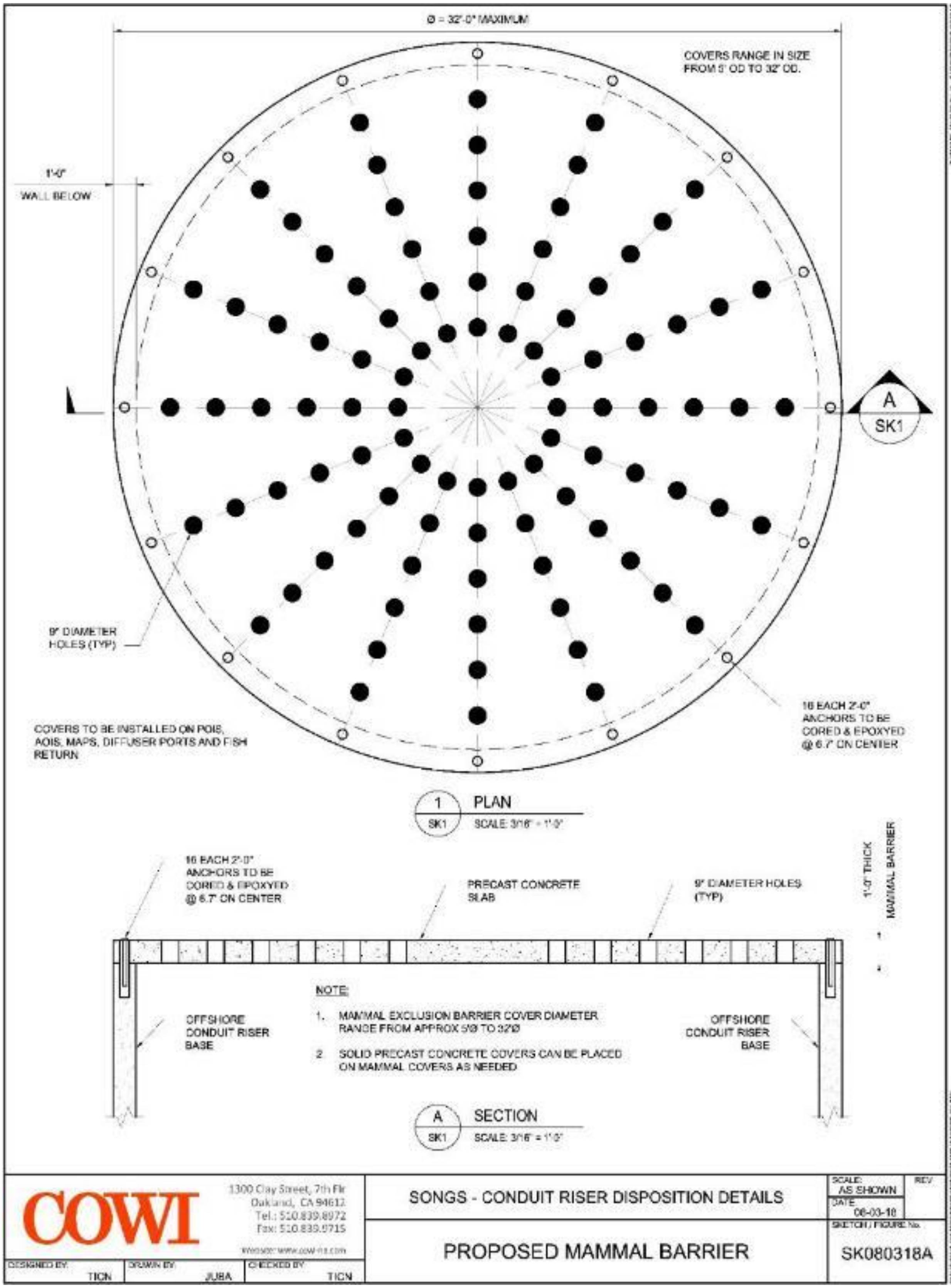
Rasmussen, D.E. 2010. "Comparisons of CPUE of five fish species inside and outside of MPA's, and correlation with recruitment events." Presentation at Western Society of Naturalists Annual Meeting.

Rasmussen, D.E. 2008. "Catch per unit effort and fish length between three spatially nearby Marine Protected Areas established at different time points." Presentation at Western Society of Naturalists Annual Meeting.

Rasmussen, D.E. 2007. "Comparisons of length and CPUE of Cabezon (*Scorpaenichthys marmoratus*) inside and outside of Big Creek Ecological Reserve." Presentation at American Fisheries Society Annual Meeting.

Last Employee Update: 8/27/2018

Attachment J



Ø = 32'-0" MAXIMUM
COVERS RANGE IN SIZE FROM 5' OD TO 32' OD.
1'-0"
WALL BELOW
A
SK1
9" DIAMETER HOLES (TYP)
16 EACH 2'-0" ANCHORS TO BE CORED & EPOXYED @ 6.7' ON CENTER
COVERS TO BE INSTALLED ON POIS, AOIS, MAPS, DIFFUSER PORTS AND FISH RETURN
1 SK1 PLAN
SCALE: 3/16" = 1'-0"
16 EACH 2'-0" ANCHORS TO BE CORED & EPOXYED @ 6.7' ON CENTER
PRECAST CONCRETE SLAB
9" DIAMETER HOLES (TYP)
1'-0" THICK MAMMAL BARRIER
NOTE:
1. MAMMAL EXCLUSION BARRIER COVER DIAMETER RANGE FROM APPROX 5'Ø TO 32'Ø
2. SOLID PRECAST CONCRETE COVERS CAN BE PLACED ON MAMMAL COVERS AS NEEDED
OFFSHORE CONDUIT RISER BASE
OFFSHORE CONDUIT RISER BASE
A SK1 SECTION
SCALE: 3/16" = 1'-0"
COWI
1300 Clay Street, 7th Flr
Oakland, CA 94612
Tel.: 510.839.8972
Fax: 510.839.9715
SONGS - CONDUIT RISER DISPOSITION DETAILS
PROPOSED MAMMAL BARRIER
SCALE: AS SHOWN
REV
DATE 08-03-18
SKETCH / FIGURE No.
SK080318A
DESIGNED BY: TICN
DRAWN BY: JUBA
CHECKED BY: TICN

Attachment K

HDR

San Onofre Nuclear Generating Station Units 2 & 3 Conduits Dispositioning Alternatives

Beneficial and Adverse Impacts Review

Prepared for
Southern California Edison Company
Prepared by
HDR
Irvine, California
And
Coastal Environments, Inc.
La Jolla, California

December 21, 2017

Contents

1 Executive Summary 1

2 Introduction 3
- 2.1 Purpose of This Study 3
- 2.2 Report Organization 4

3 History of San Onofre Nuclear Generating Station 4
- 3.1 Offshore Conduits Overview 5

4 Bathymetry, Sediments and Littoral Drift 7
- 4.1 Geophysical Setting 7
- 4.2 Offshore Bathymetry and Hard Substrate 7
  - 4.2.1 Offshore Surveys 7
  - 4.2.2 Results of the Multibeam Surveys 7
  - 4.2.3 Results of the Backscatter Images 8
- 4.3 Coastal Sediments and Littoral Transport 19
  - 4.3.1 Sediment Sources 20
  - 4.3.2 Longshore Transport at San Clemente and Dana Point 23
  - 4.3.3 Sediment Budget for San Clemente and Dana Point 24

5 Existing Biological Conditions 28
- 5.1 Special Status Biological Resources of the Area 28
  - 5.1.1 Pinnipeds 30
  - 5.1.2 Sea Turtles 31
  - 5.1.3 Abalone 34
  - 5.1.4 Fish 34
  - 5.1.5 Habitat Areas of Particular Concern 35
- 5.2 Non-Special Status Biological Resources of the Area 37
  - 5.2.1 Demersal Fish 37
  - 5.2.2 Infaunal Invertebrates 37
  - 5.2.3 Rocky Reef Communities 39
  - 5.2.4 Fishing 41
- 5.3 Radiological Environmental Monitoring Results 44

6 Conduit Disposition Alternatives 45
- 6.1 Description of alternatives and disposition activities 45
  - 6.1.1 Full Removal 45
  - 6.1.2 Partial abandonment, removing all above seafloor elements 46
  - 6.1.3 Partial abandonment, removing a subset of above seafloor elements 46
  - 6.1.4 Alternative Removal of Vertical Structures 46
- 6.2 Cooling System Trench Infilling 47
  - 6.2.1 Approach 47
  - 6.2.2 Summary 47
  - 6.2.3 SONGS Trench Configuration 48
  - 6.2.4 Waves and Currents 55
  - 6.2.5 Trench Infilling 71
  - 6.2.6 Estimated SONGS Trench Infilling Rates 83
  - 6.2.7 Trench Infilling Conclusions 95

7 Specific Impacts 95
- 7.1 Excavation 95

7.2 Cutting 96
7.3 Shading 96
7.4 Artificial Reef Habitat 97
7.5 Habitat Loss for Benthic Organisms 97
7.5.1 Impacts to Mobile Marine Life 98
8 Conclusion 99
9 References 101

Tables

Table 4-1. Estimated coarse river sand yield, Oceanside littoral cell (yd³/yr). 22
Table 4-2. San Mateo to Oceanside Harbor littoral sub-cell sediment budget (m³/yr). 27
Table 5-1. Protected Species Expected and Observed in the Project Area; Legislative Reason for Protection and a Qualitative Frequency of Occurrence is Presented. 29
Table 5-2. Sum of the Mean Station-specific Density (count/m²) and Cumulative Percentage Contributed to the Total for Each of the Ten Most Common Infaunal Invertebrates Collected in the Sediments along the SONGS Units 2 & 3 Offshore Lease Area (sourced from MBC Applied Environmental Sciences [2016b]). 38
Table 6-1. Dredge Width, Depth, and Cross-Sectional Area for Removal of Offshore Conduits Given Side Slope 1:1 H:V. 51
Table 6-2. Dredge Width, Depth, and Cross-Sectional Area for Removal of Offshore Conduits Given Side Slope 1:1.5. 52
Table 6-3. Dredge Volume of Sand for Removal of Offshore Conduits Given Side Slope 1:1. 53
Table 6-4. Dredge Volume of Sand for Removal of Offshore Conduits Given Side Slope 1:1.5. 54
Table 6-5. Alongshore and Cross-Shore Current Statistics. 67
Table 6-6. Bivariate Distribution Between Significant Wave Height Hs and Current Speed V (m/sec). Numbers in Table Show the Percentage of Time Each Combination of Current Speed and Hs Occurs. 84
Table 6-7. Bivariate Distribution Between Significant Wave Height (Hs) and Peak Wave period (T). Numbers in Table Show the Percentage of Time Each Combination of Hs and T Occurs. Percentages were Computed from Wave Data Measurements from 1978 to 1994. 87
Table 6-8. Infilling Time (Tbed) for Units 2 & 3 With Trench Slope 1:1 (Alternative 1) Computed from the Bivariate Distribution. 89
Table 6-9. Infilling Time (Tbed) for Units 2 & 3 with Trench Slope 1:1.5 (Alternative 2) Computed from the Bivariate Distribution. 90
Table 6-10. Infilling Time in Years for Selected Values of Tbed for Units 2 & 3 for Slope 1:1 (Alternative 1). 91
Table 6-11. Infilling Time in Years for Selected Values of Tbed for Units 2 & 3 for Slope 1:1.5 (Alternative 2). 91
Table 8-1. Summary of Qualitative Assessment of the Severity of Impacts Resulting from Each Disposition Option. 100

Figures

Figure 3-1. Aerial Photo Taken During Construction of SONGS Units 2 & 3 showing the Trestle Pier Extending Offshore of SONGS. 6

Figure 3-2. San Onofre Nuclear Generating Station Offshore Infrastructure and Environmental Setting (Kelp Canopy Information from California Department of Fish and Wildlife (CDFW 2017a); 2015 Kelp Canopy Estimate Represents Current Conditions; 2008 Canopy Represents Recent Maximum Canopy Extent). 6

Figure 4-1. Multibeam Echo-Sounder System Boundaries (Red Lines); Beach Profile Transects (Black Lines); and Seafloor Depth Contours, from Merged Survey Data (Color Scale Left). 9

Figure 4-2. Bathymetry Contours Offshore of SONGS. The Unit 1, 2 and 3 Intake and Unit 1 Discharge Structures are Labeled with a Red Dot. The Units 2 & 3 Diffuser Port Structures are Labeled by the Broken Lines. Each Black Dot in the Diffuser Port Line Represents an Individual Diffuser Port. 10

Figure 4-3. Comparison of 2000 and 2016 Bathymetry Contours. Close Agreement of the Data Indicates Little Change in the Area from 16-65 ft (5-15 m) Depth. 11

Figure 4-4. Color-Coded Bathymetry Map Nearshore of SONGS. Hard Bottom Areas in Red. 12

Figure 4-5. Four Longshore Transects Across the Surveyed Area (Red Lines). Details of Transect 3 are Provided in Figure 4-6. Broken Lines Represent Units 2 & 3 Diffuser Port Structures. Each Black Dot in the Diffuser Port Line Represents an Individual Diffuser Port. 13

Figure 4-6. Cross-Section of the Hard Bottom Relief at Transect 3 Fronting SONGS (Broken Lines). 14

Figure 4-7. Seafloor Image of the Nearshore Area of SONGS Comprising a Combination of the Multibeam Survey Backscatter and Color-Shaded Relief Bathymetric Data. 15

Figure 4-8. Backscatter Image of Differing Acoustic Reflectivity. Insert is Color-Shaded Image of Bathymetry (Inset from Figure 4-7). 16

Figure 4-9. Multibeam Backscatter Image of Areas with Different Acoustic Reflectivity (top). Color-Shaded Bathymetry Image (Bottom). Insets from Figure 4-7. 17

Figure 4-10. Substrate Classification Overlain onto Backscatter Data and Bathymetry Contours (CE 2016a). Hard Substrate is in Dark Blue. Shell Hash is Shown in Light Blue, and Sandy Areas are Shown in Gray. The Diffuser Lines Represent Sections of the Larger Outfall Conduits Which Extend Out from the Shoreline. Each Yellow Dot in the Diffuser Line Represents an Individual Diffuser Port. 18

Figure 4-11. Sub-Bottom Sonar Isopach Map of the SONGS Offshore Vicinity, 14 March 2000. Sub-Bottom Sediment Thickness Contours are in Feet. Note Also the Areas of Hard Bottom Exposure. The Diffuser Lines Represent Sections of the Larger Outfall Conduits Which Extend Out from the Shoreline. 19

Figure 4-12. Oceanside littoral cell, modified from Inman and Jenkins (1983). 21

Figure 4-13. Longshore Transport Potential (m^3/day) from Directional Wave Measurements, San Clemente, San Onofre, and Oceanside, 1983-1989. 24

Figure 4-14. Four Oceanside Littoral Cell Sub-Cells. 26

Figure 5-1. Habitat Areas of Particular Concern in the San Onofre Nuclear Generating Station Offshore Infrastructure Area. 36

Figure 5-2. Mean Annual Otter Trawl Catch/100 m^2 (± Standard Error) for Quarterly Sampling at Nine Stations Sampled between San Mateo Point and Don Light. Sourced from SCE (2016). 38

Figure 5-3. Mean Fish Density (Count/10 m^2) Observed During Spring Surveys Along the Units 2 & 3 Offshore Conduit Corridors. Image from MBC (2016b). 39

Figure 5-4. Mean Invertebrate Density (Count/10 m^2) Observed During Spring Surveys Along the Units 2 & 3 Offshore Conduit Corridors. Image from MBC (2016b). 40

Figure 5-5. California Department of Fish and Wildlife (CDFW) Fishing Blocks used in the Fishing Analysis. 42

Figure 5-6. Percent of the Total Commercial Passenger Fishing Vessel (Recreational Fishing) Reported Catch Occurring in the San Onofre Nuclear Generating Station Area Contributed by Department of Fish and Wildlife Block 756 Out of the Six Blocks Analyzed (see Figure 6). 43

Figure 5-7. Percent of Total Commercial Landings and California Spiny Lobster Landings in the San Onofre Nuclear Generating Station Area Contributed by Department of Fish and Wildlife Block 756. 44

Figure 6-1. Configuration of Trenches and Pits. Navigation Channels are Trenches; Trenches are not Necessarily Perpendicular to the Coast. 48

Figure 6-2. Plan View of Units 2 & 3 Offshore Conduits and Associated Water Depth. Water Depths are Indicated and Referenced to MLLW (epoch 1941-1960). 50

Figure 6-3. Cross-Section A Showing Trench for Removal of 18-ft-Diameter (6-m-Diameter) Intake and Discharge Conduits with Side Slope 1:1. 51

Figure 6-4. Wave Exposure at San Onofre Illustrating Mainland and Island-Shadowing and Resulting Wave-Exposure Windows (USACE 1986). 57

Figure 6-5. Comparison of Wave Parameters Between Oceanside and San Onofre (CEI 2000a). 58

Figure 6-6. Significant Wave Height at Oceanside (OCNSD), San Onofre (SONGS), and San Clemente (SANCL) During Winter 1984-1985 (Elwany 2016). 59

Figure 6-7. Maximum Monthly Significant Wave Height (Hs) at San Onofre. Data are from the Coastal Data Information Program Oceanside Wave Array, 1978-1994 (CEI 2000a). 60

Figure 6-8. Histogram (Upper) and Cumulative Distribution (Lower) of Peak Wave Periods (T) at San Onofre. 61

Figure 6-9. Hindcast Significant Wave Height Versus Time in 10 m Water Depth at SONGS (Monitoring and Prediction Points [MOPs] 1167, inset). Hs = 0.5, 1.5, 2.5 m (Dashed Orange Horizontal Lines) Show, Respectively, Low, Moderate, and Extreme Wave Heights used to Estimate Trench Infill Times (O'Reilly et al. 2016). 62

Figure 6-10. Beach Cross-Section Showing the Components of the Surf Zone. 64

Figure 6-11. Bathymetry Map Showing the Extent of the Surf Zone from the Shoreline Up to 7-m Water Depth and the 15-m Contour Line in Red. 65

Figure 6-12. Daily Averages of the Alongshore Current (V) off San Onofre from 1977 through 1986. Portions Shaded in Black are Upcoast Currents (towards Los Angeles) and Hatched Portions are Downcoast Currents (Elwany et al. 1990). 68

Figure 6-13. Probability Density Function of Alongshore Current (V) and Cross-Shore Current (U) Measured at 3 m below the Surface for All Data Collected from 1977-1986 (Elwany, 1993). 69

Figure 6-14. Cumulative Distribution Functions of Alongshore (V) and Cross-Shore (U) Currents Measured 3 m Below the Surface for all Data Collected from 1977 through 1986. V Positive Upcoast and U Positive Onshore. From Elwany 1993. 70

Figure 6-15. Schematic of Sediment Transport Processes in a Trapezoidal Channel (Klein 2004). Sediment is Stirred by Waves and Currents, and Advected by the Cross Channel Current. The Trench Infill Rate Depends on the Difference of Fluxes Into and Away from the Trench. 72

Figure 6-16. Diagram of Trench Transverse Section (Upper) and Plan View (Lower). Variables: ho = Mean Water Depth in Borrow Area; uo = Local Depth-Averaged Velocity; bpo = Mean Width of the Pit; dpo = Mean Dredged Pit Depth; lpo = Mean Length of the Pit in y. 74

Figure 6-17. The Fraction of the Original Volume Filled (Vin/Vpo) Versus Time for Different Values of Tbed. Solid Horizontal Lines Correspond to 0.9, 0.63, and 0.5. When T=Tbed, the e-folding Time, Vin/Vpo = 0.63. 75

Figure 6-18. Map Showing Del Mar (SO-5) and Cardiff (SO-6) Borrow Pits, Located 50 km South of SONGS, Outlined in Red. From Coastal Frontiers (2017). 77

Figure 6-19. Del Mar Borrow Pit (SO-5) Elevation Changes A-A' (Upper), B-B' (Lower) from 2012-2016. Data from Coastal Frontiers (2017). 78

Figure 6-20. Solana Beach Borrow Pit (SO-6) Elevation Changes at Transects A-A' (Upper) and B-B' (Lower) from 2012-2016. Cross-Shore Transect is B-B' (lower). Data from Coastal Frontiers Corporation (2017). 79

Figure 6-21. Schematic Configuration of a Rapidly Infilled Trench Seaward of the Surf Zone on the Dutch North Sea coast. The 700-m-long Trench was About 4 m Deep in 7 to 13 m Water Depth (A). Observed and LOMOR Model Trench Cross-Section for Laboratory Case (B) and Actual Trench (C) (Ribberink et al. 2005). 80

Figure 6-22. Observed and SUTRENCH 2000 Modeled Trench Depth Versus Alongshore Location. Results are Similar with (a) Time-Varying Wave Height H, (b) Constant H = 1.1 m (with Adjusted Friction), and (c) Constant H = 1.3 m (Klein 2004). 81

Figure 6-23. Photographs of (a) Landing Craft Excavating Channel About 2 m deep, 30 m Wide (Alongshore), and 75 m Long (Cross-Shore) Across the Surf Zone, and (b) Breaking (White Areas on Channel Sides) and Non-breaking (Dark Areas) Waves Near the Channel. The Arrows Indicate Flow direction. Sediment (Brown) and Foam (White) Carried Offshore of the Surf Zone by the Rip Currents are Visible, Especially to the Right and Offshore of the Large Rip Current Jet (Arrow Pointing Offshore). From Moulton et al. (2014). 82

Figure 6-24. Bivariate Distribution of Significant Wave Height (Hs) and Current Speed. 85

Figure 6-25. Three-Dimensional Plot for Bivariate Between Significant Wave Height Hs and Current Speed. 86

Figure 6-26. Cumulative Distribution of Significant Wave Height Hs from 2000-2016 in 10 m Water Depth at San Onofre. Hs < 1 m, 96% of the Time. 92

Figure 6-27. Cumulative Distribution of Current Speed in 10 m Water Depth, 3 m Below the Surface at San Onofre. V < 0.2 m/sec, 90% of the Time. 93

Figure 7-1. Underwater photo of diffuser port D35 showing vegetation including giant kelp and a variety of reef and kelp associated fishes. 98

Acronyms and Abbreviations

AOIS	auxiliary offshore intake structures
CEI	Coastal Environments, Inc.
CDIP	Coastal Data Information Program
cm	centimeter
CPFV	commercial passenger fishing vessels
CSLC	California State Lands Commission
CDFW	California Department of Fish and Wildlife
DNOD	Department of Navigation and Ocean Development
ft	feet
HAPC	habitat areas of particular concern
HDR	HDR Engineering, Inc.
H:V	horizontal to vertical ratio
ID	inside diameter
km	kilometer
m	meter
MAPS	manhole access ports
MBC	MBC Applied Environmental Sciences
MBES	multibeam eco-sounder system
NPDES	National Pollutant Discharge Elimination System
NMFS	National Marine Fisheries Service
pCi/g	picocuries per gram
POIS	primary offshore intake structure
SCE	Southern California Edison Company
SCB	Southern California Bight
STA	station
SONGS	San Onofre Nuclear Generating Station
USFWS	U.S. Fish and Wildlife Service
yd	yards

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1 Executive Summary

As part of the planning for the decommissioning of the San Onofre Nuclear Generating Station (SONGS), Southern California Edison Company (SCE) is proposing to disposition the offshore conduits that supported SONGS Units 2 & 3 once-through cooling water systems and associated fish return system. SCE commissioned HDR and Coastal Environments, Inc. (CEI) to perform an analysis of the conduits that would provide an estimated baseline geomorphological and ecological condition, and evaluate the potential benefits and adverse impacts of conduit dispositioning. Results of this analysis are expected to assist the California State Lands Commission (CSLC), which leases to SCE, San Diego Gas & Electric Company, and the City of Riverside, the submerged land occupied by the conduits and associated structures, in evaluating a lease extension and conduit disposition specifics that would be part of the overall decommissioning plan. The offshore portion of the once-through cooling water system is comprised of four conduits buried beneath the seafloor that connect to two primary offshore intake structures, two auxiliary offshore intake structures, 23 manhole access ports, and 126 diffuser ports. In addition, there is one fish return discharge conduit. Three final disposition options were evaluated in this analysis: (1) complete removal of all offshore elements to the point they connect with in-plant systems under the beach; (2) abandonment of all buried conduits in place and removal of all structures that rise above the seafloor; (3) abandonment of all buried conduits in place and removal of a subset of all structures that rise above the seafloor. The activities required to render the conduits and associated structures to their final disposition are expected to result in varying impacts on the marine environment.

The seafloor in the Project Area, or the area surrounding SONGS and defined in this analysis as San Mateo Point to the northwest and Don Light to the southeast, likely affected by the conduit dispositioning is composed of a mix of sand, cobble, and occasionally large rock outcroppings forming rocky reefs. The southern California coastline supports a variety of submerged aquatic vegetation that is considered to be of high value due to its heightened productivity relative to other marine habitats. Habitats include giant kelp (*Macrocystis pyrifera*) and surfgrass (*Phyllospadix* sp.) and the aforementioned rocky reef outcroppings, which have been classified as Habitat Areas of Particular Concern (HAPC) by the Pacific Fishery Management Council. Protected species commonly associated with giant kelp, surfgrass, and/or rocky reef habitats include Garibaldi (*Hypsypops rubicundus*), Giant Sea Bass (*Stereolepis gigas*), abalone (*Haliotis* spp.), California sea lion (*Zalophus californianus californianus*), harbor seal (*Phoca vitulina richardii*), and southern sea otter (*Enhydra lutris nereis*), all of which occur, or have occurred, in or adjacent to the Project Area. In addition, the concrete vertical structures of the conduits that rise above the seafloor have provided incidental habitat to many species associated with rocky reefs, rock outcroppings, and kelp forests.

Major components identified in the disposition options include the construction and use of a trestle pier, multiple construction barges with multi-point anchoring, sheet pile along the shoreline during removal of conduit and associated infrastructure from below the intertidal zone up to the plant, excavation and suction dredging of sediments, and vessel traffic (e.g., barges and monitoring boats likely from Long Beach and Dana Point Harbors from the north). All of these events would result in potentially adverse impacts to the environment driven most prominently (but not exclusively) by the full removal of the conduits, turbidity and noise generated by the underwater activities, and temporary or permanent habitat loss.

Acoustically-sensitive, highly migratory marine mammals are frequently observed in waters adjacent to the Project Area. These mammals include great whales, dolphins, California sea lion, and harbor seal. Construction noise produced during the process of dispositioning the conduits could impact marine mammals in the vicinity of the Project Area if noise exceeds determined thresholds.

All three disposition options require the removal of at least some structures that currently extend above the seafloor. These structures have developed into artificial reef habitat, many anchoring giant kelp via the kelp's holdfast. Loss of these structures may reduce important rocky reef-like habitat in the south Orange County and northern San Diego County areas and the associated submerged aquatic vegetation that has been observed on the structures. Because submerged aquatic vegetation functions as biogenic habitat, its loss is potentially associated with the fish and invertebrate communities it supports. SCE is currently providing mitigation for the loss of giant kelp in its artificial reef project, as required by a condition of the SONGS coastal development permit to operate the plant.

Any temporary loss of benthic soft-bottom habitat due to project activities would result in a corresponding temporary loss of the associated infaunal invertebrate community, which supports an overlying predator community. As a result, demersal fishes, such as California Halibut (*Paralichthys californicus*), would not have the same habitat and forage available in the Project Area. Like the benthic community, the mobile marine life common to the Project Area would be temporarily impacted during the dispositioning work and possibly affected by longer-term to potentially permanent habitat loss.

The newly created deep, artificial trenches that would result from complete removal of the conduits pose a significant concern. The current study used an analytical model (MEMPITS) to estimate the trench infill time following the full removal of the SONGS Units 2 & 3 intake and discharge cooling system conduits. The MEMPITS model incorporates several inputs from the local marine environment, such as: (1) local wave and current conditions; (2) wave-induced bottom velocity; and (3) bathymetry and sediment characteristics. The model also relies on the water depth and orientation (shape, depth, length and width) of the trench to determine infill time. The results show that the time to fill the trenches is estimated to vary from 1-10 years in water depth less than 7 meters (m) to approximately 60-90 years at the seaward limit in about 15 m water depth, dependent on the trench side slopes. Additionally, strong rip currents are likely to develop as a result of the trenches created from fully removing the conduits and could continue for decades until the seafloor topography reaches equilibrium. This poses a safety risk in an area located adjacent to a popular recreational beach.

Aside from enabling the eventual return of the Project Area seafloor to its natural state, this analysis did not identify any other ecological benefits from complete removal of the conduits and their associated infrastructure. By comparison, the two other options evaluated where the buried, horizontal portions of the conduits are abandoned under the seafloor would avoid the unnatural trenching and rip currents associated with full removal. These two partial removal options would result in some temporary adverse construction impacts, but would allow for preservation of some incidental habitat, which has developed on and around the conduit risers.

2 Introduction

2.1 Purpose of This Study

As part of San Onofre Nuclear Generating Station (SONGS) decommissioning planning, Southern California Edison Company (SCE) is evaluating the final disposition options for all submerged and buried offshore components of SONGS Units 2 & 3 once-through cooling systems, including the fish return system jointly used by both units. This technical study was commissioned to evaluate the potential benefits and adverse impacts resulting from each option to decommission and set the offshore infrastructure to its final disposition. The Project Area, or the area surrounding SONGS and potentially affected by the project, was defined in this analysis as San Mateo Point to the northwest and Don Light to the southeast. This report also aims to establish a clear description of the environmental conditions currently observed in the area. This includes types of habitats, biological communities, presence of threatened or endangered species, and an accounting of otherwise high-value habitat such as giant kelp (*Macrocystis pyrifera*), rocky reef habitat, and surfgrass (*Phyllospadix* spp.). The assumed construction methods for each option were derived from COWI Marine North America (COWI 2017) and the geological impact was based on the sediment transport model. Impacts, beneficial and adverse, were assessed after integrating effects of the likely construction methods used and the resulting impacts of suspended sediments caused by the construction.

For reference, the only other project similar to this in California was the SONGS Unit 1 offshore cooling water system, where the offshore intake and outfall conduits were configured in a similar manner to the Units 2 & 3 conduits—buried with vertical risers emerging through the seafloor. SCE's proposed disposition of the Units 2 & 3 conduits is also similar to the decommissioning of the Unit 1 conduits where vertical elements, which consisted of manhole access ports, a velocity-capped intake structure, and discharge riser, were removed by uncoupling each component from the buried conduit (CSLC 2005; CCC 2014). When the vertical elements were removed, the resulting holes in the conduits were covered by a steel grating with openings small enough to prevent humans and large marine animals from entering, but large enough to let local sediments naturally infiltrate the conduits. Maintaining these openings in the conduits allowed them to remain flooded with seawater, and satisfied the landowner's (California State Lands Commission [CSLC]) requirements to permit sand and sediment to infiltrate the conduits over time.

Based on the experience gained from the decommissioning of SONGS Unit 1, three options for ultimate dispositioning are under consideration for the Units 2 & 3 conduits and associated components: (1) completely remove all components from the environment; (2) abandon all buried horizontal components in place and remove all vertical components, leaving the resulting openings covered by a grating to allow natural sand infiltration but prevent humans and large marine organisms from entering; and (3) abandon all buried horizontal components in place and remove a select subset of vertical elements, leaving the resulting openings covered by a grating that would allow natural sand infiltration but would prevent humans and large marine organisms from entering. Each disposition alternative carries with it a unique suite of ecological benefits and adverse impacts. Benefits range from removing anthropogenic infrastructure from the environment to maintaining the existence of a mature artificial reef ecosystem. Adverse impacts likely range from potential navigation hazards of leaving the vertical components in place to habitat loss and sedimentation resulting from the excavation and removal of the buried conduits.

2.2 Report Organization

Overall report development (and integration of sections within this report) was carried out by HDR and Coastal Environments, Inc. (CEI).

HDR prepared the following sections:

- Section 1 Executive Summary
- Section 2 Introduction
- Section 3 History of San Onofre Nuclear Generating Station
- Section 5 Existing Biological Conditions
- Section 6 (except 6.2) Conduit Disposition Alternatives
- Section 7 Specific Impacts
- Section 8 Conclusion

CEI prepared the following sections:

- Section 4 Bathymetry, Sediments and Littoral Drift
- Section 6.2 Cooling System Trench Infilling

3 History of San Onofre Nuclear Generating Station

SCE is the majority owner and sole operator of SONGS, located on the U.S. Pacific coastline just south of the City of San Clemente, California. In the past, SONGS operated three reactor units. Unit 1 construction began in 1964 and it was commercially operational from 1968 through late 1992 when operations ceased (November 1992). The Pacific Ocean was the source of cooling water for SONGS to remove waste heat generated during the thermal cycle when the unit was operational. Ocean water was supplied through a dedicated intake conduit and released through a dedicated discharge. Water intake and discharge by Unit 1 was permanently stopped in December 2006 and the National Pollutant Discharge Elimination System (NPDES) permit was terminated at the request of SCE in April 2007 (SCE 2007). The Unit 1 intake and discharge conduits that extend offshore were dispositioned pursuant to the requirements of the CSLC in 2014. The buried conduits were abandoned in place, while structures rising above the seafloor (i.e., manhole access risers and terminal structures) were removed to a point below the seafloor surface. The resulting openings were covered with steel "mammal exclusion barriers." These barriers were anchored to the remnant structure and contain 6-inch (152-mm) circular openings in the steel plate to allow sand infiltration, but exclude divers, marine mammals, sea turtles, and other large animals from entering the conduits.

Construction on Units 2 & 3 began in 1974 and continued through the early 1980s. Both units began start-up testing in 1982 and became commercially operational in 1983 (Unit 2) and 1984 (Unit 3). The four offshore conduits supporting each of these units, plus a fifth conduit that is the fish return system discharge, were buried beneath the seafloor by digging a trench to a designed depth and distance offshore. A trestle pier was built to support the excavation and construction effort (Figure 3-1). Both units were permanently retired in June 2013. Units 2 & 3 each had an operating capacity of 1,100 megawatts and each unit had its own once-through cooling water intake and discharge structure. Each unit discharged approximately 4,610,632 cubic meters (m^3) (1,218 million gallons) of seawater per day while operating at near capacity for most years (except during refueling or other maintenance outages).

3.1 Offshore Conduits Overview

A comprehensive summary of the offshore conduits is provided in the SONGS Units 2 & 3 Offshore Conduit Engineering Report, prepared by COWI Marine North America (COWI 2017); the following text is adapted from that work. The Units 2 & 3 concrete cooling water conduits are buried under the seafloor and consist of one intake and one discharge for each unit (Figure 3-2). Each intake is spaced approximately 40 feet (ft) (12 m) apart on center from its associated discharge conduit. As they extend seaward, the Units 2 & 3 conduit pairs diverge from each other to a point approximately 2,500 ft (762 m) from the seawall where they cease to diverge and begin to run in parallel. For the parallel portion of the conduit pairs, the two respective intake conduits are approximately 634 ft (193 m) apart from each other measured from the conduit centerline, and the two respective discharge conduits are approximately 714 ft (218 m) apart measured from conduit centerline. The fish return conduit is independent of the unit-specific conduits described above. Extending 1,830 ft (558 m) offshore, the fish return system's 4-ft (1.2-m) diameter conduit is also buried. The fish return system for each unit discharges through a single fish return conduit, located in the Unit 2 conduit trench, to an open discharge port just above the seafloor. The fish return conduit was provided for the unharmed return to the ocean of fish that entered the circulating water system. At its seaward terminal end, the fish return conduit angles upward at an approximate 20-degree angle and extends above the seafloor. A 4-ft (1.2-m) thick stone blanket surrounds the seaward terminus of the fish return conduit. The San Onofre Kelp forest, dominated by giant kelp (*Macrocystis pyrifera*), lies within 1,640 ft (500 m) of the structures (Figure 3-2).

Figure 3-1. Aerial Photo Taken During Construction of SONGS Units 2 & 3 showing the Trestle Pier Extending Offshore of SONGS.

Figure 3-2. San Onofre Nuclear Generating Station Offshore Infrastructure and Environmental Setting (Kelp Canopy Information from California Department of Fish and Wildlife (CDFW 2017a); 2015 Kelp Canopy Estimate Represents Current Conditions; 2008 Canopy Represents Recent Maximum Canopy Extent).

4 Bathymetry, Sediments and Littoral Drift

4.1 Geophysical Setting

SONGS is situated along a coastal wave-cut marine terrace, which is underlain by Miocene (23 to 5.3 million years old) rock capped by Pleistocene (1.8 million to 12,000 years old) marine and non-marine sediments. The Pleistocene sediment layers are essentially horizontal, forming a flat terrace "mesa" surface about 60 ft (18.3 m) above the beach with prominent cliffs along the seaward edge. Both the sea cliff face and the mesa are easily eroded by marine and sub-aerial processes, respectively, causing cliff retreat and failure, and forming steep, incised canyons, locally known as arroyos (Kuhn and Shephard 1984).

4.2 Offshore Bathymetry and Hard Substrate

4.2.1 Offshore Surveys

An offshore survey using a multibeam echo-sounder system (MBES) was performed on 16-17 January 2016 (CEI 2016a) to collect information on the bathymetry and seafloor substrate around the Units 2 & 3 intake and discharge structures. The data from this survey will be utilized to determine suitable anchorage positions (avoiding hard substrate) during removal of some or all parts of the once-through cooling system.

A second multibeam survey was begun on 21 July and completed on 12 August 2016 by CEI (2016b) to characterize the nearshore area fronting SONGS from a distance of about 800-2,500 ft (250-750 m) from shore at water depths between 8 and 25 ft (2.5-7.5 m). Sonar surveys were conducted to differentiate between bottom types and to refine the bathymetric data in front of SONGS. Figure 4-1 shows the areas of the two multibeam surveys outlined in red along with the beach profile transects (black).

4.2.2 Results of the Multibeam Surveys

The data from the two MBES surveys and the 2016 beach profile survey were used to prepare the bathymetry map of the offshore area fronting SONGS (Figure 4-1). Figure 4-2 shows the same bathymetry map with the superimposed locations of the existing Units 2 & 3 intake and diffuser structures, as well as the former Unit 1 intake and discharge vertical structures (horizontal conduits remain buried beneath the seafloor). Figure 4-3 shows the superimposed bathymetry contour lines from January 2016 and August 2000. Comparison of the two surveys indicates that changes in the bathymetry between the years 2000 and 2016 are small.

Figure 4-4 is a color-coded bathymetry map of the nearshore area from 10-25 ft (3-7.5 m) depth based on the surveys conducted on 21 July and 12 August 2016. The irregularity of the bathymetric contours is indicative of hard substrate, and in this case is representative of a cobble/boulder seafloor. Seafloors that are sand/silt tend to have contours that are regular and smooth. Bathymetry data along four transects parallel to shore were extracted to show the relief of the hard bottom fronting SONGS (Figure 4-5). Bathymetry along Transect 3 is shown in

Figure 4-6 to illustrate the typical alongshore relief of the hard bottom area. Cross-section data from Transects 1, 2, and 4 are provided in Appendix A.

4.2.3 Results of the Backscatter Images

Mapping of the hard bottom offshore of SONGS using multibeam backscatter is shown on Figure 4-7 for the 3 to 8 m water depth. Insets of Figure 4-7 are shown in Figures 4-8 and 4-9. This area is parallel to the shoreline and extends northwest and southeast of SONGS (Figure 4-5). Backscatter data are useful because the acoustic return signal is a function of the bottom reflectivity, and therefore produces a pseudo side-scan image. The processing accounts for the angle of incidence of the acoustic pings along the multibeam path to attempt to normalize the return signal. The backscatter image provides good information to visualize the seafloor configuration and clearly shows areas of hard substrate and seafloor expressions from the excavations for the placement of the intake/discharge pipeline.

Bottom mapping and imaging are helpful to visualize the unusual bottom conditions just offshore of SONGS. The accumulation of boulders and cobbles has created a stable terrace or shelf configuration that efficiently dissipates wave energy. Figures 4-8 and 4-9 show that backscatter images from seafloors with different characteristics (e.g., coarse sand/shell hash/sand ripples vs. exposed hard bottom) can appear different, which is why it is helpful to collect multibeam bathymetric data to aid interpretation. Both figures show areas of high acoustic backscatter (darker areas), and in both cases the darker areas are 0.6-1 ft (0.2-0.3 m) below the surrounding seafloor. The area shown on Figure 4-6 is an example of dark stringers that are oriented perpendicular to shore adjacent to SONGS. The dark areas are generally scour depressions with little relief of 8-12 in (20-30 centimeters [cm]) that lead to winnowing of fine sediments, leaving coarser sand, shell hash, and 2- to 4-inch-high (5-10 cm) sand ripples. The coarser material produces extremely dark backscatter return. The second area, depicted in Figure 4-7, is offshore and just upcoast of SONGS, and consists of interspersed sand and scour depressions that expose hard bottom. The backscatter images in Figures 4-8 and 4-9 are similar to those in Figure 4-7, but with color-shaded relief that clearly shows the exposure of hard bottom.

Figures 4-10 and 4-11 show the hard substrate classifications around the intakes of the Units 2 & 3 intake systems as well as the sediment thickness contour lines. The survey shown in Figure 4-10 was carried out in 2016, and the survey shown in Figure 4-11 was carried out in March 2000 (CEI 2000).

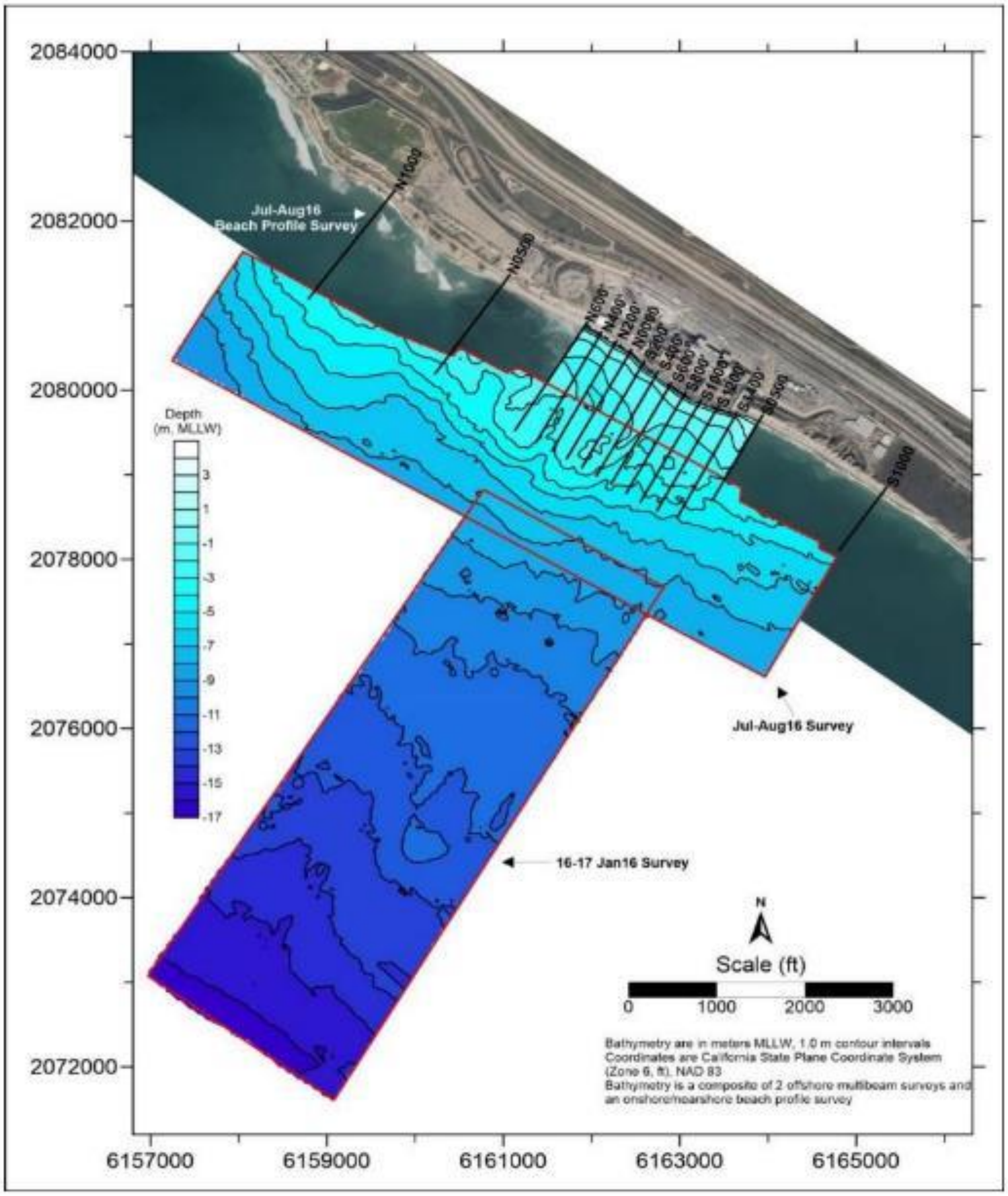

Figure 4-1. Multibeam Echo-Sounder System Boundaries (Red Lines); Beach Profile Transects (Black Lines); and Seafloor Depth Contours, from Merged Survey Data (Color Scale Left).

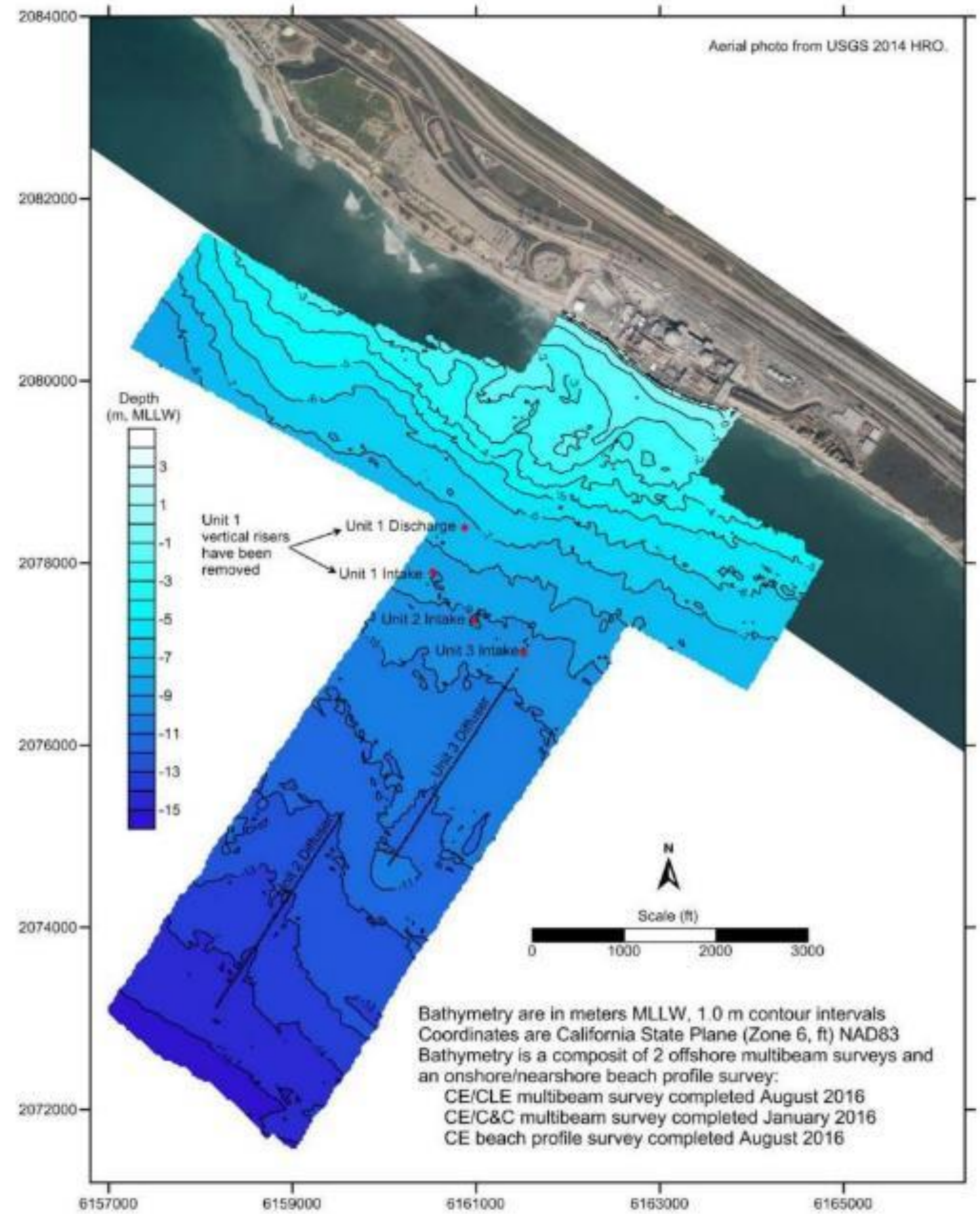

Figure 4-2. Bathymetry Contours Offshore of SONGS. The Unit 1, 2 and 3 Intake and Unit 1 Discharge Structures are Labeled with a Red Dot. The Units 2 & 3 Diffuser Port Structures are Labeled by the Broken Lines. Each Black Dot in the Diffuser Port Line Represents an Individual Diffuser Port.

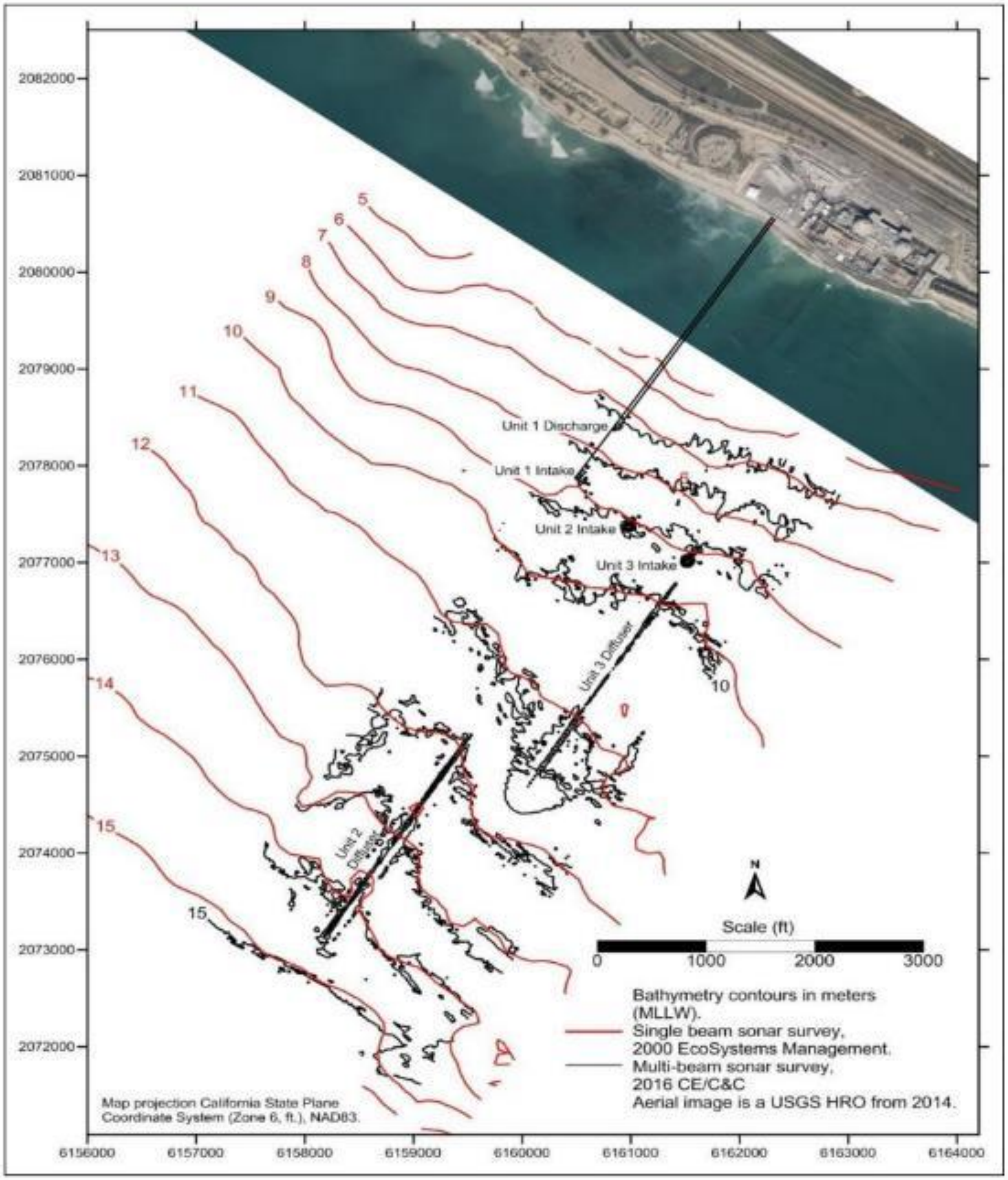

Figure 4-3. Comparison of 2000 and 2016 Bathymetry Contours. Close Agreement of the Data Indicates Little Change in the Area from 16-65 ft (5-15 m) Depth.

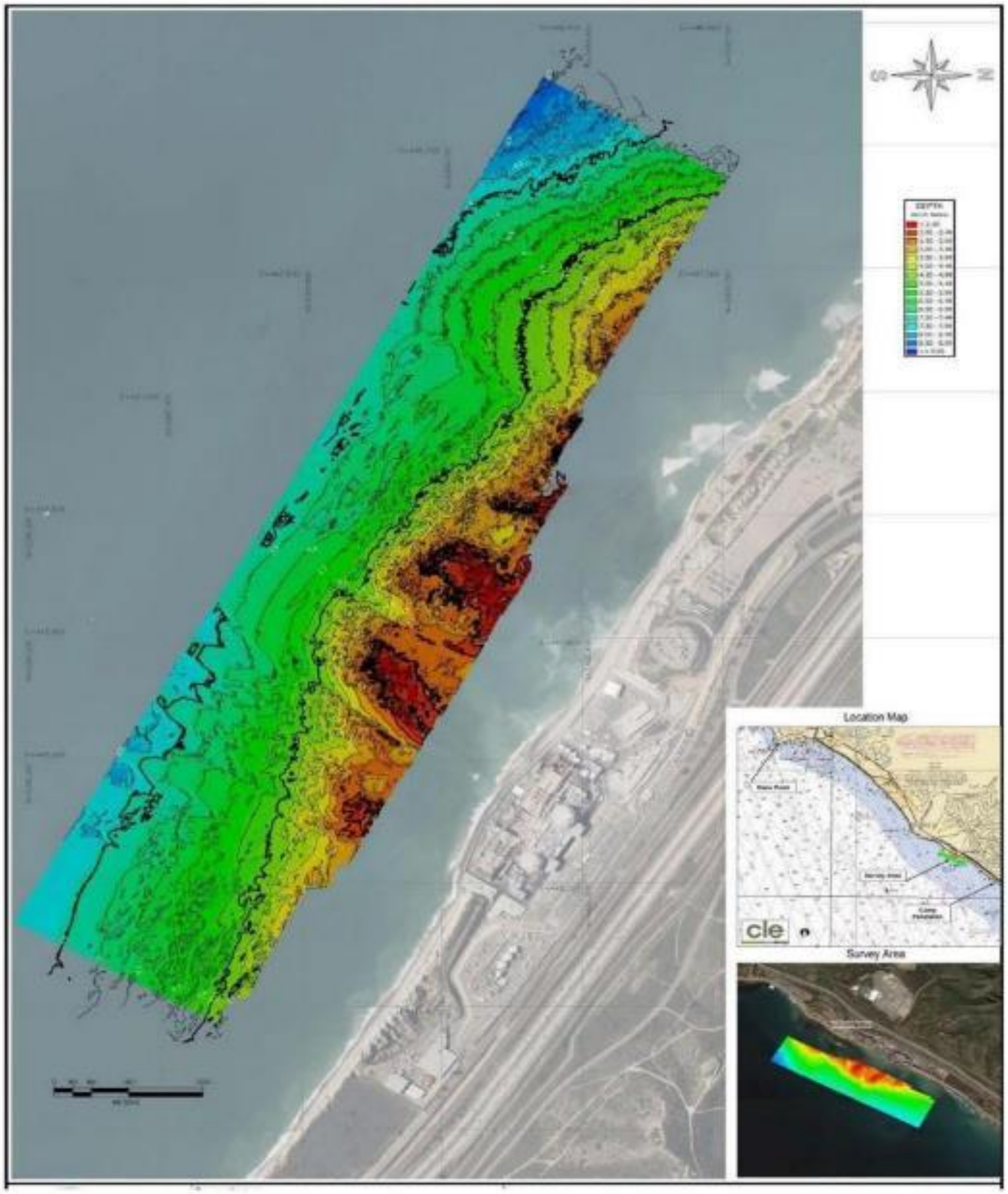

Figure 4-4. Color-Coded Bathymetry Map Nearshore of SONGS. Hard Bottom Areas in Red.

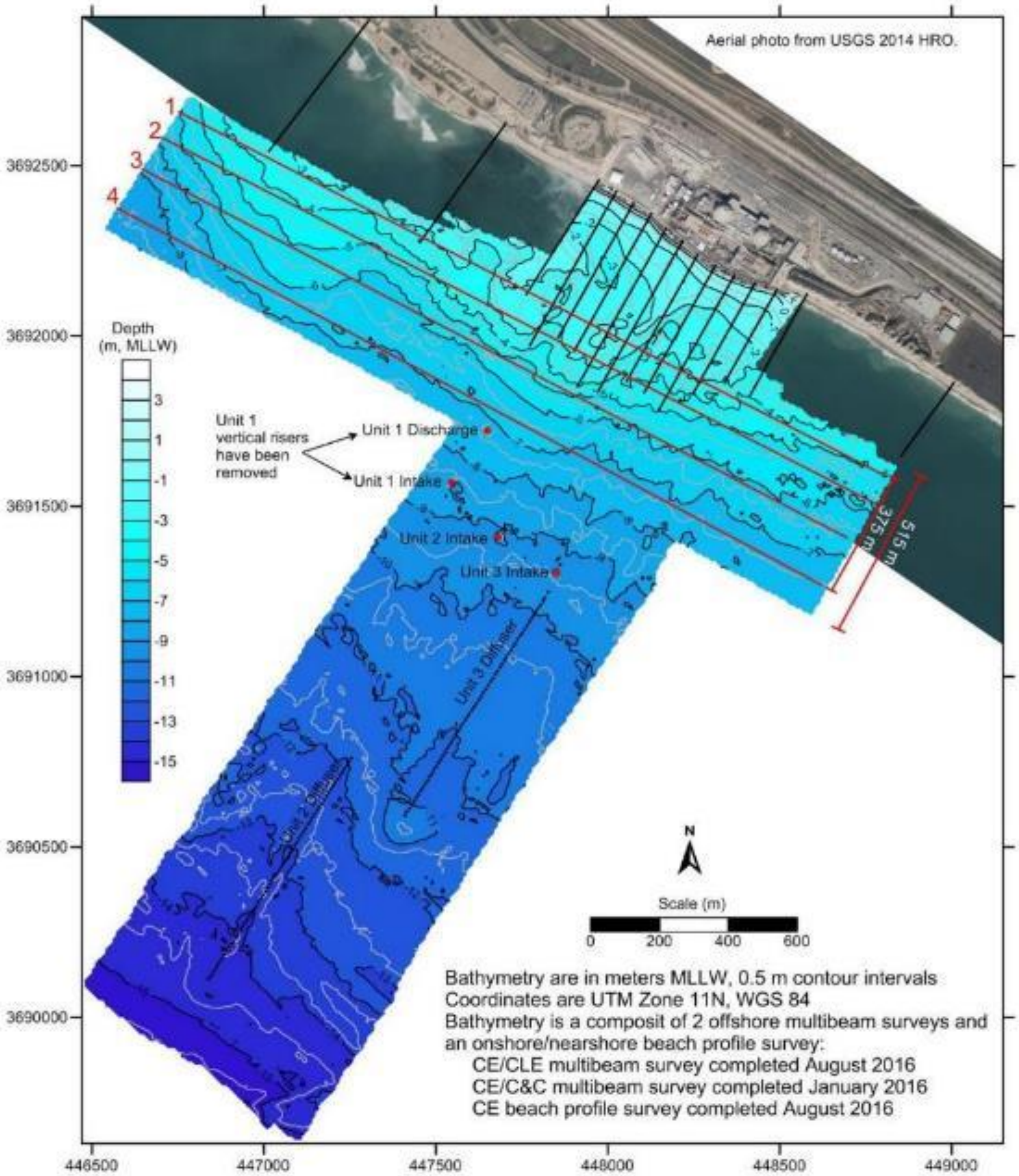

Figure 4-5. Four Longshore Transects Across the Surveyed Area (Red Lines). Details of Transect 3 are Provided in Figure 4-6. Broken Lines Represent Units 2 & 3 Diffuser Port Structures. Each Black Dot in the Diffuser Port Line Represents an Individual Diffuser Port.

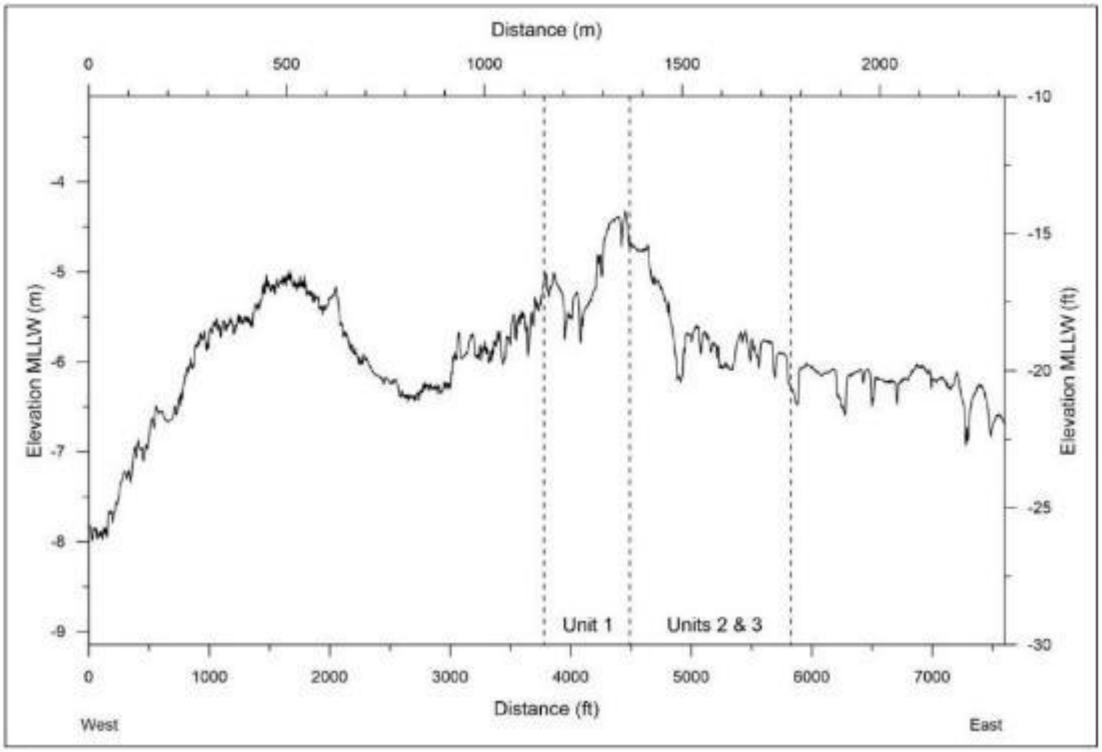

Figure 4-6. Cross-Section of the Hard Bottom Relief at Transect 3 Fronting SONGS (Broken Lines).

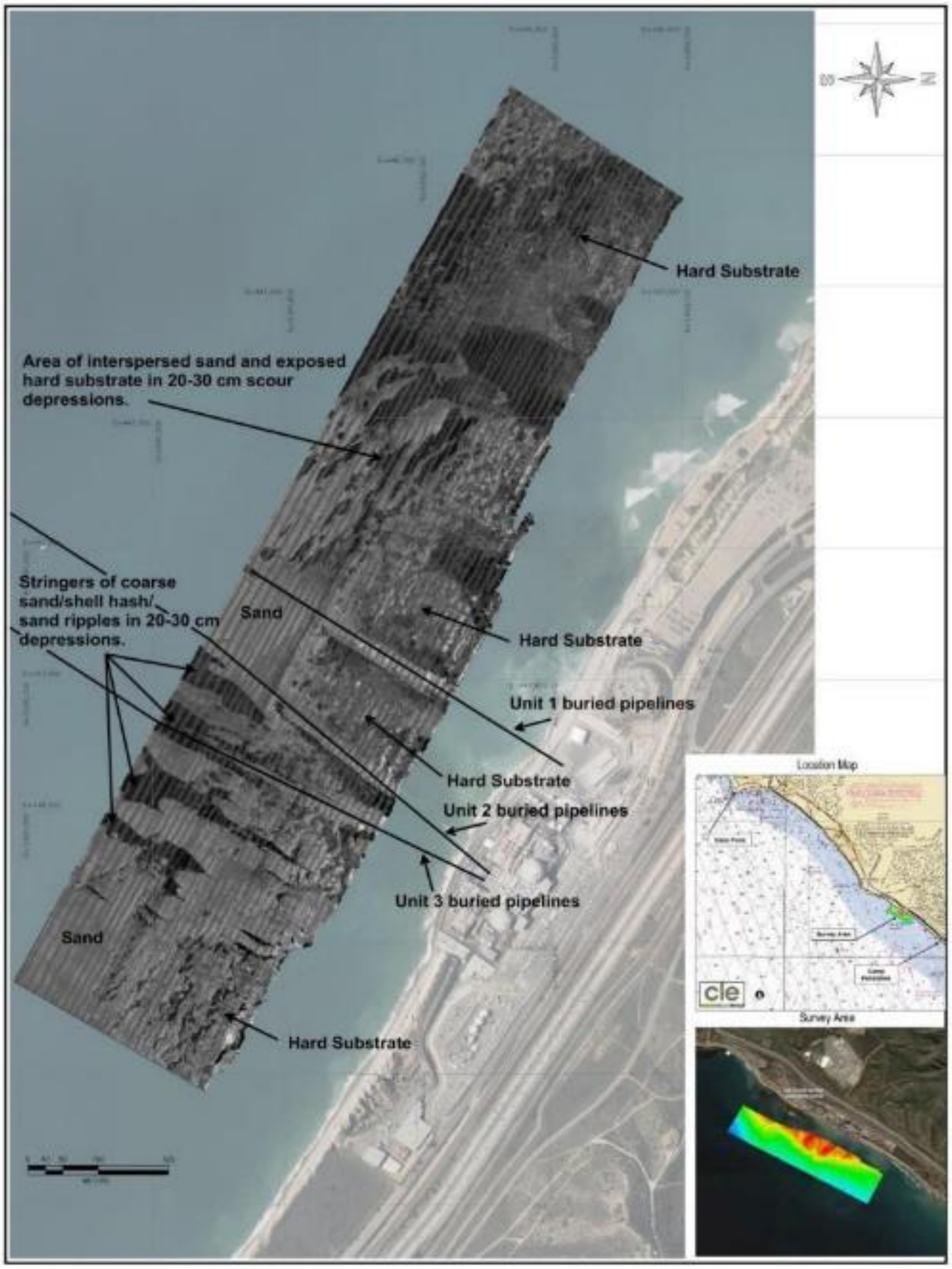

Figure 4-7. Seafloor Image of the Nearshore Area of SONGS Comprising a Combination of the Multibeam Survey Backscatter and Color-Shaded Relief Bathymetric Data.

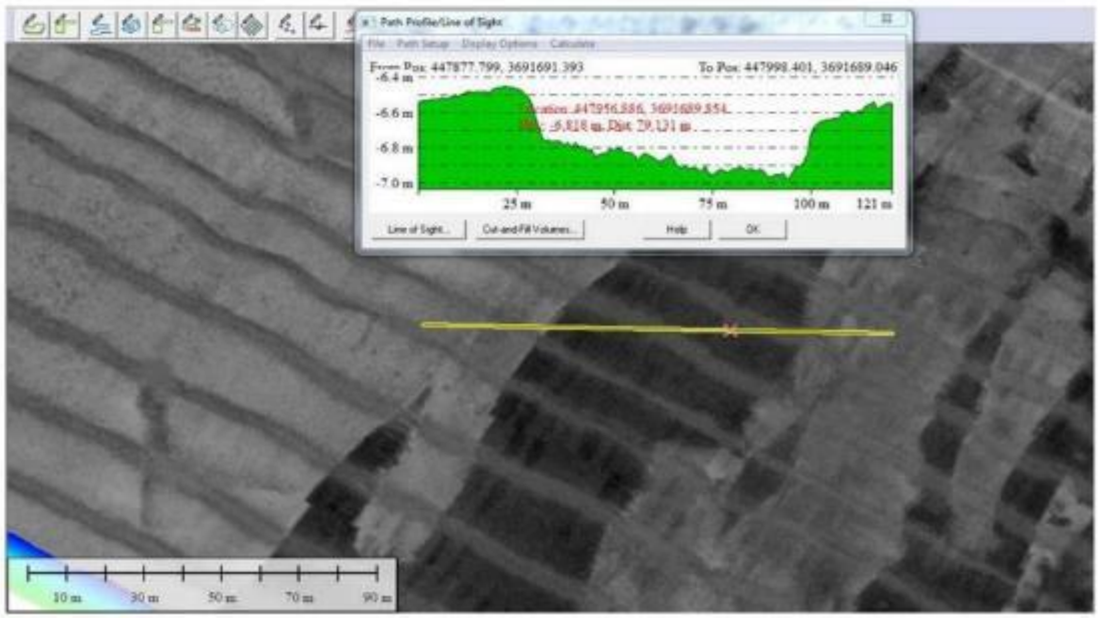

Figure 4-8. Backscatter Image of Differing Acoustic Reflectivity. Insert is Color-Shaded Image of Bathymetry (Inset from Figure 4-7).

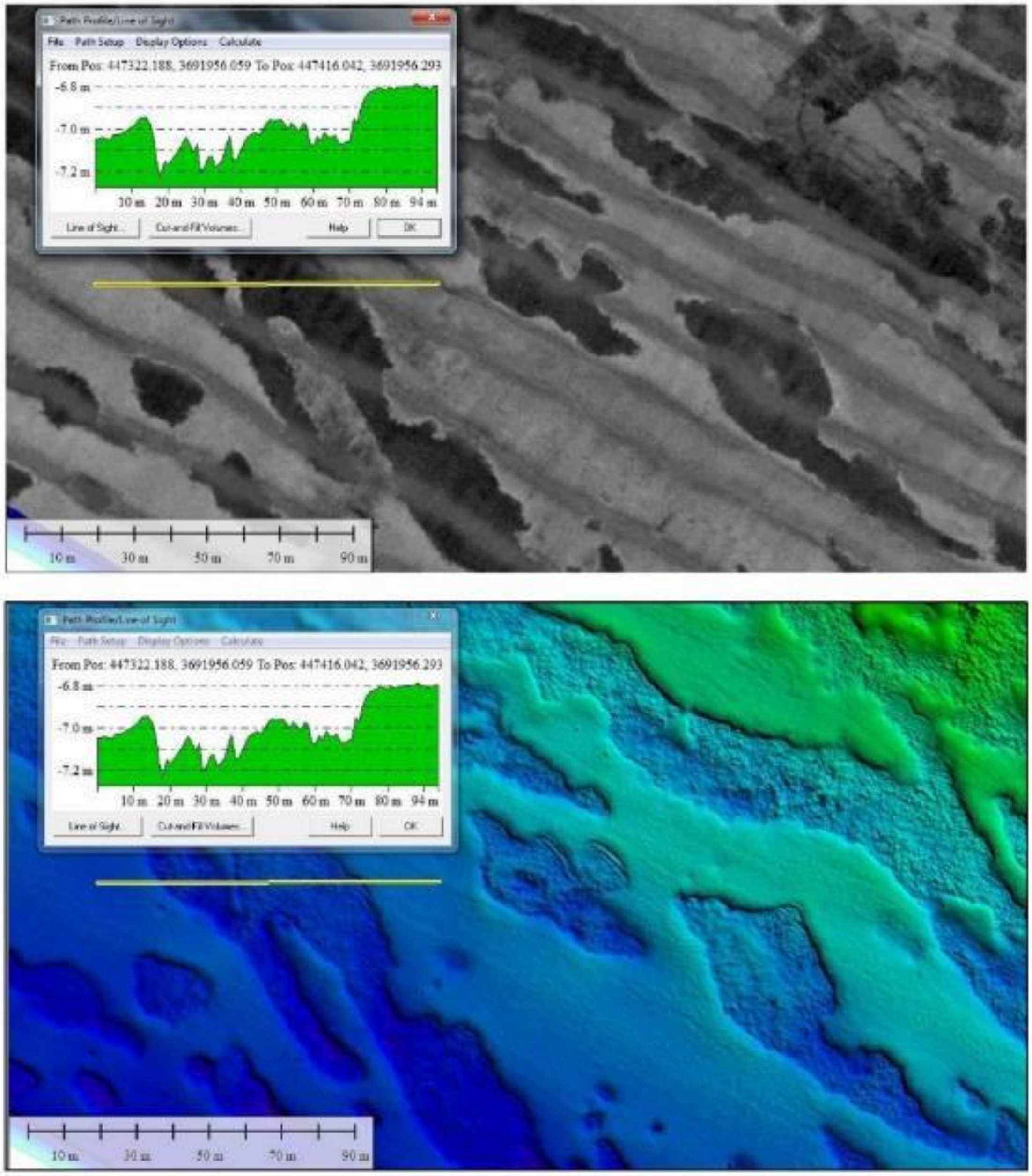

Figure 4-9. Multibeam Backscatter Image of Areas with Different Acoustic Reflectivity (top). Color-Shaded Bathymetry Image (Bottom). Insets from Figure 4-7.

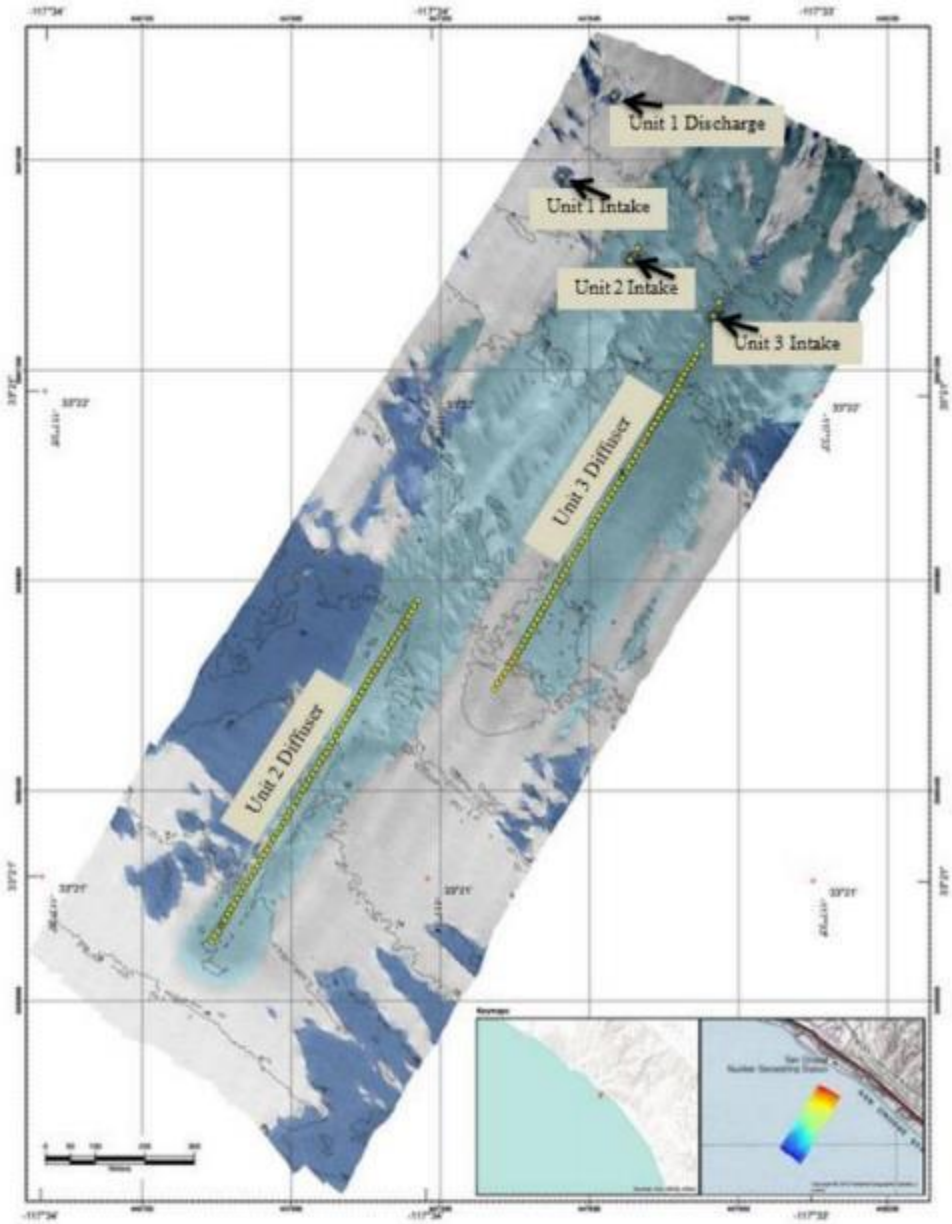

Figure 4-10. Substrate Classification Overlain onto Backscatter Data and Bathymetry Contours (CE 2016a). Hard Substrate is in Dark Blue. Shell Hash is Shown in Light Blue, and Sandy Areas are Shown in Gray. The Diffuser Lines Represent Sections of the Larger Outfall Conduits Which Extend Out from the Shoreline. Each Yellow Dot in the Diffuser Line Represents an Individual Diffuser Port.

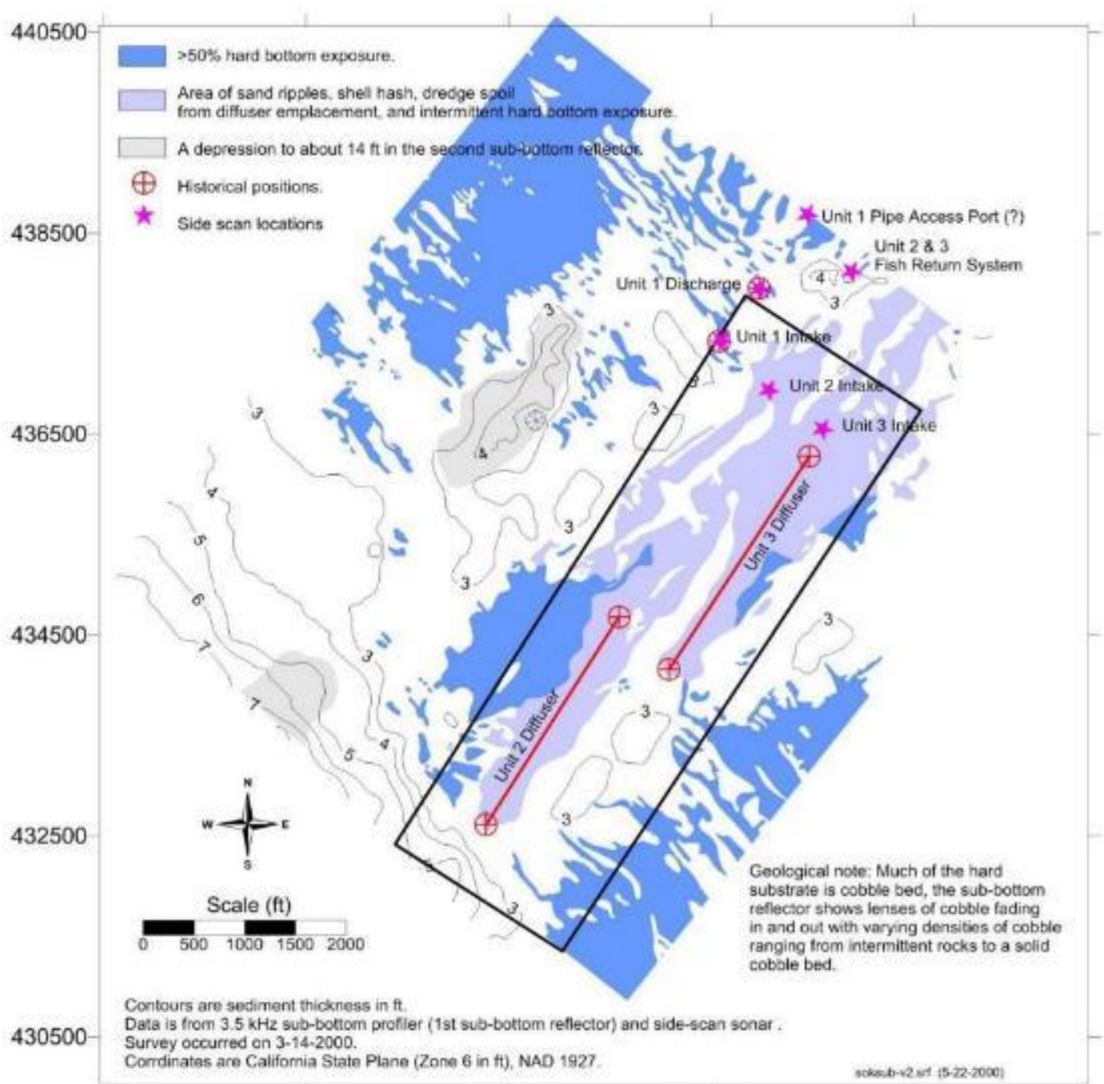

Figure 4-11. Sub-Bottom Sonar Isopach Map of the SONGS Offshore Vicinity, 14 March 2000. Sub-Bottom Sediment Thickness Contours are in Feet. Note Also the Areas of Hard Bottom Exposure. The Diffuser Lines Represent Sections of the Larger Outfall Conduits Which Extend Out from the Shoreline.

4.3 Coastal Sediments and Littoral Transport

A littoral cell is defined as a geographic area with a complete cycle of littoral sand sources, transport paths, and sinks (Inman and Frautschy 1965). The Oceanside Littoral Cell extends approximately 60 miles (100 kilometers [km]) from Dana Point to Point La Jolla and the Scripps-La Jolla submarine canyon system (Figure 4-12). The Dana Point headland to the north and

Point La Jolla to the south define the boundaries of the cell. These boundaries are considered littoral barriers, where no littoral sediment is exchanged between the two adjacent littoral cells. The main sources of sand in the Oceanside Littoral cell are river discharge, cliff erosion, and to a smaller extent, artificial beach nourishment (discussed below). The sand sink is the La Jolla submarine canyon. Sand may also be lost offshore along the littoral cell during large storms. The Oceanside cell can be divided into two main segments or sub-cells, one extending from Dana Point to Oceanside Harbor, and the other from Oceanside Harbor to Point La Jolla. San Onofre State Beach and SONGS are at the northern updrift end of the cell. Since the 1930s, the amount of sediment entering the system has decreased because of river damming (Inman 1985).

4.3.1 Sediment Sources

Rivers

Despite damming and engineered stabilization, rivers along the Oceanside cell contribute some sediment to the littoral cell during periods of high rainfall and runoff. U.S. Army Corps of Engineers (USACE) (1987) estimated that the average total sediment yield of all the major rivers in the Oceanside cell was about 159,000 cubic yards per year (yd^3/yr) (121,500 m^3/yr). Table 4-1 shows the range of estimated volumes of littoral sediments supplied by the major rivers in the Oceanside cell (Zampol et al. 1997). The total range of sediment volume entering the cell is estimated at 67,240-167,840 yd^3/yr (51,400-128,300 m^3/yr). The volume of sediment entering the littoral cell from river sources is greater to the north of Oceanside Harbor relative to the south, as shown in Table 4-1.

Cliffs

Since the beaches within the Oceanside cell are relatively narrow, the elevated water level and increased wave action produced by storms occasionally reach the base of the sea cliffs, which results in mild to moderate erosion. Estimates of cliff erosion rates and total yield of sandy sediments were presented by (Table 9-6 in USACE 1991) and Young and Ashford (2006). Young et al. (2014) summarized historical cliff retreat rates at San Onofre, which ranged from 0.6-0.9 ft/yr (0.2-0.3 m/yr). These estimates are highly variable and depend on the location, time period, and configuration of the cliffs. Estimates of total sandy sediment yield over a 79-year period for the cliffs north of Oceanside Harbor at Camp Pendleton, and for the cliffs at Torrey Pines State Beach, are 23.6 million yd^3 (18 million m^3) and 4.4 million yd^3 (3.4 million m^3), respectively. This represents an overall sediment contribution rate of approximately 354,000 yd^3/yr (270 m^3/yr) from the cliffs to the beaches within the Oceanside cell.

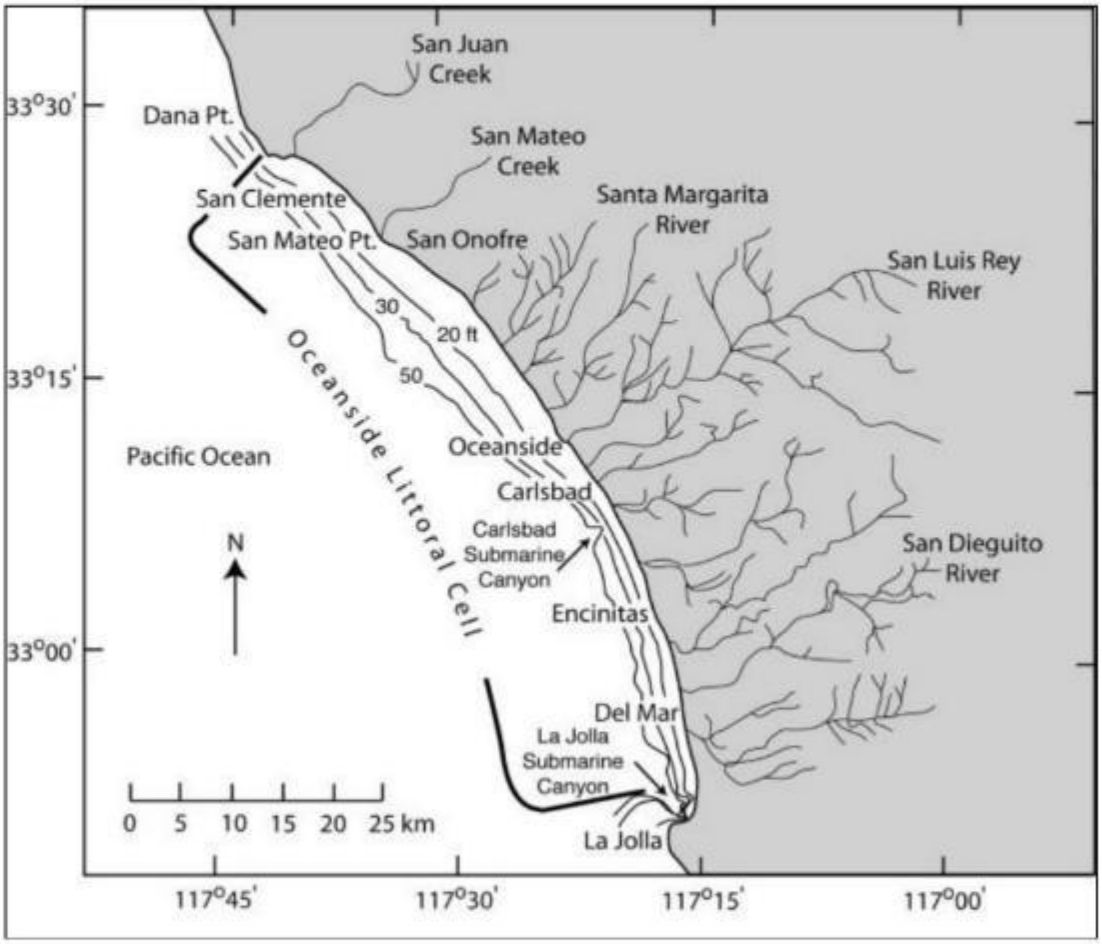

Figure 4-12. Oceanside littoral cell, modified from Inman and Jenkins (1983).

Table 4-1. Estimated coarse river sand yield, Oceanside littoral cell (yd³/yr).

River/Stream	DNOD[1] (1977)	Brownlie[2] & Taylor (1981)	Inman[3] & Jenkins (1983)	Simons,[4] Li & Assoc. (1988)	Range of Estimates (yd³/yr)	Average Estimates (yd³/yr)
San Juan Creek	47,000 /56,000[5]	---	---	34,000	34,000-56,000	45,000
San Mateo Creek	32,000	---	---	8,100	8,100-32,000	20,050[9]
San Onofre Creek	5,000	---	---	1,800	1,800-5,000	3,400[9]
Las Flores Creek	4,000	---	---	2,700	2,700-4,000	3,350[9]
Aliso Canyon Creek	---	---	---	900	900	900[9]
Santa Margarita River	15,000	7,000	9,000	19,000	7,000-19,000	13,000[9]
Oceanside Harbor						
San Luis Rey River	351,000	18,000	22,000	10,800	10,800-18,000 (351,000)[6]	14,400
Loma Alta Creek[7]	14,000[7]	---	---	940	940	940
Buena Vista Creek[7]		---	---	0	0	0
Agua Hedionda Creek[7]		---	---	0	0-14,000[7]	7,000
San Marcos Creek[7]		---	---	0	---	---
Encinitas Creek[7]		---	---	0	---	---
Escondido Creek	14,000	---	---	0	0-14,000	7,000
La Orilla Creek	---	---	---	0	0	0
San Dieguito River	4,000	1,500	2,000	1,000	1,000-4,000	2,500
Carmel Valley Creek[8]	---	---	---	0	---	---
Los Peñasquitos Creek[8]	---	---	---	0	---	---
Carroll Canyon Creek[8]	---	---	---	0	---	---
			Total Range		**67,240-167,840**	**72,540**

[1] Present sediment production
[2] Period of maximum control, or total period of record, if less
[3] Values calculated using the data of Brownlie & Taylor (1981) and assumed to be sand-to-suspended-load ratios of Inman & Jenkins (1983)
[4] Present condition
[5] USGS estimate of sediment discharge reported in DNOD (1977)
[6] Extreme value
[7] San Marcos Group of DNOD (1977) assumed to include Loma Vista Creek to Encinitas Creek

[8] DNOD (1977) sediment estimates from these creeks were not directly given (see Table 2 and footnote 5)
[9] Sediment supply from rivers between San Mateo and Oceanside harbor is 40,700 yd^3/yr

4.3.2 Longshore Transport at San Clemente and Dana Point

The principal mechanism for transporting beach sand along the shore is the longshore or littoral drift of sand in the surf zone (Inman and Frautschy 1965; Inman et al. 1968; Komar and Inman 1970). The longshore transport moves sand suspended by the turbulence of breaking waves and carries it along the shore via the longshore current produced by breaking waves approaching the shore obliquely.

The Seymour and Higgins formula (1978) relates the longshore sediment transport rate in the surf zone to the component of radiation stress in the longshore direction (Sxy) and significant wave height (Hs) at the array. This involves two assumptions: (1) that the shoreline contours are straight and parallel, so that Sxy is conserved between the array and the breakpoint (Longuet-Higgins 1970); and (2) that the depth at breaking (h_b) can be approximated by 1.65 times Hs at the array (Griswold 1964). The relation used in the present study is:

$$Q_P = (3.843 \times 10^6)\ Sxy\,(Hs)^{0.5} \quad (4\text{-}1)$$

where Q_P is the "at rest" volume transport rate of sand in yd^3/yr, *Sxy* and *Hs* at the array are expressed in ft^2, respectively, and the proportionality coefficient, 3.843×10^6, has units $yd^3/(yr \times ft^{2.5})$.

In metric units, the equation above can be written as:

$$Q_P = 980\ Sxy\,(Hs)^{0.5} \quad (4\text{-}2)$$

where Q_P is the "at rest" volume transport rate of sand in m^3/yr, *Sxy* and *Hs* at the array are expressed in their Coastal Data Information Program (CDIP) reported units of cm^2 and cm, respectively, and the proportionality coefficient of 980 has units $m^3/(yr \times cm^{2.5})$.

Figure 4-13 shows a plot of monthly averaged daily longshore transport potential calculated from directional wave measurements made at San Clemente, San Onofre, and Oceanside. The data from San Clemente are represented by a dashed line, while the data from Oceanside are represented by a solid line. San Onofre is located 2,000 ft (600 m) south of San Mateo Point between Oceanside and San Clemente. Directional wave data from San Clemente and Oceanside were routinely collected by the CDIP at Scripps Institution of Oceanography (CDIP 1992) at 35 ft (11 m) water depth. Wave data from San Onofre were collected by EcoSystems Management Associates, Inc. (Reitzel and Elwany 1988) using the directional wave meter at 10 m water depth. Wave height data collection began in 1981, but directional measurements only cover the period from April 1985 to December 1986.

Over the five-year period from 1983-1988 when simultaneous data were recorded, there was good qualitative agreement between the transport rates at San Clemente and Oceanside. The dotted line in Figure 4-13 shows the directional measurements at San Onofre. There is also good agreement of magnitude and phase with the results reported for Oceanside and San Clemente. This is important because it implies continuity in the longshore transport rates along the entire Oceanside cell. There is good agreement between the pattern and the magnitude of longshore transport for northward and southward longshore transport amongst the three sites.

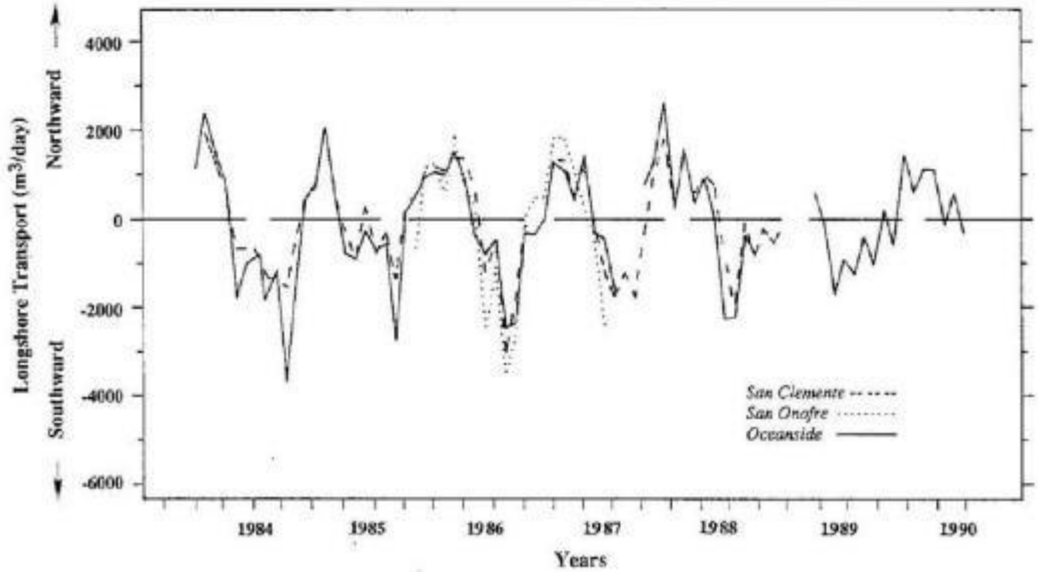

Figure 4-13. Longshore Transport Potential (m³/day) from Directional Wave Measurements, San Clemente, San Onofre, and Oceanside, 1983-1989.

Elwany et al. (1999) calculated longshore sediment transport at Oceanside from 1978 to 1994. That study estimated the longshore transport to the north per year to be +320,600 yd^3/yr (245,100 m^3/yr) and transport to the south per year to be 371,600 yd^3/yr (284,000 m^3/yr). The net transport per year was 51,000 yd^3/yr (37.2 m^3/yr) to the south. These numbers are estimates of longshore transport for the cities of San Clemente and Oceanside.

4.3.3 Sediment Budget for San Clemente and Dana Point

The Oceanside littoral cell from Dana Point to the La Jolla Submarine Canyon can be divided into four major sub-cells. These sub-cells are separated either by promontories, harbor breakwaters, or canyons. These sub-cells are shown in Figure 4-14.

In this section, we compute the sediment budget in order to determine whether the section of the coast between San Mateo Point and Oceanside Harbor is in balance (i.e., there is no significant erosion or accretion). The method is simple—it is based upon calculating the volume of sediment input and the volume of sediment output. The difference between these two quantities will provide the following: (1) the volume of sand gained or lost; (2) information for calculating the long-term average of shoreline/beach width changes in the study area; and (3) the ability to calculate offshore sand losses, based upon knowledge of shoreline changes derived from historical sources.

Table 4-2 summarizes the sediment budget for the sub-cell between San Mateo and the Oceanside littoral cell. For this table, it was assumed that the cross-shore transport was small because the offshore portion of the beach profile in this area is, in general, gently sloped.

Q_a = Beach nourishment

Q_y = Longshore transport

Q_x = Cross-shore transport

Q_b = Cliff sediment yield

Q_r = Stream sediment yield

The values of $Q_a = 0.0$ and $Q_x = 0.0$, assuming the seasonal sand migration during winter and summer seasons is equal volume, Q_b and Q_r are estimated as follows.

The cliff sediment yield (Q_b) is estimated from Young and Ashford (2006). In this paper (Table 4), the authors estimated the total sediment from San Onofre and Camp Pendleton gullies and cliffs (sand, cobbles, and boulders) and the beach sand content. The total estimated beach sand content from these locations was about 78,500 yd^3/yr (60,000 m^3/yr). The stream sediment yield Q_r, estimated from Table 4-1, is about 40,700 yd^3/yr (31,000 m^3/yr), which is the sum of the average yields from all river sources from San Mateo Creek to Santa Margarita River (Table 4-1, right column, Rows 2-6).

Table 4-2 shows net losses of sand of about 39,000 m^3/yr (51,000 yd^3/yr) during dry periods and about 50,000 m^3/yr (65,000 yd^3/yr) during wet periods. Based upon Table 4-2, this reach of the coast will be stable during wet time periods, and the beach will erode slightly during dry time periods. Since SONGS and San Onofre State Beach are located at the midpoint of the littoral cell and are protected from north-northwest waves, the shoreline at SONGS is likely to undergo only small changes during dry time periods and to be stable during wet time periods. However, it is important to note that although the beach will retreat during large storm events, it is likely to recover.

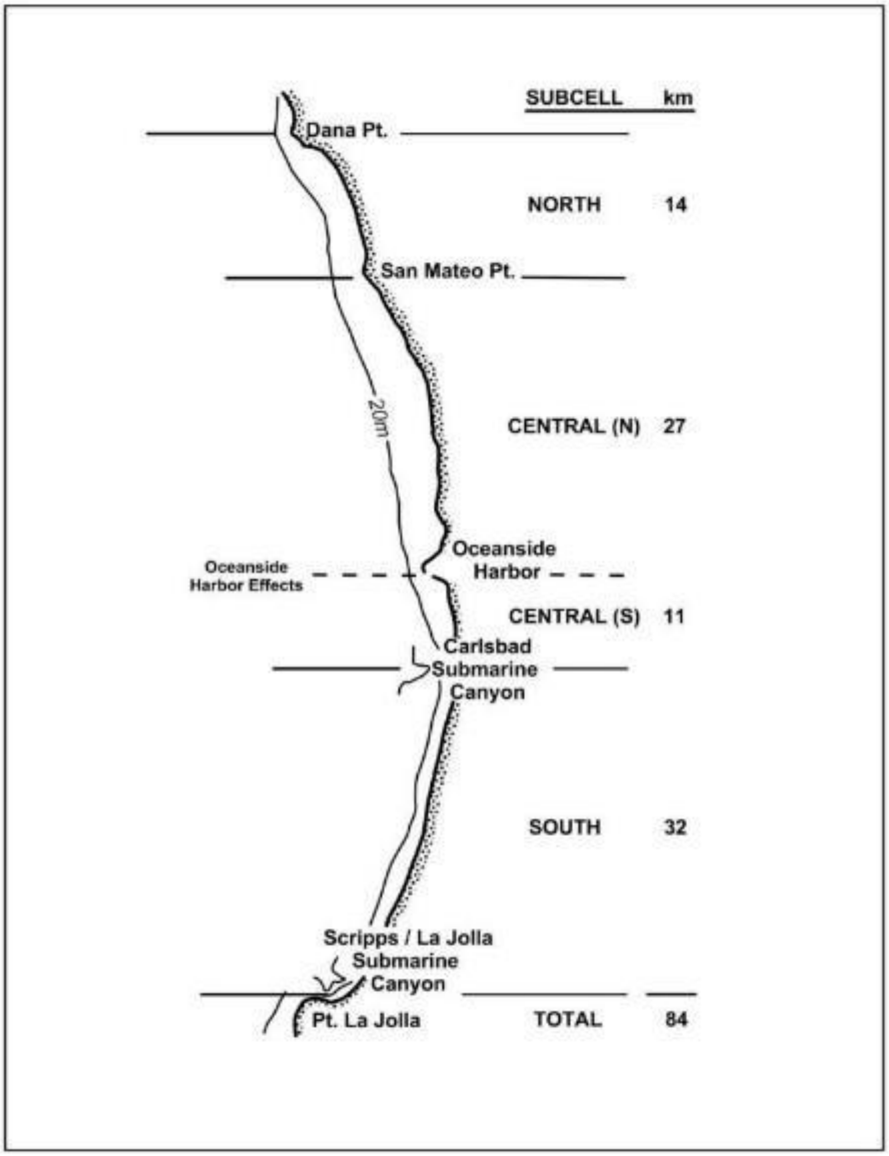

Figure 4-14. Four Oceanside Littoral Cell Sub-Cells.

Table 4-2. San Mateo to Oceanside Harbor littoral sub-cell sediment budget (m^3/yr).

Sediment Sources	Dry Period		Wet Period	
	Input	Output	Input	Output
Q_a	0	0	0	0
Q_y	245,150	-284,100	245,000	-284,100
Q_x	0	0	0	0
Q_h	0	0	59,000	0
Q_r	0	0	30,000	0
Sediment total (m^3/yr)	245,150	-284,100	334,000	-284,100
Net m^3/yr	-39,000 (erosion)		50,000 (accretion)	

Q_a = Beach nourishment
Q_y = Longshore transport
Q_x = Net cross-shore transport sand losses
Q_h = Cliff sediment yield
Q_r = Stream sediment yield

5 Existing Biological Conditions

The environmental setting (Figure 3-2) includes the corridor extending offshore from SONGS Units 2 & 3 that comprises the CSLC Lease (Lease No. PRC 6785.1) and areas surrounding this corridor. Construction activities to set the conduits to their final disposition, for which three alternatives are examined in Section 6 of this document, will result in varying environmental impacts, each with a different spatial and temporal extent. Therefore, while this evaluation focuses on the area within the lease boundaries, additional assessments of the marine environment ranging from San Mateo Kelp to Barn Kelp were carried out. These boundaries were chosen based on data availability as well as the existing precedent of using these sites as reference stations for turbidity impacts to the San Onofre Kelp community (Bence et al. 1989). The sections that follow detail the current status of the marine environment likely to be impacted by each of the disposition alternatives, assuming the methods described by COWI (2017) are used. Previous field studies were used to characterize the substrate and sediments, submerged aquatic vegetation, and marine animals in the area that could potentially be impacted by SONGS decommissioning activities (MBC 2003, 2014, 2016 a, b, c).

5.1 Special Status Biological Resources of the Area

Twenty-nine subtidal marine animals considered special status species occur or have a reasonable potential to occur in the Project Area (Table 5-1). Reasonable potential means they have been previously observed in the area more than once, rather than having a reported range, including the waters offshore southern Orange County and northern San Diego County. For each taxon, the general taxonomic grouping, scientific name, common name and protective regulation are listed. The protective regulations include: Marine Mammal Protection Act (MMPA), Endangered Species Act, an in-place harvest moratorium, and protection in the State as the California State Marine Fish. The qualitative frequency of occurrence for all species are very common, common, rare, and very rare. These qualitative designations do not represent comparable abundance estimates, as they are relative and species-specific based on the nominal population size of each species as potential population size increases with decreasing mean size. For example, in the absence of any harvest pressure whales are the largest animals in the ocean and would be less abundant than the substantially smaller invertebrates listed in Table 5-1. Information used to make each determination came from a combination of personal field observations by E. Miller, SONGS marine mammal and sea turtle entrapment records (1981-2009), citizen science abalone stock enhancement programs (Coastkeeper 2016), newspaper reports (OCR 2017), reported marine mammal sightings in 2017 from commercial whale watching operations running out of Dana Point Harbor (Capt. Dave 2017), and aerial marine mammal surveys of the Southern California Range (HDR 2013). Southern California Edison installed a Large Organism Exclusion Device on all intake structures for Units 2 & 3 in 2015. Prior to this, no barriers were present to prevent marine mammals or sea turtles from entering the intake structures.

Table 5-1. Protected Species Expected and Observed in the Project Area; Legislative Reason for Protection and a Qualitative Frequency of Occurrence is Presented.

Scientific Name	Common Name	MMPA	ESA	Qualitative Frequency of Occurrence
Large Whale Species				
Balaenoptera musculus	Blue whale	X	E	Rare
B. physalus	Fin whale	X	E	Rare
B. borealis	Sei whale	X	E	Very Rare
B. edeni	Bryde's whale	X	-	Very Rare
B. acutorostrata	Minke whale	X	-	Common
Eschrichtius robustus	Gray whale	X	-	Very Common
Megaptera novaeangliae	Humpback whale	X	T	Common
Dolphins and Porpoises				
Delphinus spp.	Common dolphin	X	-	Very Common
Tursiops truncatus	Bottlenose dolphin	X	-	Common
Orcinus orca	Killer whale	X	-	Rare
Seals, Sea Lions, and Otters				
Phoca vitulina richardii	Harbor seal	X	-	Very Common
Zalophus californianus	California sea lion	X	-	Very Common
Mircunga angustirostris	Northern elephant seal	X	-	Very Rare
Enhydra lutris nereis	Southern sea otter	X	T	Very Rare
Sea Turtles				
Caretta caretta	Loggerhead sea turtle	-	E	Very Rare
Chelonia mydas	Green sea turtle	-	T	Common
Dermochelys coriacea	Leatherback sea turtle	-	E	Very Rare
Lepidochelys olivacea	Olive ridley sea turtle	-	E	Very Rare
Invertebrates				
Haliotis fulgens	Green abalone	-	SOC	Rare
H. corrugata	Pink abalone	-	SOC	Very Rare
H. sorenseni	White abalone	-	E	Very Rare
Fish				
Stereolepis gigas	Giant Sea Bass	Fishing Moratorium, Common		
Hypsypops rubicundus	Garibaldi	California State Marine Fish, Common		

X = Applicable to this taxon
T = Threatened
E = Endangered
MMPA = Marine Mammal Protection Act
ESA = Endangered Species Act
SOC = Species of Concern
NA = Not Available
- = Not Applicable

Those species most likely to occur and/or are the most susceptible to impacts in the Project Area based on prior occurrences are listed in the following subsections along with relevant brief summaries.

5.1.1 Pinnipeds

California sea lion

The population of the California sea lion (*Zalophus californianus*) is divided into five stocks (Lowry et al. 1917). Some movement has been documented between these geographic stocks, but rookeries in the United States are widely separated from the major rookeries of western Baja California, Mexico (NMFS 2016a). The northernmost Southern California Bight (SCB) rookery was identified on San Miguel Island (Bonnell and Dailey 1993). California sea lions feed on fishes and invertebrates; however, El Niño warm-water events affect prey availability such that their diet is susceptible to these changes (Bonnell and Dailey 1993).

The minimum population size of the U.S. stock was determined from counts of all age and sex classes that were ashore at major rookeries and haul-out sites during the breeding season. The estimated population size of the U.S. stock was 296,750 in 2014 based on counts in 2011 (NMFS 2016a). That number includes all California sea lions counted during the 2011 census at the Channel Islands in southern California and at haul-out sites located between Point Conception and the Oregon-California border. An additional unknown number of California sea lions were either at sea or hauled out at locations that were not included in the census (e.g., on the southern California mainland).

Between 1964 and 2010, non-pup counts in southern California increased at an average 2.8% annually (Lowry et al. 2017). This average increase captures the interannual variation such as impacts of (1) El Niño events, (2) domoic acid poisoning, and (3) lower survivorship of pups due to hookworm infestations. In 2013, an Unusual Mortality Event was declared in response to record numbers of emaciated pups washing ashore due to reduced forage fish caloric content in the area (McClatchie et al. 2016). Increased protections afforded by virtue of the MMPA precipitated the population increase as targeted and non-targeted harvesting and harassment has been curtailed since the MMPA passage.

Anthropogenic threats to California sea lions include entrapment in power plants, interactions with recreational hook and line fisheries, and acoustic pollution (NMFS 2016a). California sea lions were frequently entrapped in the SONGS cooling water systems. Between 1981 and 2009, 462 California sea lions were entrapped and required removal from the forebay for either Unit 2 or Unit 3. The frequency of entrapped individuals occurring in the forebay suggests the Project Area is routinely occupied by California sea lions. Insufficient information was available to classify these individuals as a resident population. Acoustic pollution has caused a variety of behavioral responses in California sea lions including increased respiration to hauling out or extended diving time. Permanent impacts to California sea lion hearing occurs at acoustic levels of 203 dB (decibels, impulsive) to 219 dB (non-impulsive) (NMFS 2016c) when accumulated over a 24 hour period.

Harbor seal

The eastern Pacific subspecies of the harbor seal (*Phoca vitulina richardii*) is currently divided into three stocks inhabiting the waters off the west coast of the continental United States: (1) the California stock, (2) the Oregon-Washington coastal stock, and (3) the Washington Inland stock. An unknown number of harbor seals inhabit the coastal waters of Alaska and Baja California (NMFS 2015c), but the southern California population is located near this subspecies' southern range limit (Bonnell and Dailey 1993). In southern California, 71 percent of all harbor seals at sea were observed within 10 km of land (Bonnell and Dailey 1993). Harbor seals in southern California reportedly consume Blacksmith Chromis (*Chromis punctipinnis*) and surfperches (family Embiotocidae), and prey data indicate harbor seals forage on benthic or epibenthic fishes in relatively shallow water (Bonnell and Dailey 1993; DoN 2013).

Numbers of harbor seals in California increased rapidly from approximately 1972 (when the MMPA was enacted) to 1990; however, net production rates appeared to decrease from 1982 to 1994. Although earlier analyses were equivocal (Hanan 1996), there has been no formal determination that the California stock has reached its Optimal Sustainable Population level (as defined by the MMPA). Anthropogenic threats to harbor seals include entrapment in power plants, interactions with recreational hook and line fisheries, and acoustic pollution (NMFS 2016a). Like California sea lions, harbor seals were frequently entrapped in the SONGS cooling water systems. Between 1981 and 2009, 346 harbor seals were entrapped and required removal from the forebay for either Unit 2 or Unit 3. The frequency of entrapped individuals occurring in the forebay suggests the Project Area is routinely occupied by harbor seals. Insufficient information was available to classify these individuals as a resident population. As with all marine mammals, acoustic pollution was considered a substantial threat to harbor seals. Permanent impacts to harbor seal hearing occurs at acoustic levels of 185 dB (impulsive) to 201 dB (non-impulsive) (NMFS 2016c) when accumulated over a 24 hour period.

5.1.2 Sea Turtles

Sea turtles breathe air and, therefore, need access to the surface where they can raise their heads above the water to respire. This may pose problems during the construction operations to modify the offshore conduit dispositions. Specifically, vessel traffic, movement of heavy construction equipment, and movement of large pieces of conduit, among other things, represent likely threats to sea turtles resulting from the conduit disposition construction. All sea turtles can stay submerged for several minutes to hours (depending on level of activity) before returning to the surface to breathe, naturally have a low profile with minimal disturbance at the surface to alert human observers, and have limited swimming speed and maneuverability to avoid vessels and construction equipment (Davenport and Davenport 2006; Hazel et al. 2009). These aspects of general sea turtle biology expose all sea turtle species discussed below to potential impacts during the construction phase of the project, especially vessel strike while equipment is moving around in the area.

Loggerhead sea turtle

Loggerhead sea turtles (*Caretta caretta)*, federally listed as threatened in 1978, are currently reported in all temperate and tropical waters throughout the world (NMFS 2017a). The major factors contributing to their listed status include human encroachment and associated activities on nesting beaches, such as commercial harvest of eggs, sub-adults and adults; predation; lack of comprehensive and consistent protective regulations; and incidental take in fisheries (Conant et al. 2009).

While loggerhead sea turtles occur throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans (Dodd 1988), the majority of loggerhead nesting has been recorded at the western rims of the Atlantic and Indian oceans. Their breeding grounds include a restricted number of sites in the North Pacific and South Pacific oceans. Within the North Pacific Ocean, loggerhead turtle nesting has been documented only in Japan, although low level nesting may occur outside of Japan in areas surrounding the South China Sea. In the South Pacific Ocean, nesting beaches are restricted to eastern Australia and New Caledonia and, to a much lesser extent, Vanuatu and Tokelau (Conant et al. 2009). Loggerheads occurring off California originate from Japanese nesting beaches (NMFS 2017a). During the last 50 years, nesting populations from Japan have decreased by between 50 and 90 percent. The Japanese nesting aggregation was last estimated at approximately 1,000 females, and fewer than 500 females nest annually in eastern Australia (NMFS 2017a).

In both the oceanic and neritic zones, loggerhead sea turtles are primarily carnivorous, although they consume some plant matter as well (Conant et al. 2009). Loggerheads consume a wide variety of food items, but there are ontogenetic and regional differences in diet. Loggerhead diets have been described from few coastal regions and very little information is available about differences or similarities in diet at various life stages.

Between 1981 and 2009, two loggerhead sea turtles were collected from within the Units 2 & 3 forebays. The rarity of their entrapment confirms that loggerhead sea turtles pass through the Project Area, albeit infrequently.

Green sea turtle

Breeding colonies of green sea turtles (*Chelonia mydas*) in Florida and on the Pacific Coast of Mexico were federally listed as endangered in 1978, whereas all other breeding colonies were listed as threatened (NMFS 2016b; NMFS 2017b). Green sea turtles occur throughout the world in tropical and subtropical waters. It was estimated that the global population of green sea turtles has declined by between 34 and 58 percent over the last three generations, or about 150 years (NMFS 2017b). Reasons for this decline include harvesting of eggs, juveniles, and adults; incidental capture by fisheries; loss of habitat; and disease.

Most green sea turtles are herbivorous and feed on algae and sea grasses; however, some turtles along the eastern Pacific coast are carnivorous. In the eastern North Pacific, green sea turtles have been sighted from Baja California to southern Alaska, but most commonly occur from San Diego southward (NMFS 2017b). They have rarely been observed in the open ocean. Previously, the northernmost resident population of green sea turtles was thought to occur in San Diego Bay. Genetic and morphologic data indicate these turtles originated from nesting beaches in the eastern Pacific and the Revillagigedo Islands west of Baja California, although some may also have originated from nesting beaches in Hawaii. A small population of green sea turtles has been observed in the lower San Gabriel River and nearby Seal Beach National Wildlife Refuge (Crear et al. 2016).

Green sea turtle was the most commonly entrapped sea turtle species while Units 2 & 3 were operating their cooling water systems. Between 1981 and 2009, 35 green sea turtles were entrapped, with most being recovered and returned to the ocean alive. At least one green sea turtle was entrapped annually during the 1981 to 2009 period suggesting frequent passage through the Project Area.

Leatherback sea turtle

The leatherback sea turtle (*Dermochelys coriacea*) was listed as endangered in 1978 throughout its range (NMFS 2017c). The leatherback sea turtle is reportedly the largest of the marine turtles and has the most extensive range of any living reptile; leatherbacks have been reported circumglobally from 71°North to 47°South in the pelagic Pacific and in all other major pelagic oceans. Their lives are spent entirely in pelagic waters, foraging in temperate waters except when they return to tropical beaches to nest. They are highly migratory, and exploit convergence zones and upwelling regions in the open ocean, along continental margins, and in archipelagic waters. Leatherbacks feed on cnidarians (siphonophores and jellyfishes) and tunicates (salps and pyrosomes).

Aerial surveys conducted from 1999-2001 recorded leatherbacks foraging off the central California coast in late summer and fall, coinciding with warm water temperatures and reduced upwelling. Leatherbacks have been commonly observed off Point Reyes, south of Point Arena, in the Gulf of the Farallones, and in Monterey Bay, all considered to be upwelling shadows, where prey organisms are retained in the upper water column due to relaxation of upwelling. Genetic analyses indicate that most leatherbacks found off the California coast originate from western Pacific nesting beaches (i.e., Indonesia, Solomon Islands, and Malaysia; NMFS 2017c).

During the 1981-2009 period, two leatherback sea turtles were entrapped in a SONGS Units 2 & 3 forebay. Both were dead when discovered in the forebay and each weighed in excess of 300 lbs. The rarity of their entrapment confirms that loggerhead sea turtles pass through the Project Area, albeit infrequently.

Olive ridley sea turtle

Olive ridley sea turtles (*Lepidochelys olivacea*) were listed as threatened in 1978, although breeding populations along the Pacific coast of Mexico are presently listed as endangered (NMFS 2017d). Today, they are distributed globally in tropical and subtropical regions of the Atlantic, Pacific, and Indian Oceans. Southern California was considered the normal northern range limit in the eastern Pacific, although some have ventured as far north as the Gulf of Alaska. Hubbs (1977) observed mating off the coast of San Diego in 1973, nearly 615 miles north of the nearest known nesting beach. Primarily pelagic, olive ridley sea turtles also inhabit coastal bays and estuaries. They are omnivorous and feed on algae, invertebrates (lobsters, crabs, tunicates, shrimps, and mollusks) and fishes.

Current information for the eastern North Pacific reports that nesting occurs along beaches in Mexico and Central America, with a few turtles nesting as far north as southern Baja California. The largest nesting aggregations, or arribadas, in the eastern Pacific have occurred off Costa Rica (roughly 475,000 to 650,000 females nesting annually) and in southern Mexico (about 800,000 nests per year at La Escobilla in Oaxaca). Numbers of nesting females increased in Mexico, potentially due to heightened nest and egg protection efforts. However, in Central America, allowable harvesting, poaching, predation, disease, and fisheries interactions have resulted in declining populations. One olive ridley sea turtle was entrapped in the Unit 3 forebay in 2009, with no prior occurrences.

5.1.3 Abalone

Abalone were, at one time, a common macroinvertebrate found on the rocky reefs of southern California. Overfishing led to a rapid decline after the southern California commercial harvest peaked in 1957 (Haaker et al. 2001). Recreational harvest was not documented during the early-1900s, but anecdotal information affirms recreational harvest occurred throughout the area (Haaker et al. 2001). Commercial and recreational abalone harvesting in the SCB was closed by 1997 by the California Department of Fish and Game in response to the declining population trend. Abalone were not recorded during routine monitoring of the San Onofre Kelp in the last decade (MBC 2014). Intertidal surveys of the shorefront the length of SONGS found no abalone (MBC 2017c). Occasional sightings have occurred in the southern Orange County area upcurrent of the SONGS intakes (MBC 2014), but no significant populations have been observed. Efforts to culture and stock green abalone along the Orange County Coast between Newport Beach and Dana Point have been undertaken (NMFS 2009; Coastkeeper 2016). If successful, the predominantly downcoast current in the Oceanside Littoral Cell would likely carry green abalone (*Haliotis fulgens*) larvae from the stock enhancement sites offshore Orange County to the Project Area. The riprap armoring the shoreline, cobble reefs, and other hard substrata in the Project Area, including the SONGS infrastructure rising above the seafloor, presents hospitable habitat for abalone, especially green abalone and black abalone. Pink abalone (*H. corrugata*) historically ranged through the Project Area at depths consistent with those likely impacted by one or more of the project options. No pink abalone have been observed in the Project Area recently, but at their low population levels a lack of observations should not be taken as absence from the area. Suitable pink abalone habitat exists in the Project Area. White abalone (*H. sorenseni*) prefer deeper depths than occur throughout most of the Project Area, although the habitat near the offshore end of the Unit 2 diffuser could support white abalone individuals. As stated for pink abalone, the lack of observations should not be misinterpreted as absence from the area. The critical habitat review team determined that the black abalone (*H. cracherodii)* range along the coastline ends at Dana Point, or north of SONGS (NMFS 2011), hence black abalone was excluded from this list.

5.1.4 Fish

Two species of protected fish species commonly occur in the SONGS area. Giant Sea Bass (*Stereolepis gigas*) was protected from harvest (recreational or commercial) in 1981 in response to steady declines in population abundances. After 1981, only incidentally caught individuals could be landed by commercial fishers. Despite continually depressed abundances in coastal waters, the Giant Sea Bass populations began to rebound in the late 1990s after the implementation of the nearshore gill net ban in 1994 (Pondella and Allen 2008; House et al. 2016). Recent surveys in the area encompassing San Mateo Kelp and Barn Kelp have observed Giant Sea Bass in kelp beds and on rocky reefs (Reed et al. 2015). Garibaldi (*Hypsypops rubicundus*) is the California State Marine Fish and thereby protected from all harvesting activity. Surveys in 2016 along the conduit corridor (MBC 2016b) observed Garibaldi. Additional occurrences at nearby San Mateo Reef, Wheeler North Reef, and Barn Kelp were documented (Reed et al. 2015). Garibaldi are relatively ubiquitous across shallow rocky reefs in the SCB (Pondella et al. 2015).

5.1.5 Habitat Areas of Particular Concern

The Pacific Fishery Management Council has designated six habitat types as Habitat Areas of Particular Concern (HAPC) due to their importance to the sustained vitality of populations managed by a fishery management plan and the habitats' rarity in the environment (PFMC 2017). The current HAPC types are: estuaries, canopy kelp, seagrass, rocky reefs, and "areas of interest" (a variety of submarine features such as banks, seamounts, and canyons, along with Washington state waters). Of these, the HAPC types occurring in the SONGS area include canopy kelp, seagrass, and rocky reefs (see Figures 3-2 and 5-1). Estuaries and other areas of interest do not occur within the Project Area or the area that will likely be impacted during the dispositioning of the SONGS offshore conduits.

Kelp canopy (as giant kelp) and rocky reef habitat are common throughout the Project Area, especially within 1 km of the conduits (Figure 5-1). Kelp surface canopy sizes in the area peaked in 2008, when sizes measured substantially larger than the reduced 2015 areas (Figure 3-2; MBC 2016c). The San Mateo Kelp, San Onofre Kelp, and Barn Kelp beds are all situated within the Project Area and have been studied as a group, with San Mateo and Barn Kelp beds acting as control sites for studies of impacts to San Onofre Kelp resulting from SONGS' cooling water discharges (Reed et al. 2015). These three kelp beds do not include random outcroppings of kelp that can develop and form canopy when oceanographic conditions are conducive to kelp growth, such as the Horno Canyon Kelp bed situated between San Onofre Kelp and Barn Kelp beds. Kelp throughout the SCB, including the Project Area, has been highly resilient over the last 20 years with a canopy present nearly every year except during strong El Niño conditions (i.e. 1997-1998) when warm water and low nutrient concentrations weaken and stunt kelp growth.

Figure 5-1. Habitat Areas of Particular Concern in the San Onofre Nuclear Generating Station Offshore Infrastructure Area.

Each of the kelp beds in the Project Area anchors to rocky reefs along the seafloor. Reef structure ranges in the Project Area from low-lying cobbles to moderate relief consisting of exposed bedrock and/or boulders (MBC 2016a). Biological communities typical of southern California rocky reefs inhabit all three of the primary reefs (Reed et al. 2015) and likely the reef anchoring Horno Canyon Kelp as well. Kelp beds and their associated marine life have a history of sensitivity to turbidity generated by construction and operations within the area (Bence et al. 1989). Bence et al. (1989) concluded the use of diffusers to maximize mixing of the thermal waste resulted in dispersion of a turbid plume that shaded parts of the San Onofre Kelp and reduced the kelp density by restricting light penetration to the kelp. This impact resulted in Condition C of the SONGS Coastal Development Permit (No. 6-81-330-A), requiring mitigation to replace lost kelp resources.

Surfgrass (*Phyllospadix* spp.) has been observed in the SONGS area (see Figures 3-2 and 5-1; CDFW 2017b). In 2003, surveys along the Unit 1 intake and outfall corridor recorded small patches of surfgrass (MBC 2003). Surveys of the Units 2 & 3 primary offshore intake structures also revealed small patches of surfgrass, specifically near the Unit 3 structure (MBC 2012). Recently, a dedicated surfgrass survey of the area identified several patches of surfgrass in shallow areas and along the edges of the conduit corridors (MBC 2017a). Surfgrass was observed at nine of 74 stations with between 0.3 m^2 and 282.7 m^2 areas of surfgrass at each station. A total of 1052 m^2 (0.26 acres) of surfgrass was observed during the surveys. More than 99 percent of the observed surfgrass occurred along the upcoast edge of the Unit 2 conduit corridor (MBC 2017a).

5.2 Non-Special Status Biological Resources of the Area

The non-special status resources in the area include various species of fish and invertebrates. These include species targeted by the fishing community and those receiving minimal fishing pressure. Various data sources published since 2010 were reviewed to compile the following; these included demersal trawl surveys conducted in support of SONGS NPDES-permit requirements (SCE 2016), infaunal invertebrate surveys (MBC 2016b), conspicuous fish and invertebrate surveys within the conduit lease area and around the diffuser ports (MBC 2016b), and reef surveys from the area monitoring the performance of the Wheeler North Mitigation Reef (Reed et al. 2015). The demersal trawl surveys document the taxa and relative abundance of fish and invertebrates residing near the sandy seafloor. Invertebrate infaunal sampling characterizes the invertebrate community residing within the sediments that are often largely immobile or minimally mobile. Both MBC (2016b) and Reed et al. (2015) surveys focused on areas not readily sampled by other techniques due to the occurrence of rocky reefs, kelp, and other natural structures that would snag a net.

5.2.1 Demersal Fish

Prior to 2015, the SONGS NPDES permits required that the only fish catch data that needed to be reported were from otter trawl surveys. Beginning in 2015, invertebrates were added to the study design and reporting requirements. Since at least 2001, quarterly sampling has occurred offshore of San Mateo Point, SONGS, and Don Light along the 6.1-, 12.2-, and 18.3-m isobaths. Over this time, more than 2 fish/100 m^2 were taken annually across the area (Figure 5-2). Fish communities reached their peak density in 2013, largely the result of anomalously high catches of White Croaker (*Genyonemus lineatus*) offshore San Mateo Point and SONGS. No special status fishes were caught during the surveys. The four quarterly surveys in 2015 reported an average of 0.6/100 m^2 (± 0.1) invertebrates across the nine stations sampled.

5.2.2 Infaunal Invertebrates

Sediment samples were collected and processed to assess the infaunal invertebrate community within the lease area (Table 5-2) (MBC 2016b). At each sampling site, four replicate one-liter diver-operated box sediment cores (0.01-m^2 surface area) were collected by divers, screened through 1-millimeter screens to remove fine sediments, and sorted in the MBC Aquatic Sciences (formerly MBC Applied Environmental Sciences) taxonomy laboratory located in Costa Mesa, California. All organisms were identified to the lowest practicable taxon and counted by taxon. Nematode worms accounted for over 50 percent of all infaunal individuals.

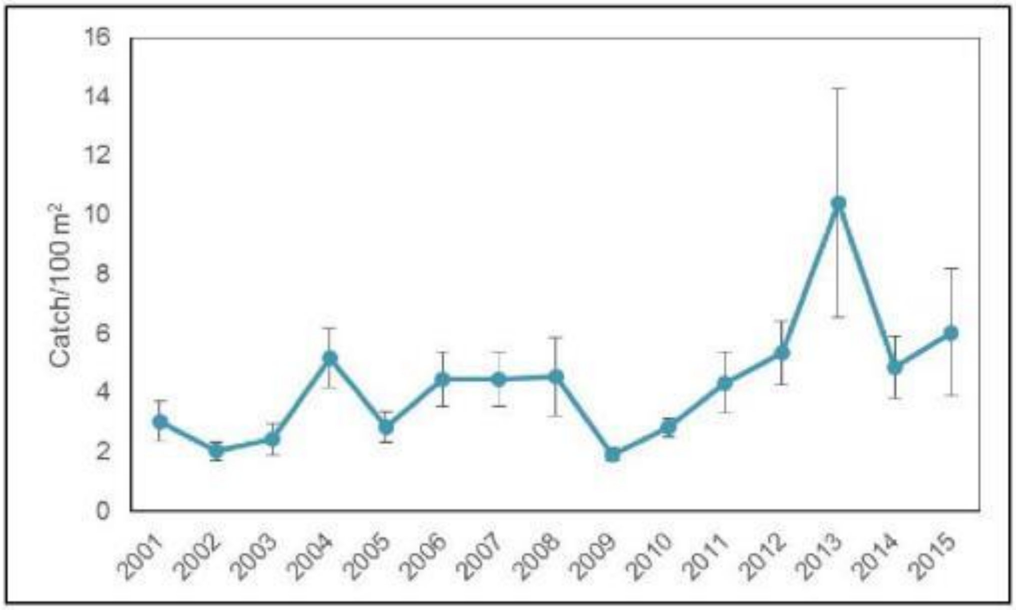

Figure 5-2. Mean Annual Otter Trawl Catch/100 m² (± Standard Error) for Quarterly Sampling at Nine Stations Sampled between San Mateo Point and Don Light. Sourced from SCE (2016).

Table 5-2. Sum of the Mean Station-specific Density (count/m²) and Cumulative Percentage Contributed to the Total for Each of the Ten Most Common Infaunal Invertebrates Collected in the Sediments along the SONGS Units 2 & 3 Offshore Lease Area (sourced from MBC Applied Environmental Sciences [2016b]).

Taxa	Sum Density (Count/m²)	Cumulative %
Nematoda	141,533	53
Pareurythoe californica	23,067	61
Hesionura coineaui difficilis	20,267	69
Protodorvillea gracilis	17,700	75
Saccocirrus eroticus	14,733	81
Pisione remota	7,367	84
Polychaeta	5,833	86
Apoprionospio pygmaea	3,533	87
Oligochaeta	3,300	88
Microphthalmus hystrix	3,233	90
Total across all Taxa	**268,700**	
Number of Taxa	**133**	

5.2.3 Rocky Reef Communities

MBC (2016b) recently deployed divers to swim transects at each of the 18 stations sampled for infaunal invertebrates within the CSLC lease area identifying and counting all conspicuous fishes and invertebrates. Visibility was poor during the survey on some transects, especially at the shallower depths subject to greater wave energy and increased suspended sediments. No fishes were observed on nine of the 18 transects, while only one species was observed on six additional transects, located along both conduit corridors (Transects 1, 7, 8, 16, 17, and 18; Figure 5-3). Multiple taxa were observed on two of the transects. Total fish densities ranged from 0.00 to 0.80 fish/10 m^2 across all transects with Kelp Bass (*Paralabrax clathratus*) ranking as the most abundant species observed. Kelp Bass was observed on four transects in densities ranging from 0.05–0.40 fish/10 m^2. Barred Sand Bass (*Paralabrax nebulifer*), Black Perch (*Embiotoca jacksoni*), and California Lizardfish (*Synodus lucioceps*) were each observed on multiple transects. The remaining eight species were observed only on one transect. The most fish, in terms of abundance and species, were observed on the shallowest transects and included Garibaldi.

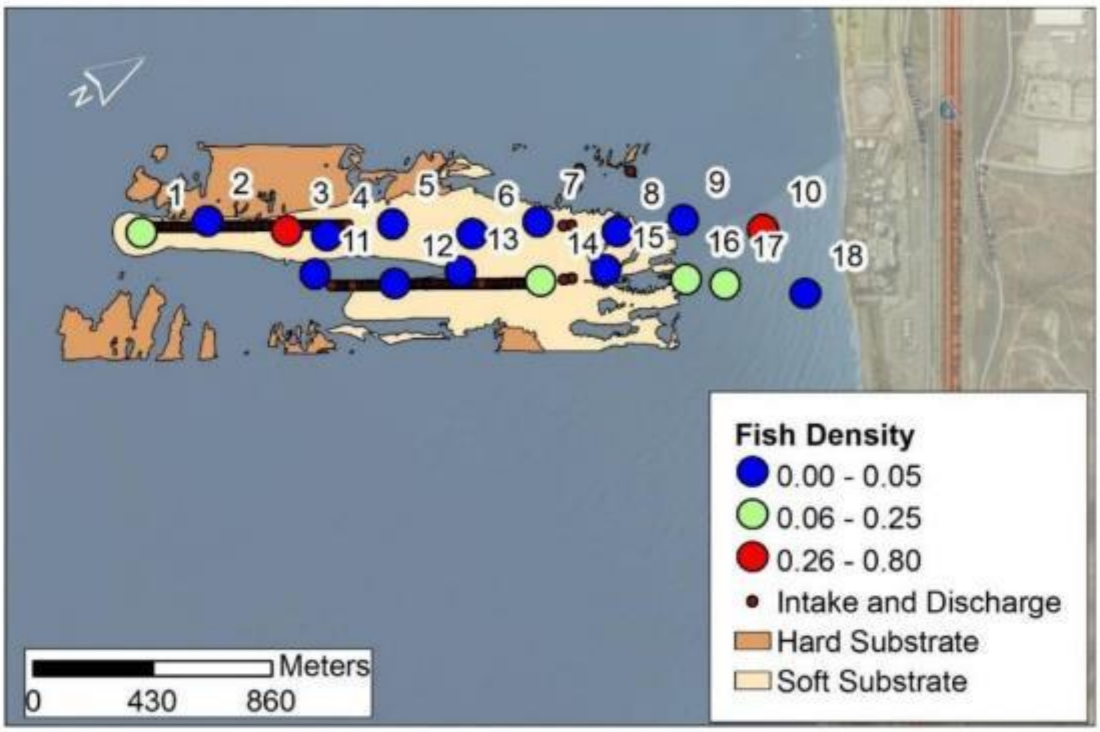

Figure 5-3. Mean Fish Density (Count/10 m^2) Observed During Spring Surveys Along the Units 2 & 3 Offshore Conduit Corridors. Image from MBC (2016b).

During the same survey inside the lease area as described above for fish, invertebrates were counted as they were observed (MBC 2016b). Seven invertebrate species were observed during the survey with no apparent spatial pattern. Pacific sand dollars (*Dendraster excentricus*) were the most frequently observed and the most populous invertebrate. Pacific sand dollars were observed at four stations with densities ranging between 0.50–5.00 individuals/10 m^2 on Transects 8, 13, 14, and 15 (Figure 5-4). Most Pacific sand dollar observations were in aggregations, or beds, on the seafloor. Purple sea urchin (*Strongylocentrotus purpuratus*) and red sea urchin (*S. franciscanus*) were the next two most common species and were observed on Transects 1 and 3. No special-status invertebrate species were observed.

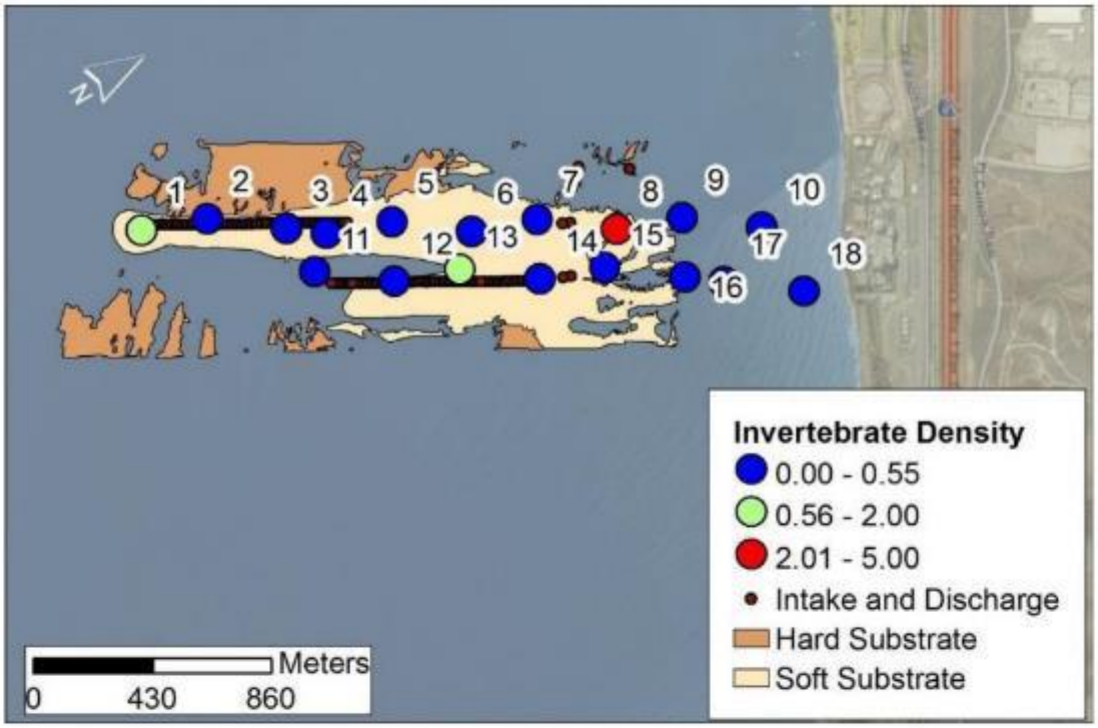

Figure 5-4. Mean Invertebrate Density (Count/10 m^2) Observed During Spring Surveys Along the Units 2 & 3 Offshore Conduit Corridors. Image from MBC (2016b).

Rocky reef communities on the Wheeler North Reef, San Mateo Kelp, and Barn Kelp were surveyed and reported in Reed et al. (2015). Common resident reef fish (e.g. Kelp Bass, Barred Sand Bass, and California Sheephead [*Semicossyphus pulcher*]) were present at each of the reefs with a total community density of approximately 10 fish/100 m^2 in 2015. Commercially important invertebrates such as California spiny lobster (*Panulirus interruptus*) and red sea urchins occur in the area, with 2015 densities up to nearly 5.0/100 m^2 for California spiny lobster and 20-40 red sea urchins/100 m^2.

5.2.4 Fishing

Sportfishing is a popular activity in the Project Area with Dana Wharf Sportfishing located to the northwest and Helgren's Oceanside located to the southeast. Both Dana Wharf Sportfishing and Helgren's Oceanside support commercial passenger fishing vessels (CPFVs) operating from their respective landings. These CPFVs take paying angler passengers out to local fishing grounds only accessible by boat and provide a fishing platform (the boat) staffed by trained crew and often providing live bait among other fishing-related services. In addition to the sportfishing operations, public marinas in the area (Dana Point Harbor, Oceanside Harbor, etc.) support private boaters that either launch their trailered boat or rent a slip from the harbor operator. Among other activities, private boaters enjoy recreational fishing in the area at sites only accessible by boat. These same marinas support commercial fishery operations as well, ranging from smaller vessels targeting California spiny lobster to larger purse seine vessels targeting schooling fishes and invertebrates.

Rocky reefs and kelp beds are of particular interest due to their above average fish productivity (Claisse et al. 2014). In the southern Orange County area, large sections of rocky reef and kelp bed habitat were closed to fishing with the implementation of the Marine Life Protection Act in the South Coast Region on January 1, 2012 (CDFW 2017). This includes the coastline between Newport Bay and Dana Point. Therefore, anglers (recreational and commercial) targeting species common to rocky reefs and kelp beds (e.g. California spiny lobster, and Kelp Bass (*Paralabrax clathratus*)) must target the coastline southeast of Dana Point Harbor to find such habitat open to fishing. This encompasses the Project Area and both the natural and artificial rocky reef and associated kelp bed habitats located directly offshore of SONGS.

The California Department of Fish and Wildlife (CDFW) designated a grid of squares, or partial squares when they abut the coastline, to provide a consistent geographic reference to fishing location. This grid system predates modern geographic positioning systems and allows fishers to report a geographic location without identifying the exact location of their efforts. The SONGS area is situated in CDFW Block 756, shown on Figure 5-5. Five additional CDFW blocks were analyzed and compared to CDFW block 756 to assess fishing catch patterns in the area.

All commercial fishers and operators of the CPFVs are required to report the location, species, landed weight (commercial) or number (CPFVs) of fish and invertebrates caught. In some cases, measures of fishing effort (e.g., number of anglers, hours fished, number of traps set) are also provided, but not always. Fishing success is dependent upon fishing effort and local target fish and invertebrate densities. Therefore, the available fishing records are presented to show what percentage of the area's catch was reported from CDFW Block 756. For the CPFV data, which represent the recreational catch of fishers who have paid a fare to be taken to the fishing grounds to engage in sportfishing, values are presented as a function of total catch across all species. The commercial catch was also represented as the total across all species, and catch was totaled for California spiny lobster individually. California spiny lobster ranks among the state of California's most valuable commercial fisheries. Furthermore, the fishery is limited by the California spiny lobster's preference for rocky reef habitat.

Figure 5-5. California Department of Fish and Wildlife (CDFW) Fishing Blocks used in the Fishing Analysis.

The recreational catch from CDFW Block 756 represents more than 30 percent of the total catch recorded across all six analyzed blocks in most years since 1957 (Figure 5-6). Only recently has the percentage of the six-block total catch declined at a time coinciding with anomalously warm waters offshore of California (DiLorenzo and Mantua 2016), which brought prized gamefish typically found offshore of Baja California into coastal southern California waters. Commercial landings of all taxa have been sporadic since 1972, with CDFW Block 756 typically contributing a small percentage of the total with occasional substantial increases such as 1987 and 1989 when more than 50 percent of all landings were reported from CDFW Block 756 (Figure 5-7). California spiny lobster pose a unique analysis as they may not account for a substantial portion of total biomass in comparison to the larger biomass round haul fisheries for Northern Anchovy (*Engraulis mordax*) and Pacific Sardine (*Sardinops sagax*), but the price per pound is the highest among California's commercial fisheries (Miller 2014). Looking exclusively at California spiny lobster landings, CDFW Block 756 accounted for a steadily increasing percentage of the commercial catch from the six-block area before declining after 2012. This timing coincides with implementation of the Marine Life Protection Act, but no further research has been published on the cause of this shift.

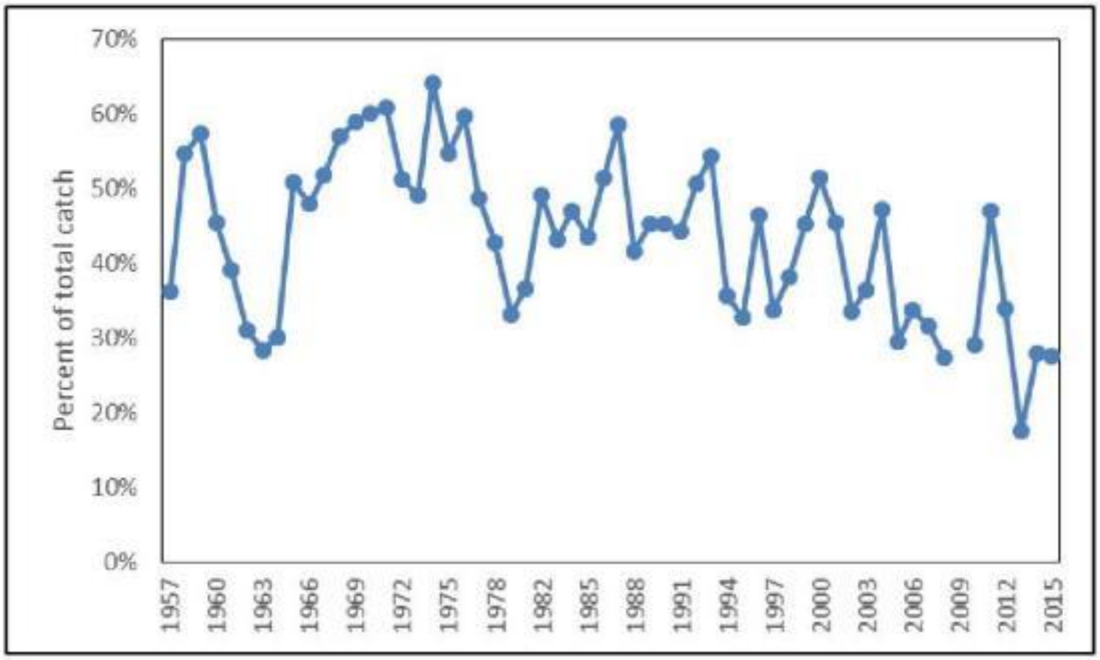

Figure 5-6. Percent of the Total Commercial Passenger Fishing Vessel (Recreational Fishing) Reported Catch Occurring in the San Onofre Nuclear Generating Station Area Contributed by Department of Fish and Wildlife Block 756 Out of the Six Blocks Analyzed (see Figure 6).

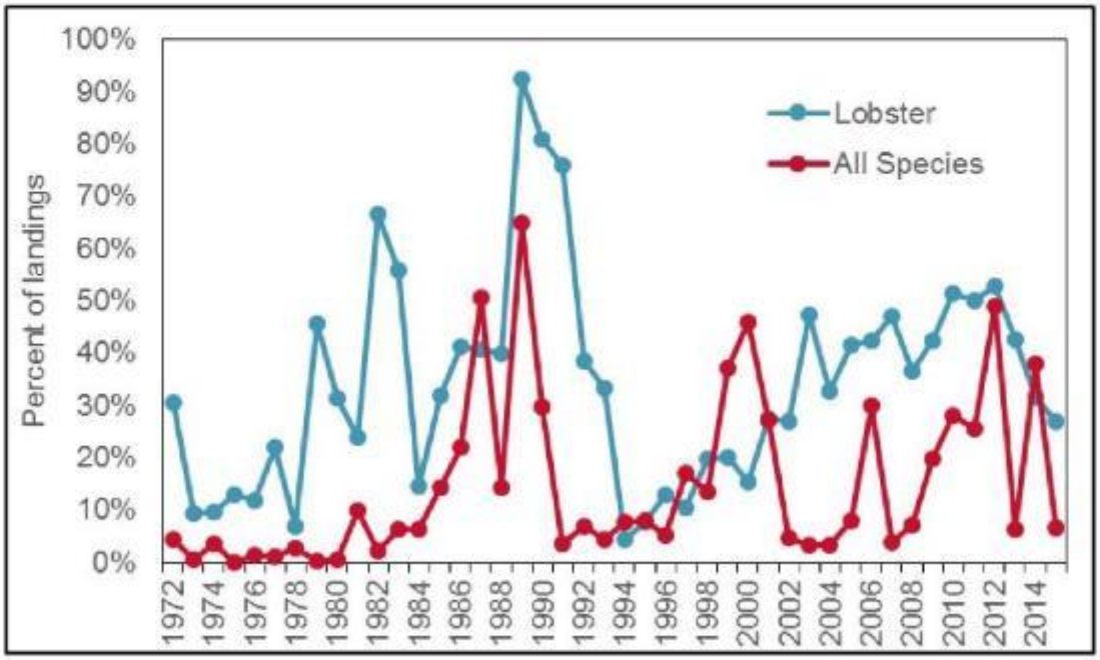

Figure 5-7. Percent of Total Commercial Landings and California Spiny Lobster Landings in the San Onofre Nuclear Generating Station Area Contributed by Department of Fish and Wildlife Block 756.

5.3 Radiological Environmental Monitoring Results

SCE monitors the environment surrounding SONGS, including the marine environment, for levels of radioactivity detailed in reports such as the Annual Radiological Environmental Operating Report (SCE 2015). These data and studies are submitted to the United States Nuclear Regulatory Commission in compliance with License Numbers DPR-13, NPF-10, and NPF-15. Marine monitoring includes select fish, invertebrates, kelp, sediments, and water. Comparing the results of the 2014 monitoring data with the conservative limits defined in the SONGS operating license, no statistically significant radiological impact occurred to the marine environment as a result of plant operations in 2014.

Additional sampling from within the discharge conduits in December 2016 found licensed radionuclides (Cesium-137 and Cobalt-60) in sediments and biofouling marine life (scrapings) that was scrapped off the conduit walls (CB&I 2017). Peak concentrations of each radionuclide in sediment and scrapings was detected in samples collected in the Unit 2 discharge conduit. Cobalt-60 (Co-60) was detected in all 10 sediment samples with a peak concentration of 2.2 picocuries per gram (pCi/g). Four of the 10 scrapings collected from the Unit 2 conduit were also positive for Co-60 peaking at 0.79 pCi/g. One sediment sample from the Unit 2 conduit was positive for Cesium-137 (Cs-137) at 0.14 pCi/g and no scrapings were positive for Cs-137. Similar sampling from the Unit 3 discharge conduit resulted in fewer positive tests with Co-60 detected in one sediment sample (0.66 pCi/g) and one scraping (0.049 pCi/g). Cesium-137 was detected in two Unit 3 sediment samples peaking at 0.12 pCi/g. No Unit 3 scrapings were positive for Cs-137. Additional sediment samples were collected near select diffuser ports and tested for Cs-137 and Co-60. Only three samples were positive for only Co-60 with a peak concentration of 0.092 pCi/g.

6 Conduit Disposition Alternatives

6.1 Description of alternatives and disposition activities

Descriptions for the three conduit disposition construction alternatives were sourced from COWI (2017) and supplemented with additional information on trench infilling described below in Section 6.2. Dredge volumes assuming a side slope of 1.5:1 (horizontal: vertical [H:V]) were used to evaluate the most conservative approach, i.e. likely most impactful. For the purposes of this study, it is assumed that means and methods described by COWI (2017) would be employed to disposition the conduits.

6.1.1 Full Removal

Full removal of all vertical and horizontal structures would require extensive dredging to expose and remove the buried conduits (see Section 3.1 for conduit description). Shallow water depths extend a significant distance offshore from the station creating a large surf zone; therefore, temporary trestles would be constructed from the 0-foot contour (mean lower low water [MLLW] = 0 feet) at Station (STA) 9+75 to approximately STA 39+00 to assist with dredging and removal of the conduits. The trestles, which may be built in series, would provide approximately 3,400 linear feet (1,036 m) of access for conduit removal and will extend out to a depth of 29 feet (9 m) (i.e., STA 39+00). While trestle construction equipment would be site-specific, the deck and piles would be built near the offshore intake structure and would move incrementally inwards toward the shoreline. Conduits would be hoisted out of the water using a mounted crane and cradle horse assembly on the trestle. Excavation activities would include removing pipe in 24-foot long units and proceed from offshore to onshore. A dive team would be on-site to assist with underwater disconnection of the compression joints between the 24-foot length pipes. Pipe sections would be floated to deeper water and lifted onto material barges with the help of the trestle crane and workboats; up to 60 barge loads of pipe would be towed from San Onofre to the Port of Long Beach for processing.

Beyond the extent of the trestle, water is deep enough to allow a barge to safely work outside the surf zone. A spud-anchored and multi-point anchor arrangement system barge would be used to extract the conduits, while leaving the vertical structures intact (to be removed with the conduits as a whole unit). Arrangement of anchors would be subject to change based on the contractor's specifications and coordination with regulatory agencies to ensure sensitive habitats are protected, where possible. Pipe sections would be hoisted up from deep water with the help of two derrick barges, placed onto a material barge near the primary offshore intake structure, and transported to Port of Long Beach.

Removal of the intertidal and shoreline structures could commence when all pipe is removed from the surf and deep water zones. While the temporary trestle is in place, a sheet pile cut-off wall could be installed to isolate the intertidal area to provide access for demolition teams and equipment. The demolition area would be dewatered using a minimum of three dewatering pumps and concrete debris would be lifted to the trestle via crane bucket for off-site transport. Existing rock groins may be used as backfill in areas where culverts were removed and, after the sheet pile cut-off wall is removed from the trestle, marine equipment (floating) would remove the crane trestle piles and decking. Excavation would be carried out at the existing walkway location for removal of culverts from STA 8+30 to the stop gates. Unused rock could be used as slope protection.

6.1.2 Partial abandonment, removing all above seafloor elements

All vertical structures, including primary offshore intake structures (POISs), auxiliary offshore intake structures (AOISs), manhole access port structures (MAPSs), and all diffuser ports (i.e., 126 ports), would be removed to below the seafloor under this scenario. All horizontal features, including the fish return, intake, and discharge conduits, would be abandoned in place below the seafloor, thus generating no additional sediment redistribution. Removal of the vertical structures would result in points of entry into the open conduit; therefore, barriers would be installed to preclude entry by large marine organisms but allow for sand infiltration.

Upon initial installation of the vertical features, stone blankets were installed around the base of most of the structures, with the top of the stone blanket flush with the seafloor. Because sediment has accumulated over time, there is an approximate 2-ft to 5-ft-thick layer of sand/silt overlying the stone blankets such that, at each structure, sediment would be removed to a minimum of 2-ft below the top of the stone blanket for installation of mammal exclusion barriers similar to what was required during the Unit 1 conduit dispositioning (CSLC 2005).

6.1.3 Partial abandonment, removing a subset of above seafloor elements

All vertical structures (POISs, AOISs, and MAPS), with the exception of the diffuser ports, would be removed to below the seafloor under this scenario. Only a subset of diffuser ports would be removed (i.e., 6 per discharge conduit for a total of 12 ports). Removal of the vertical structures would follow the same process described under Section 6.1.2.

6.1.4 Alternative Removal of Vertical Structures

Methods proposed by COWI (2017) and the preceding work to set the Unit 1 conduits to their final disposition included excavating sediments around each vertical structure to be removed down to the buried conduit. Using this method, the vertical structure could be disconnected from the conduit by removing the attachment hardware. Alternatively, the vertical structures could be removed by cutting the structure off at the seafloor elevation with no sediment excavation. For the purposes of this analysis, a diamond wire saw was assumed to be used.

6.2 Cooling System Trench Infilling

The emphasis of this section of the report is on estimating the time it would take to fill the trenches created by removal of the buried cooling system pipes. These trenches would have a volume of about 500,000 m^3. In this analysis, we describe several published trench and pit-filling models and apply one of them, MEMPITS, to estimate the time required to fill about 2/3 of the (remaining) trench volume ("e-folding time") as a function of distance offshore (Ribberink 2004; Ribberink et al. 2005). Figure 6-1 is a schematic diagram that defines the configuration of a trench versus a pit. Notice the difference in shape. An example of a trench is a navigation channel, while a pit is generally used to extract sand from the nearshore area for use on land (e.g., for sand nourishment projects).

Trench infilling rates depend on the interplay of wave-driven currents, which are important in the surf zone where infilling can be rapid, and currents related to tidal flow and wind, which dominate offshore areas where infilling is generally slower. The amount, type, and mobility of available sediment, particularly sand, are also important factors. The available wave and current data at SONGS are used as inputs to MEMPITS, which is applied in three regimes: the surf zone, an intermediate region, and offshore. Sediment transport and the nearshore sand budget are characterized using bathymetry and hard substrate surveys carried out in 2000 and 2016 near the intake and outfall systems.

6.2.1 Approach

The existing (limited) observations of trench infilling, as well as several published trench-filling models based on theoretical estimates of sediment transport by waves and currents, are described and reviewed. The numerical model MEMPITS (Ribberink 2004; Ribberink et al. 2005), developed under the European Union project SANDPIT (2005) for engineering applications, is used to estimate potential trench infill rates at SONGS. Trench infilling rates depend on the waves and currents that move sediment. The MEMPITS program used in this study requires wave data as input, estimated using a 16-year hindcast, and data on currents observed near the SONGS outfalls, or discharge conduits. The availability and mobility of sediment at SONGS, potentially important factors, are characterized using bathymetry and hard substrate surveys from 2000 and 2016. The seafloor substrate near the conduit pipes is a mix of cobbles, shell hash, and hard bottom. Numerical models assume a single grain size. Infilling is accelerated in the surf zone, where wave-breaking drives strong circulation, including rip currents.

6.2.2 Summary

The time to fill the trenches created by removing the SONGS Units 2 & 3 intake and discharge conduits is estimated to be 1-10 years in the nearshore area (0-7 m water depth), and at the seaward limit (7-15 m water depth), more than 60 years for trenches with a slope of 1:1 H:V and 90 years for trenches with a slope of 1:1.5 H:V. The difference in infilling times reflects the higher water velocities and sediment transport rates in shallow water relative to deep water.

The mix of sediment types (hard-bottom, cobbles, and shell hash) in the nearshore and offshore areas causes an unknown and perhaps larger increase in infill times relative to those estimated above. In the nearshore area, hazardous swimming conditions, including powerful rip currents, would likely be created near the surf zone trench, and there would be impacts on beaches north and south of SONGS. The results of this study are in agreement with observations of the infilling time of other trenches in southern California and worldwide that have similar trench sizes and wave/current conditions.

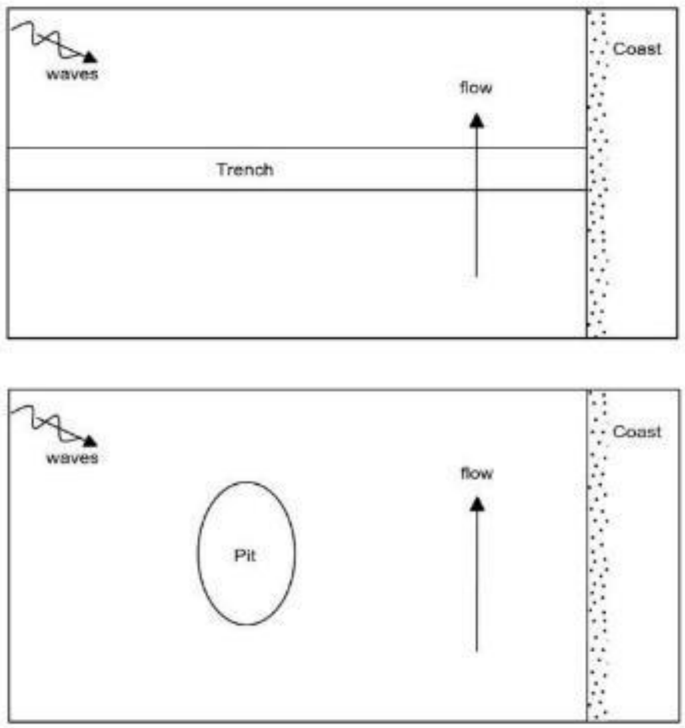

Figure 6-1. Configuration of Trenches and Pits. Navigation Channels are Trenches; Trenches are not Necessarily Perpendicular to the Coast.

6.2.3 SONGS Trench Configuration

The plan view of the Units 2 & 3 offshore conduits (Figure 6-2), as well as the locations of four separate cross-sections (A, B, C and D), were used to estimate the dredge volume of sand required to remove the Units 2 & 3 offshore conduits. For the 18-ft, 14-ft, and 10-ft inside diameter (ID) conduits, we assumed that the wall thickness for each pipe was 1 ft. We also assumed that there was a total of 4.5 ft (1.5 m) of backfill/sediment on top of the conduits, based on Figures 6-2 and 6-3 in the COWI report (2017). In this study, we considered two designs for the trench excavations in order to reduce the sloughing of excavation walls during dredging: either 1:1 H:V side slopes (Alternative 1) or 1:1.5 H:V side slopes (Alternative 2).

In determining the dredge volume of sand required at cross-section A (Figure 6-3), each intake conduit is spaced approximately 40 feet (12.2 m) apart from the center of its associated discharge conduit (COWI 2017). Because the intake and discharge conduits are so closely spaced, we assumed that a single trench would be constructed in order to remove both conduits. In cross-section A, a length of 3,200 ft (975.36 m) was used to calculate the dredge volume of sand required to remove the portion of the Units 2 & 3 intake and discharge conduits that runs in parallel.

Cross-sections A, B, C, and D are presented in Appendices B and C for side slopes 1:1 H:V and 1:1.5 H:V, respectively. Volume calculations for calculating the dredge volume of sand required to remove the Units 2 & 3 discharge conduits are given in Appendix D. Dredge width, depth, and cross-sectional area for removal of offshore conduits are given in Tables 6-1 and 6-2 for side slopes 1:1 H:V and 1:1.5 H:V, respectively.

The estimated total dredged volume is about 450,000 m^3 and 564,000 m^3 for trenches 1:1 H:V (Alternative 1) and 1:1.5 H:V (Alternative 2), respectively. Tables 6-3 and 6-4 and Appendix D provide the cross-sectional areas and the lengths for each of the four cross-sections used to compute the volume as shown in Figure 6-3, and the volume to be dredged for side slopes 1:1 H:V and 1:1.5 H:V, respectively.

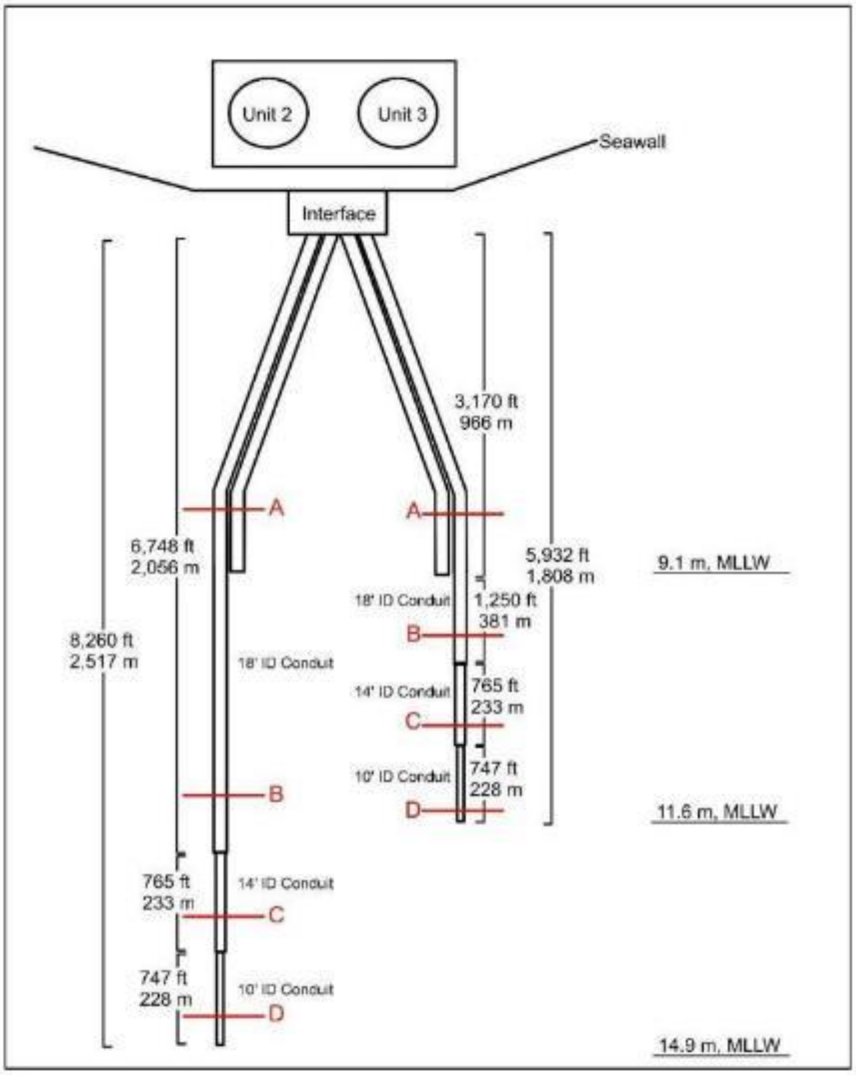

Figure 6-2. Plan View of Units 2 & 3 Offshore Conduits and Associated Water Depth. Water Depths are Indicated and Referenced to MLLW (epoch 1941-1960).

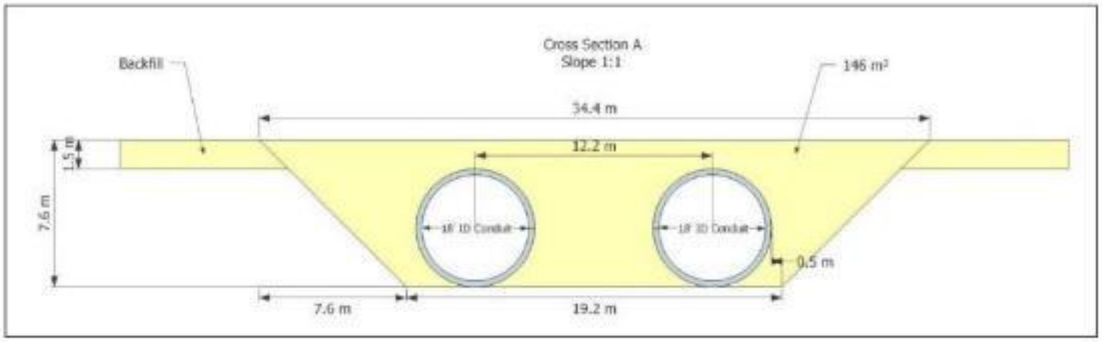

Figure 6-3. Cross-Section A Showing Trench for Removal of 18-ft-Diameter (6-m-Diameter) Intake and Discharge Conduits with Side Slope 1:1.

Table 6-1. Dredge Width, Depth, and Cross-Sectional Area for Removal of Offshore Conduits Given Side Slope 1:1 H:V.

UNIT 2 Cross-sections	Conduit Diameter (ft)	Water Depth (m, MSL)		Trench Width (m)	Trench Depth (m)	Trench Area (m^2)
		Start	End			
A	2 x 18	0	10.06	34.4	7.6	146
B	18	10.06	14.03	22.3	7.6	82
C	14	14.03	14.63	18.6	6.4	59
D	10	14.63	15.8	15	5.2	40
UNIT 3 Cross-sections	**Conduit Diameter (ft)**	**Water Depth (m, MSL)**		**Trench Width (m)**	**Trench Depth (m)**	**Trench Area (m^2)**
		Start	**End**			
A	2 x 18	0	10.06	34.4	7.6	146
B	18	10.06	11.81	22.3	7.6	82
C	14	11.81	12.12	18.6	6.4	59
D	10	12.12	12.50	15	5.2	40

Table 6-2. Dredge Width, Depth, and Cross-Sectional Area for Removal of Offshore Conduits Given Side Slope 1:1.5.

UNIT 2 Cross-sections	Conduit Diameter (ft)	Water Depth (m, MSL)		Trench Width (m)	Trench Depth (m)	Trench Area (m²)
		Start	End			
A	2 x 18	0	10.06	34.4	7.6	175
B	18	10.06	14.03	22.3	7.6	111
C	14	14.03	14.63	18.6	6.4	80
D	10	14.63	15.8	15	5.2	54

UNIT 3 Cross-sections	Conduit Diameter (ft)	Water Depth (m, MSL)		Trench Width (m)	Trench Depth (m)	Trench Area (m²)
		Start	End			
A	2 x 18	0	10.06	34.4	7.6	175
B	18	10.06	11.81	22.3	7.6	111
C	14	11.81	12.12	18.6	6.4	80
D	10	12.12	12.50	15	5.2	54

Table 6-3. Dredge Volume of Sand for Removal of Offshore Conduits Given Side Slope 1:1.

UNIT 2 Cross-sections	Conduit Diameter (ft)	Area (m^2)	Length (m)	Volume (m^3)
A	2 x 18	146	966.2	141,110
B	18	82	1090.6	89,768
C	14	59	233.17	13,842
D	10	40	227.7	9,117
		Total	**2,517.6**	**253,836**

UNIT 3 Cross-sections	Conduit Diameter (ft)	Area (m^2)	Length (m)	Volume (m^3)
A	2 x 18	146	966.2	141,110
B	18	82	381	31,361
C	14	59	233.2	13,842
D	10	40	227.7	9,117
		Total	**1,808**	**195,430**
			Units 2 & 3 Total (m^3)	**449,265.8**

Table 6-4. Dredge Volume of Sand for Removal of Offshore Conduits Given Side Slope 1:1.5.

UNIT 2 Cross-sections	Conduit Diameter (ft)	Area (m^2)	Length (m)	Volume (m^3)
A	2 x 18	175	966.2	169,116
B	18	111.3	1090.6	121,387
C	14	79.8	233.17	18,614
D	10	53.5	227.7	12,172.52
		Total	**2,517.6**	**321,282**
UNIT 3 Cross-sections	**Conduit Diameter (ft)**	**Area (m^2)**	**Length (m)**	**Volume (m^3)**
A	2 x 18	146	966.2	169,116
B	18	82	381	42,404
C	14	59	233.2	657,365
D	10	40	227.7	429,869
		Total	**1,808**	**242,308**
			Units 2 & 3 Total (m^3)	**563,589**

6.2.4 Waves and Currents

Waves

Waves provide the largest source of energy to the coast of California and are a critical influence for sand transport and beach erosion as well as coastal flooding and damage. This section reviews the relevant properties of waves in the study area as an introduction to the trench infilling analysis to follow.

Wave Climate Overview

In southern California, ocean waves fall into the following three primary categories (USACE 1986):

1. Northern Hemisphere Swell: Relatively long waves generated in the North Pacific that propagate into southern California waters;
2. Southern Hemisphere Swell: Similar waves generated south of the equator during the boreal summer; and
3. Local Seas: Relatively short-period, wind-generated waves within the Southern California Bight.

SONGS is sheltered from waves arriving from the west and southwest by Santa Catalina and San Clemente Islands, and from northwesterly waves by the mainland (Figure 6-4; Pawka 1982). The relatively narrow openings between the islands lower the typical swell[1] wave energy at SONGS. Thus, it is the local seas inside the Southern California Bight, with relatively short-period waves (periods <12 sec) and an approach angle of about 279°-295°, that are able to reach San Onofre.

Wave Characteristics

Long-term wave data were collected by the CDIP (1992) at Oceanside and San Clemente in 36-ft (11-m) water depth using a directional pressure-sensor array over a 16-year period from late 1978 to December 1994 (including some data gaps). The maximum monthly wave height (Hs) derived from the CDIP measurements shows that wave conditions in Oceanside, and by extension at San Onofre, vary both seasonally and from year to year.

Directional wave measurements made offshore of San Onofre and Oceanside during three deployment periods from 27 March through 16 June 2000 were compared to establish the wave transformation function between them (Figure 6-5). The methods used are described in CE (2000b) and Elwany et al. (2016). From these wave data, we can conclude that during the spring and early summer of 2000, Hs was generally slightly larger at Oceanside than at San Onofre. The measurements were used to derive empirical formulas to adjust Hs and alongshore radiation stress (Sxy) measured at Oceanside to be representative of San Onofre conditions. Hs

[1] Swell is loosely defined as waves generated outside the area and having periods longer than about 12 sec.

and Sxy time series are used to estimate sediment transport potential calculations at San Onofre (Elwany et al. 2016).

The linear relationship of Hs at the two sites is:

San Onofre Hs (m) = 0.76 Oceanside Hs + 0.13

This relation was used to estimate the hourly wave height at SONGS from the measured directional data at Oceanside from 1978-1994. Comparisons between significant wave height at Oceanside (OCNSD), San Onofre (SONGS), and San Clemente (SANCL) during the winter of 1984-1985 are shown in Figure 6-6. Maximum monthly significant wave height Hs at San Onofre is shown in Figure 6-7. The largest wave storm was recorded on 18 January 1988, with Hs of 4.7 m.

A graph showing percentage occurrence by wave period for those waves having Hs > 1.2 m is shown in Figure 6-8. Two distinct peaks are evident, at wave periods of 8-10 sec and 14-16 sec.

Wave Hindcast Modeling

SONGS is sheltered from deep-ocean waves by numerous offshore islands and shoals, thus greatly complicating the coastal wave climate and numerical modeling (Pawka 1982). Using a network of directional wave buoys to define wave conditions in coastal southern California and numerical propagation modeling, waves at SONGS were hindcast for 2000-2016 (O'Reilly et al. 2016).[2]

With peak periods usually about 7-18 seconds, waves are influenced by local bathymetry as they propagate into depths less than about 200 m. The wave hindcast modeling agrees well with the directional wave measurements at the Camp Pendleton buoy, located about 20 km south of SONGS in 20 m water depth.

Hindcast wave heights in 10 m water depth near SONGS usually range from 0.5-1.5 m, and are rarely above 2.5 m (Figure 6-9). At southern Camp Pendleton and at SONGS, wave energy is seasonal, with the largest waves in winter (Figure 6-9).

[2] These wave hindcasts were also used in the SONGS decommissioning Phase 2 Coastal Processes Analysis.

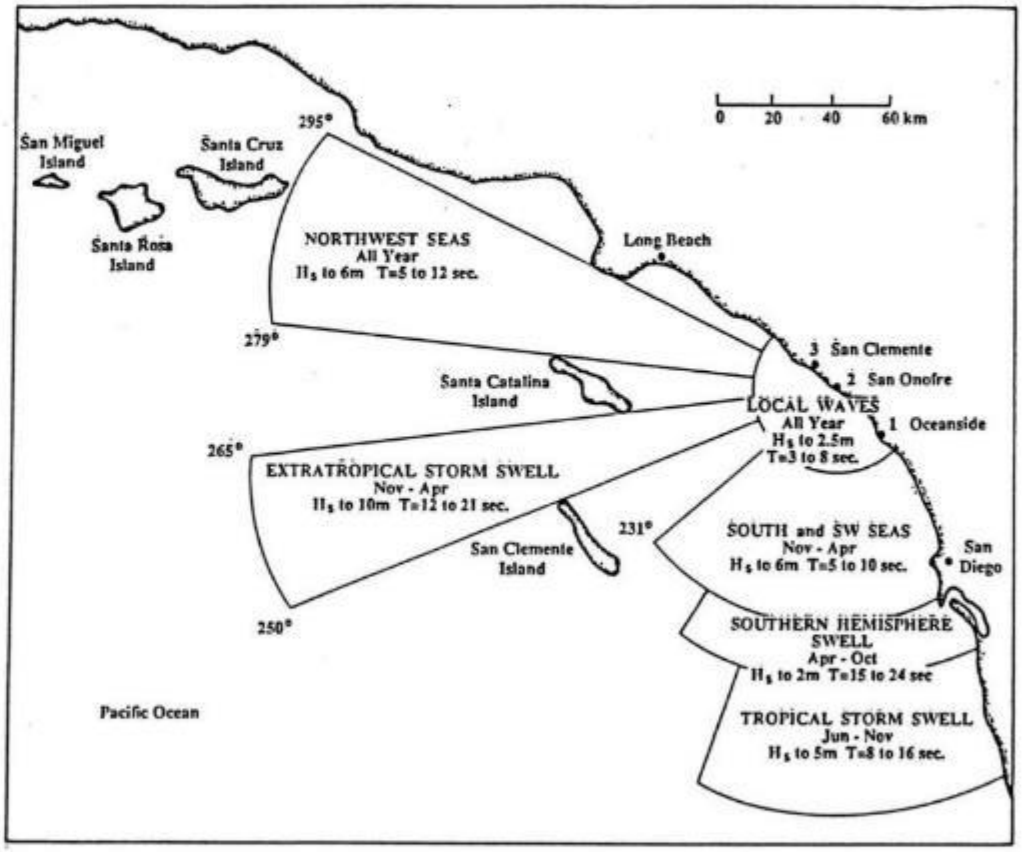

Figure 6-4. Wave Exposure at San Onofre Illustrating Mainland and Island-Shadowing and Resulting Wave-Exposure Windows (USACE 1986).

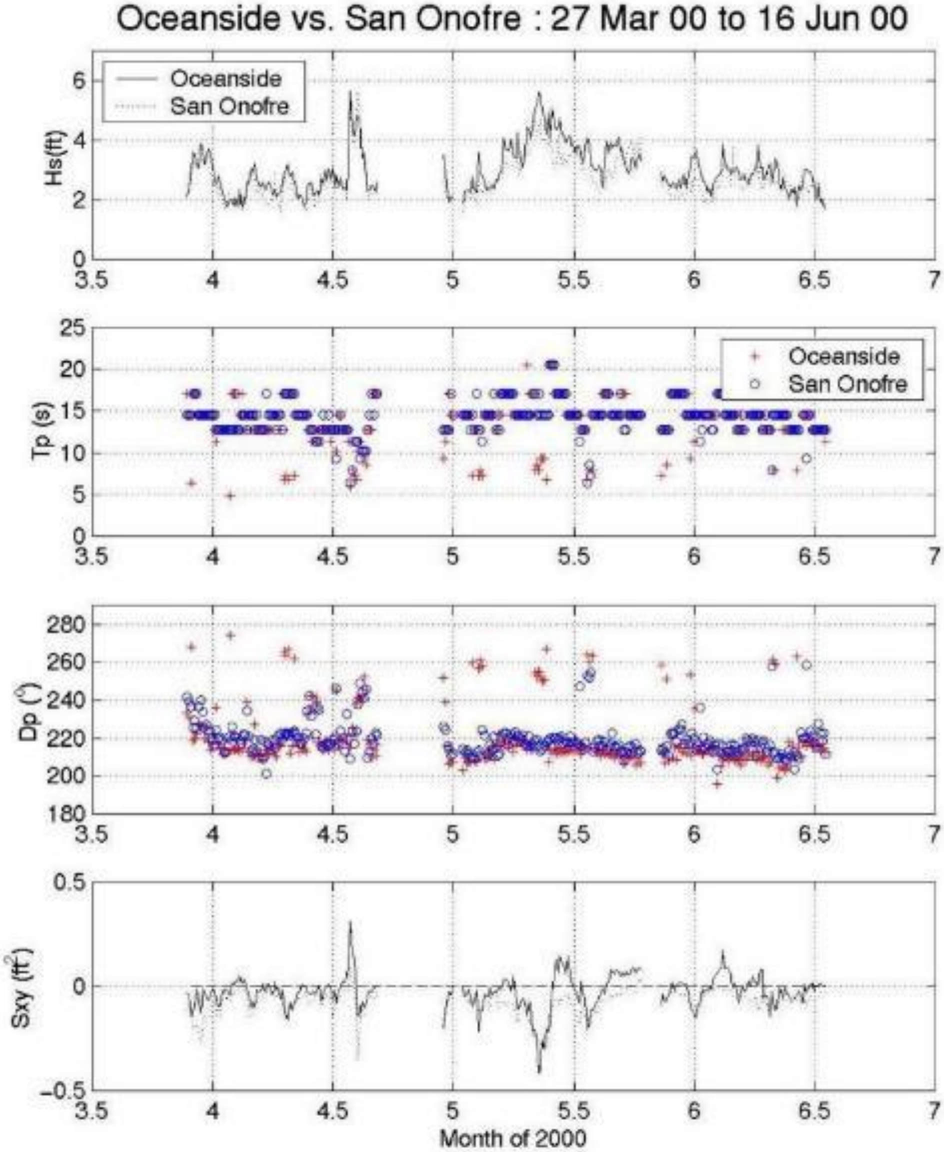

Figure 6-5. Comparison of Wave Parameters Between Oceanside and San Onofre (CEI 2000a).

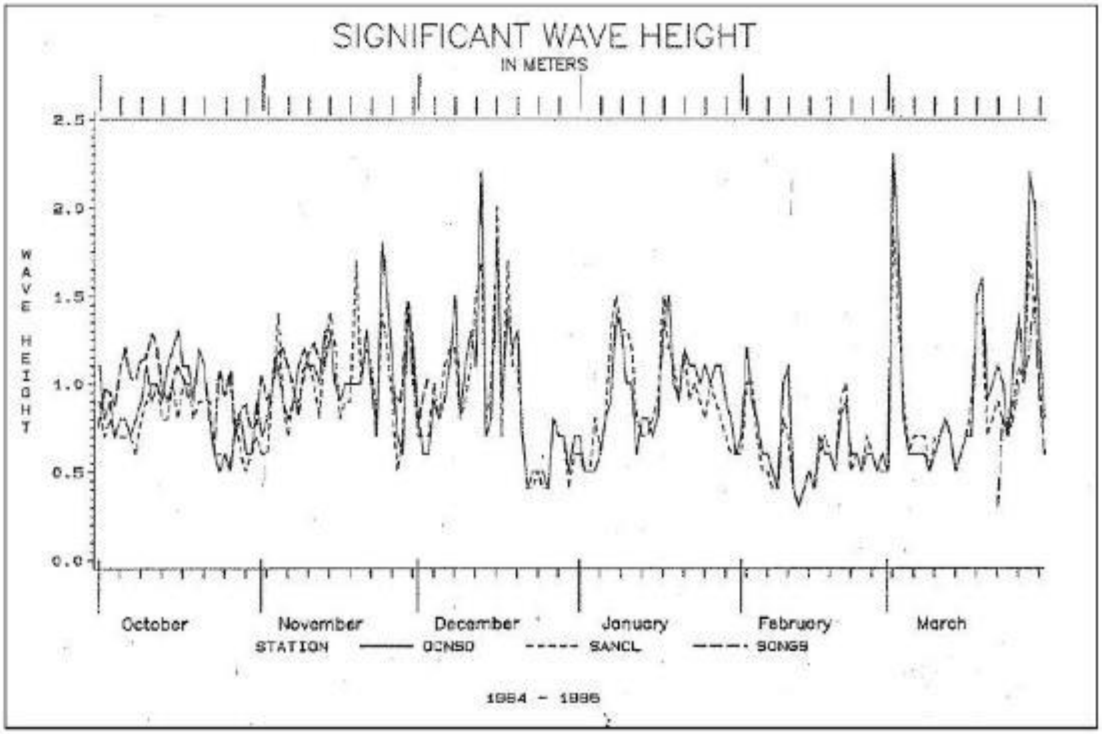

Figure 6-6. Significant Wave Height at Oceanside (OCNSD), San Onofre (SONGS), and San Clemente (SANCL) During Winter 1984-1985 (Elwany 2016).

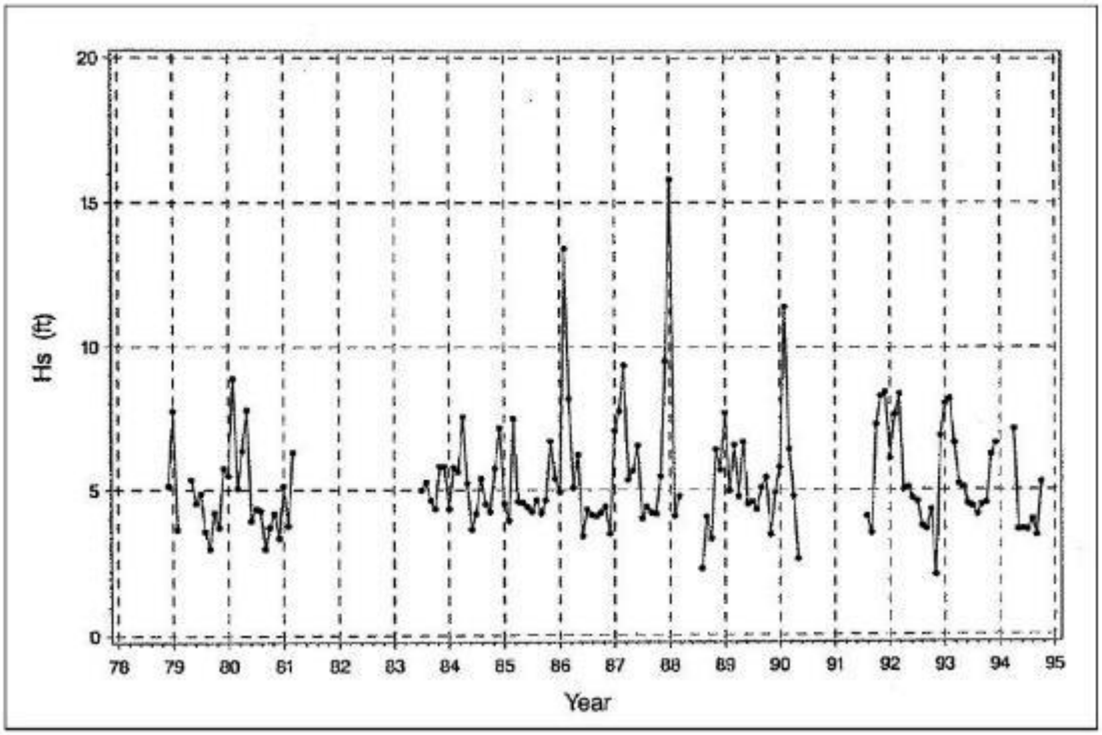

Figure 6-7. Maximum Monthly Significant Wave Height (Hs) at San Onofre. Data are from the Coastal Data Information Program Oceanside Wave Array, 1978-1994 (CEI 2000a).

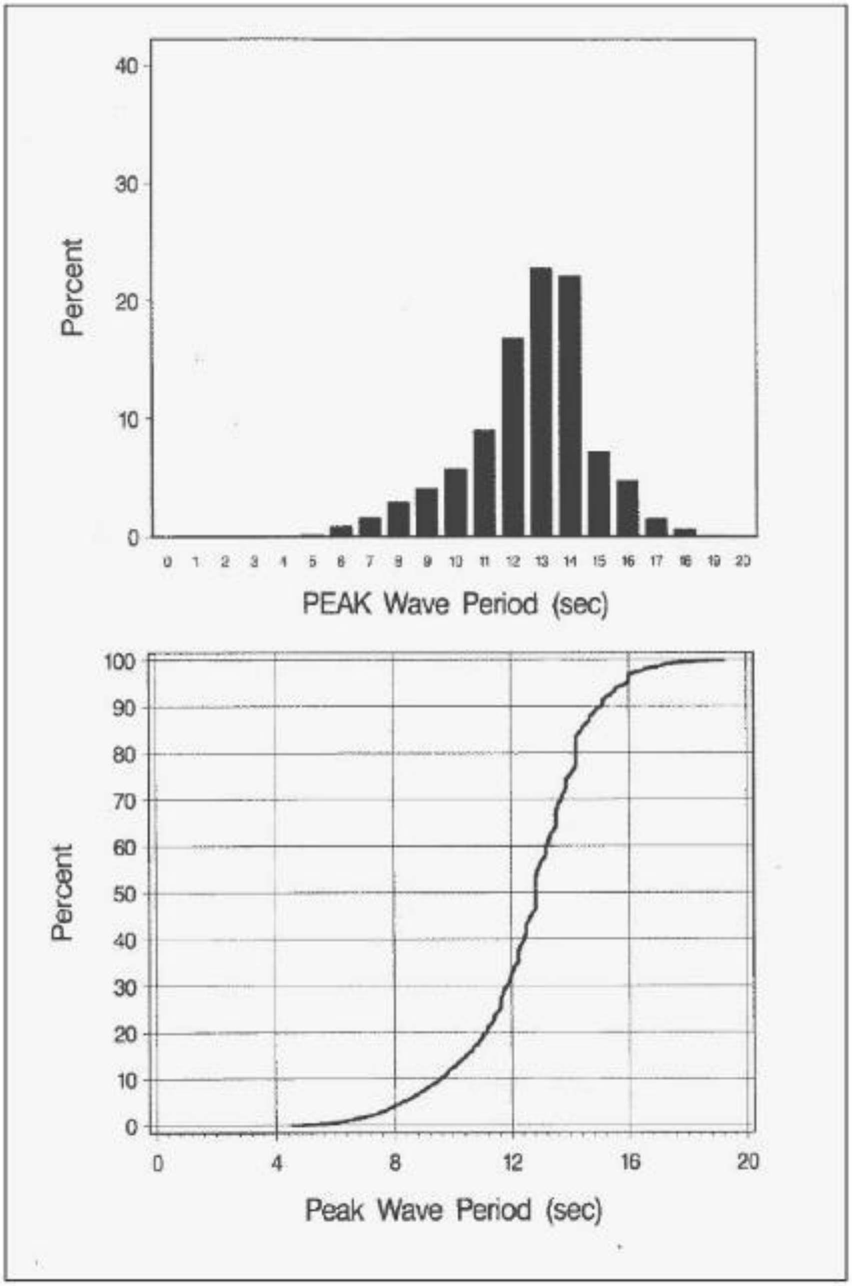

Figure 6-8. Histogram (Upper) and Cumulative Distribution (Lower) of Peak Wave Periods (T) at San Onofre.

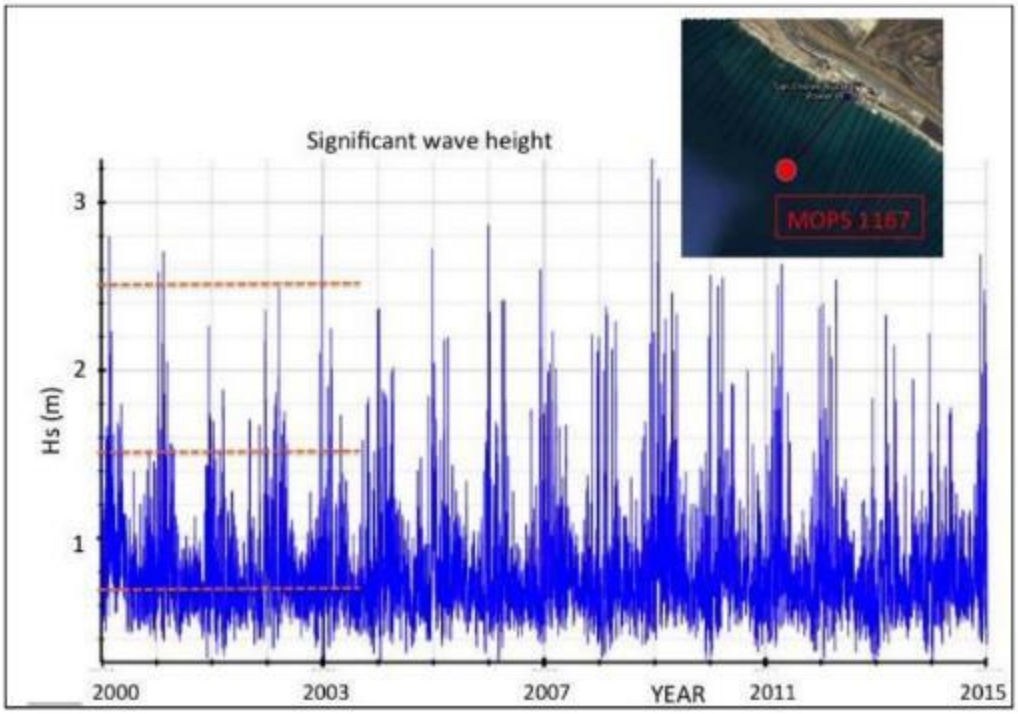

Figure 6-9. Hindcast Significant Wave Height Versus Time in 10 m Water Depth at SONGS (Monitoring and Prediction Points [MOPs] 1167, inset). Hs = 0.5, 1.5, 2.5 m (Dashed Orange Horizontal Lines) Show, Respectively, Low, Moderate, and Extreme Wave Heights used to Estimate Trench Infill Times (O'Reilly et al. 2016).

Surf Zone Currents

The surf zone is defined as the area offshore where waves break between the outermost breaker and the limit of wave uprush onto the beach (Figure 6-10). There is no single continuous wave break line; waves break over a large region as the bottom of the wave comes in contact with the seafloor with increasing intensity (wave setup) toward the beach. The width and characteristics of the surf zone vary constantly, driven by changes in tide elevation, incident wave height and direction, low frequency motion, and local wind speed.

Numerous shallow water studies (e.g., Bowen 1969; Longuet-Higgins 1975; Battjes and Jansen 1978; Thornton and Guza 1983; Battjes and Stive 1985) have estimated that the relation between wave height at the wave-breaking point and water depth can be written as:

$$H = \gamma D \qquad (6\text{-}1)$$

Thornton and Guza (1983) estimated $\gamma = 0.42$, the value used in this study.

At an extreme Hs = 3 m, breaking begins in about 7 m water depth. The bathymetry map on Figure 6-11 shows the 7 m contour line at SONGS in red. With a more typical moderate Hs=1.5 m, the surf zone is located in approximately 3.75 m water depth. At San Onofre, waves are less than 1.5 m high 98 percent of the time, and based on equation 6-1, waves at San Onofre would break in a water depth of about 4 m above mean sea level (MSL), or less, 98% of the time. Large waves (Hs > 1.5 m), which rarely occur in the Project Area, would break at greater water depths.

Obliquely incident breaking waves drive mean alongshore surf zone currents, and are often stronger than offshore tidal and wind-driven currents (Thornton and Guza 1982; Guza et al. 1986; Feddersen et al. 1998).

Longshore current depends on the incoming angle of wave propagation. Estimation of the longshore currents in the surf zone is based on the concept of radiation stress (Longuet-Higgins 1970). When incident waves propagate obliquely to the beach, there is a mean shoreward flux of the longshore momentum gradients, which act as a driving force for the mean longshore current.

Several studies and numerical models were developed and tested in the field by measuring currents in the surf zone and waves offshore. Theoretical models successfully predict longshore currents for planar beaches, but not for beaches with more complicated topography. Several simple estimates for longshore currents are available (Komar 1978, 1979, 1988; Wang and Kraus 1999; USACE 1984 and 1986; Guza et al. 1986). Komar's equation for estimating longshore currents is a function of wave height at the breaking point (H_b) and the incident wave angle measured from the beach normal.

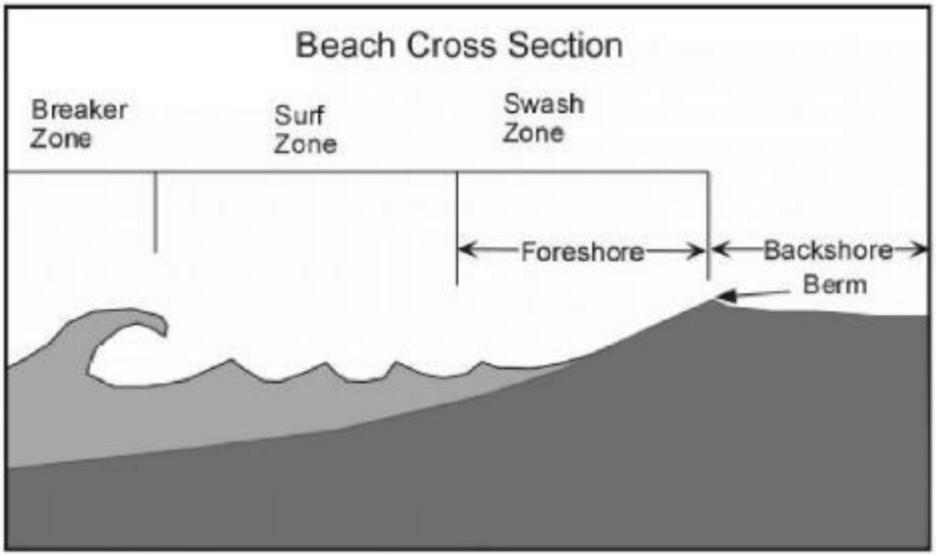

Figure 6-10. Beach Cross-Section Showing the Components of the Surf Zone.

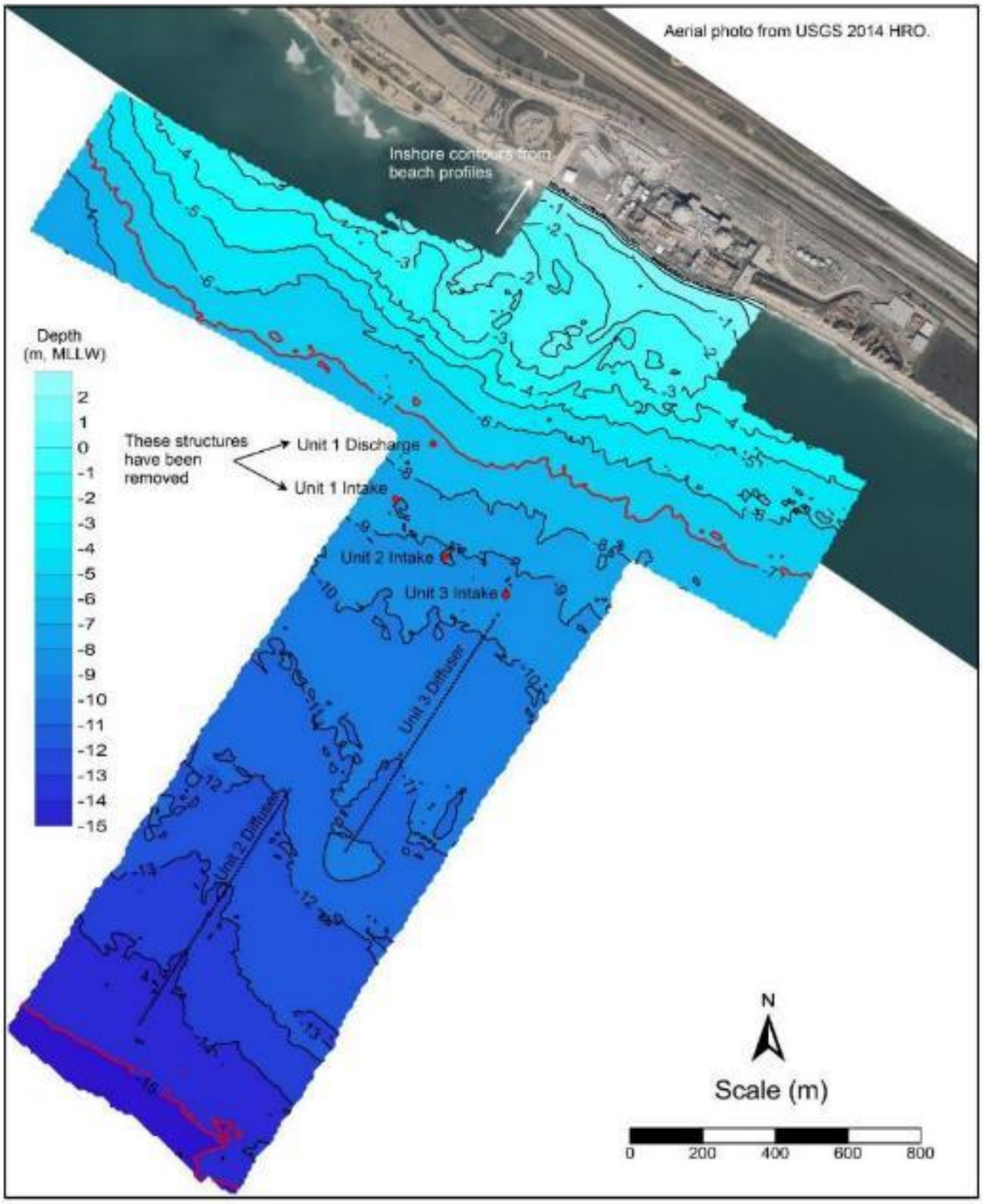

Figure 6-11. Bathymetry Map Showing the Extent of the Surf Zone from the Shoreline Up to 7-m Water Depth and the 15-m Contour Line in Red.

Coastal Currents

Coastal currents along the southern California coast have been the focus of several major studies. The environmental impact study sponsored by SCE and carried out by the Marine Review Committee[3] offshore of SONGS produced a ten-year record that has been the source of much of the information concerning circulation along the southern California nearshore coast in water depths less than < 20 m.

Tide and wind-driven currents in southern California are generally relatively weak (Winant 1983). Elwany et al. (1990) observed tide and wind-driven currents in 10-18 m water depth near the SONGS diffusers for nine years from 1977-1986. During summer, strong stratification seaward of the surf zone is expected, with considerable vertical variation of currents owing to (sometimes breaking) internal waves (e.g., Winant 1974; Winant and Olsen 1976; Omand et al. 2011; Hally-Rosendahl et al. 2015). About 3 m below the surface, the combined wind-driven, internal wave, and tidal alongshore current speed rarely exceeded 35 cm/sec.

Coastal currents off San Onofre were measured from 1977 through 1984 using Vector-Measuring Current Meters (Weller and Davis 1980), which measure velocity in two orthogonal directions (Elwany 1993). The current direction is measured with an internal flux gate compass, which allows the measurements to be converted into the alongshore (V) and cross-shore (U) components. From the data collected, a composite time series was formed to examine the long-term current variability for the inner shelf off San Onofre. The results for both alongshore (positive upcoast) and cross-shore (positive onshore) currents are presented in Table 6-5. The distributions of current velocity for the summer and winter seasons are presented for each year. Summer alongshore and cross-shore currents are spread over a larger velocity distribution than during winter. This is due to the presence of energetic internal waves in the summer. The magnitudes of both the means and standard deviations in summer are larger than those during the winter for all years except the summer of 1979.

Figure 6-12 shows the daily average of the composite time series, which depicts the dominant sub-inertial variability of the currents at San Onofre. Figure 6-12 also shows that downcoast current fluctuations occurred more often than upcoast fluctuations throughout the study. Upcoast current events typically last a few days, while downcoast events are more persistent and last in some cases for nearly a month. The downcoast events tend to be stronger in amplitude and longer in duration during the summer than in the winter. Figure 6-13 presents a probability density function for V and U for all of the data collected from 1977 through 1986 (Elwany 1993). Figure 6-14 is a cumulative distribution diagram for V and U.

[3] The Marine Review Committee was selected by the California Coastal Commission to address the impacts of the operation of SONGS on the marine environment.

Table 6-5. Alongshore and Cross-Shore Current Statistics.

Year	Season	Alongshore Current[a] (cm/s)				Cross-shore Current[a] (cm/s)				N[b]
		Mean	Std	Upcoast Maximum	Downcoast Maximum	Mean	Std	Upcoast Maximum	Downcoast Maximum	
77	Summer	-3.4	9.5	28.6	39.0	0.7	4.1	13.4	15.0	2,525
77-78	Winter	-1.7	8.1	27.9	35.6	-0.4	4.1	12.4	15.8	2,120
78	Summer	-3.0	9.9	42.0	37.6	0.3	3.7	16.1	15.4	3,128
78-79	Winter	-0.4	7.9	37.2	35.6	0.2	2.1	8.7	10.8	4,345
79	Summer	-1.2	7.0	20.0	29.3	-0.6	2.2	7.6	10.3	4,391
79-80	Winter	-3.7	11.6	29.0	61.4	0.2	4.5	17.5	24.4	2,068
80	Summer	-8.2	12.8	30.4	46.4	-3.0	5.7	16.8	24.5	2,006
81	Summer	-7.8	11.4	29.4	41.8	2.0	4.8	24.1	11.4	2,614
81-82	Winter	-2.7	10.9	34.6	41.3	-0.6	4.2	14.2	16.8	2,488
82	Summer	-7.5	13.4	30.2	50.2	-0.7	4.9	17.2	20.0	2,799
82-83	Winter	-1.0	9.0	37.1	25.1	0.6	3.4	17.2	18.6	1,595
83	Summer	-3.8	11.2	36.9	32.7	1.3	6.2	24.0	22.2	2,136
83-84	Winter	-1.9	10.4	41.0	46.0	-3.3	5.0	18.0	45.9	4,293
84	Summer	-4.2	11.3	36.5	45.5	-3.4	6.7	24.9	28.9	4,223
84-85	Winter	-3.2	7.8	20.2	40.8	-0.9	6.5	21.7	45.9	4,092
85	Summer	-2.6	9.3	27.9	32.2	1.0	4.5	24.8	14.9	4,333
85-86	Winter	-0.5	8.0	31.5	27.6	0.6	3.8	15.6	14.4	4,345
86	Summer	-4.6	11.3	37.5	35.0	1.9	5.6	24.8	17.4	4,392
86-87	Winter	-1.9	6.9	20.3	26.9	1.1	3.3	15.3	14.2	2,185
ALL[c]	**Summer**	**-4.3**	**10.8**	**42.0**	**50.2**	**-0.1**	**5.3**	**24.9**	**28.9**	**32,547**
ALL[c]	**Winter**	**-1.7**	**9.1**	**41.0**	**61.4**	**-0.4**	**4.5**	**21.7**	**45.9**	**28,515**
ALL[c]	**Data**	**-3.1**	**10.1**	**42.0**	**61.4**	**-0.2**	**5.0**	**24.9**	**45.9**	**61,062**

[a] Computed from the composite time series.
[b] Number of hourly values used in computation.
[c] All available data.

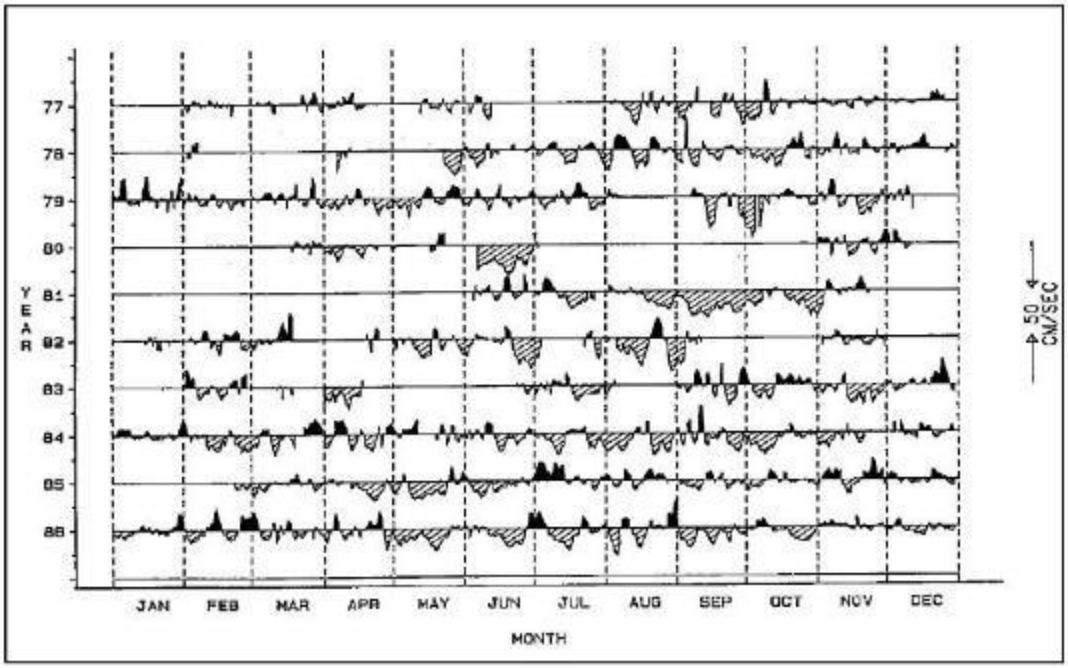

Figure 6-12. Daily Averages of the Alongshore Current (V) off San Onofre from 1977 through 1986. Portions Shaded in Black are Upcoast Currents (towards Los Angeles) and Hatched Portions are Downcoast Currents (Elwany et al. 1990).

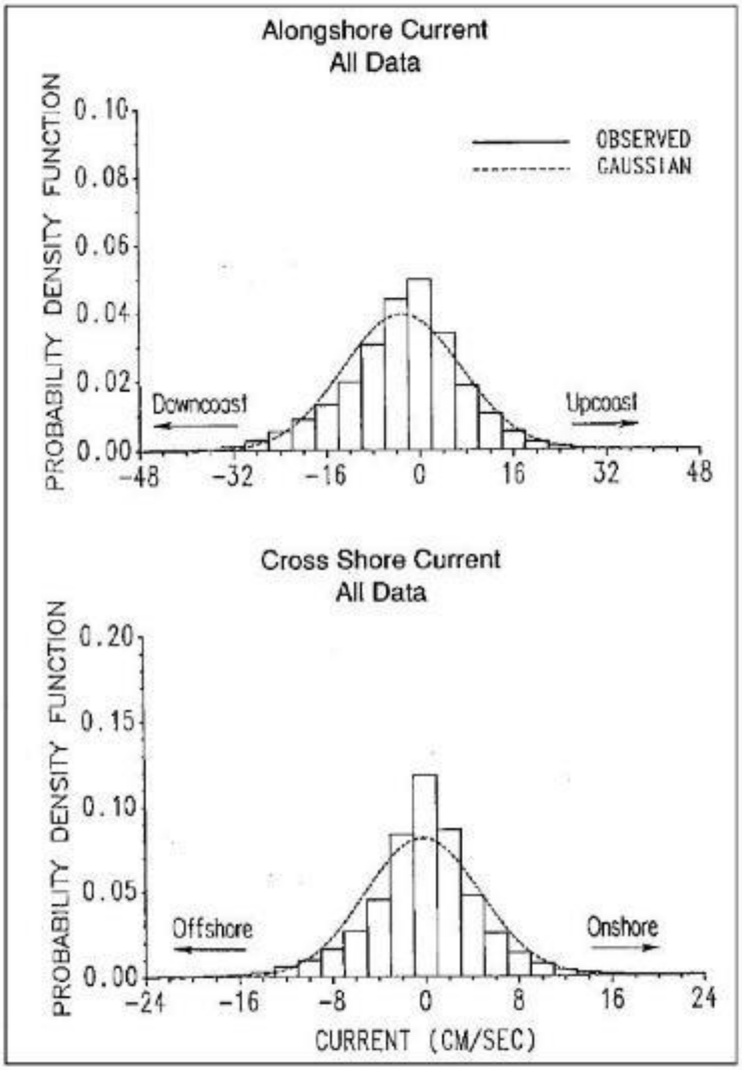

Figure 6-13. Probability Density Function of Alongshore Current (V) and Cross-Shore Current (U) Measured at 3 m below the Surface for All Data Collected from 1977-1986 (Elwany, 1993).

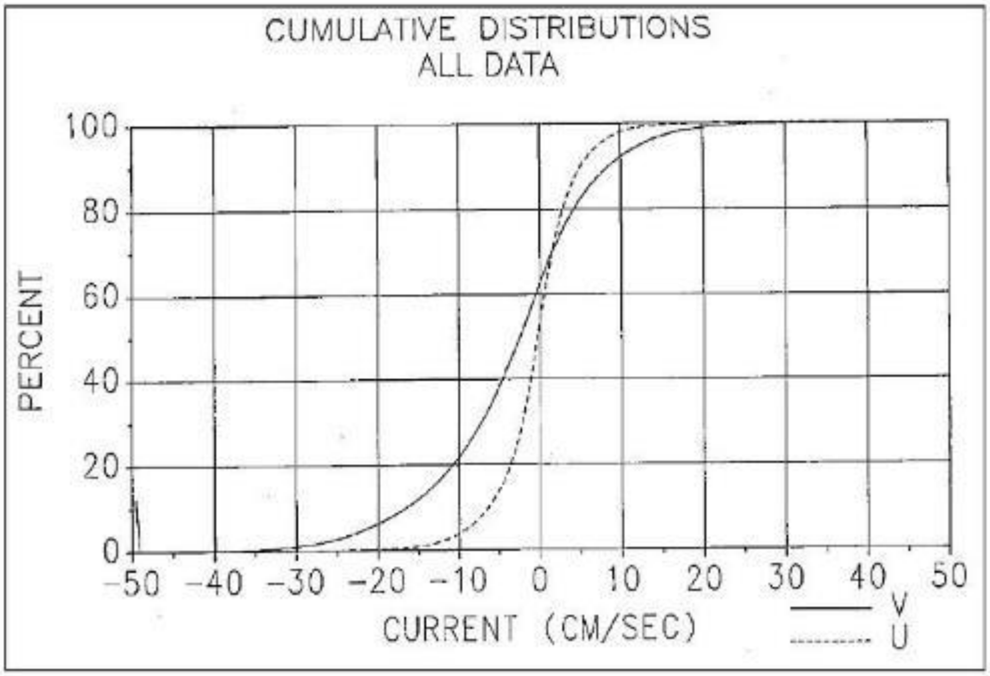

Figure 6-14. Cumulative Distribution Functions of Alongshore (V) and Cross-Shore (U) Currents Measured 3 m Below the Surface for all Data Collected from 1977 through 1986. V Positive Upcoast and U Positive Onshore. From Elwany 1993.

6.2.5 Trench Infilling

Modeling and Observations

Numerical models that calculate the time for infilling of sand pits and trenches in the marine environment can range from numerically intensive to simplistic modeling procedures. These models have most frequently been used to study sand pits and trenches in the nearshore zone: beaches, harbor channels, estuaries, and tidal inlets (Basco and Lonza 1997; Bender 2001). Infilling of offshore trenches, such as those that would be left by the removal of the SONGS conduits without backfilling, are less studied. However, Gonzales et al. (2010) simplified existing models for predicting the morphological behaviors of trenches with a semi-analytical numerical model (MEMPITS) (Ribberink 2004; Ribberink et al. 2005). The MEMPITS model is described below and in Appendix E.

Infilling rates depend on spatial gradients of sediment flux, that is, the difference between the rates of sediment flow into and out of the trench or pit (Patsch and Griggs 2007). Sediment can move as suspended load or bedload, driven by both waves and currents (Figure 6-15). Sediment deposited in the trench may be affected by wave action stirring the sediment, and consequently sediment may be carried out of the trench by the current or be re-deposited in the trench (Figure 6-15). Some models account for the collapse of steep-sided trenches, whereas others lack such detail. Sediment is usually characterized by a single grain size. Complicated fluid and sediment processes are included in model packages such as Delft2D/3D, Telemac, MIKE, SUTRENCH, and LOMOR. Klein (2004) compared various numerical models with a range of observations and noted variable levels of robustness and capability. All models contain empirical factors that must be adjusted to fit the observations (i.e., calibration) when observations are available.

The morphodynamic effects on ocean beaches of sand extraction pits seaward of the surf zone in the US, UK, Canada, and the Netherlands were summarized by van Rijn et al. (2005). Pits in water depths of 5-25 m are generally filled from the landside by the offshore movement of sediment rather than by alongshore transport. The time it takes to fill the pit increases exponentially with water depth, and ranges from 5-10 years in 5-15 m depth, to 100 years or more in 15-25 m depth. A key conclusion from the pit-filling model simulations is that wave forces greatly accelerate morphodynamic evolution, and large, sudden step changes in pit morphology are associated with storms (Hume et al. 2015). Consequently, in many environments, sand mining is restricted to depths greater than 20 m in order to minimize both the rapid trapping of nearby sand in the pit and the effects on shoreline waves.

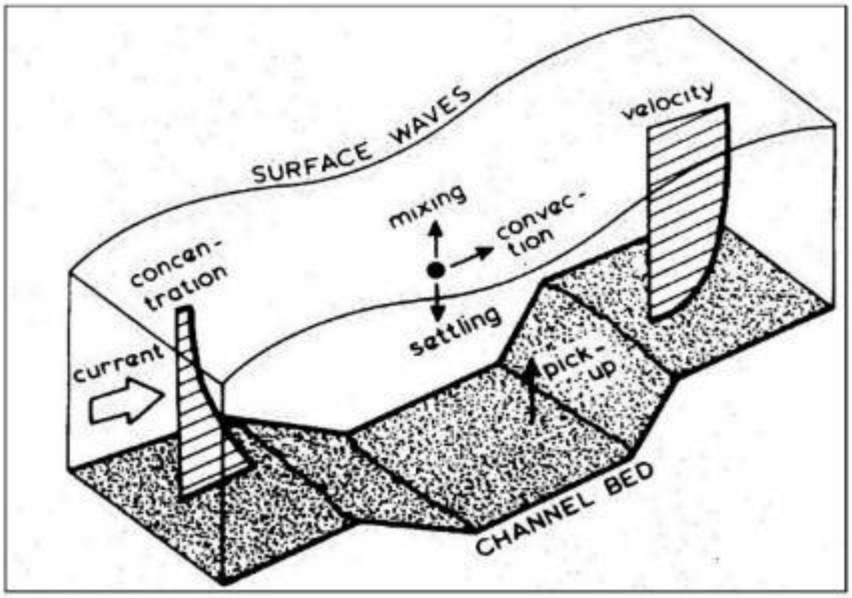

Figure 6-15. Schematic of Sediment Transport Processes in a Trapezoidal Channel (Klein 2004). Sediment is Stirred by Waves and Currents, and Advected by the Cross Channel Current. The Trench Infill Rate Depends on the Difference of Fluxes Into and Away from the Trench.

MEMPITS Model

Advanced numerical infill time models are time-consuming to implement. More important, their expected performance at SONGS is fundamentally limited by the complexity of the seafloor, which is composed of interlaid and shifting sand, shell hash, small rocks, cobbles, and hard bottom. Furthermore, the time series of waves and near-bottom currents needed to drive advanced sediment transport models are lacking at SONGS.

However, the simplified model MEMPITS (Ribberink 2004; Ribberink et al. 2005) may be utilized to estimate potential trench infill rates at SONGS. MEMPITS was developed under the European Union project SANDPIT, and is intended for use as a simple engineering tool for the design of trenches and pits. MEMPITS mimics the results of complicated numerical models developed in the Netherlands for the analysis of the morphological consequences of offshore sand extraction in the North Sea (Van Alphen et al. 1990). MEMPITS has been calibrated with the numerical model LOMOR and was used by Gonzalez et al. (2010) in the Balearic Islands.

The MEMPITS model estimates the e-folding time T_{bed} (i.e., time to 2/3 trench infilling or amplitude decay time). T_{bed} depends on waves, currents, sediment fall velocity, and tunable model parameters (Appendix E), and is presented below as a function of trench depth:

$$dp(t) = d_{p0} e^{-t/T_{bed}}$$

where $d_p(t)$ is the time-varying trench depth, and d_{p0} is the initial trench depth d_{bo} (Figure 6-16).

The trench volume V(t) is proportional to $d_p(t)$. The filling is exponential, with e-folding time T_{bed}. When $T = T_{bed}$, $d_p(t) = 0.34\, d_{po}$, and the trench is 2/3 full. The relationship between fraction infill (V_n/V_{po}) and time, for various T_{bed}, is shown in Figure 6-17. The relation between T_{bed} (years) and other trench infill times are: $T_{bed50\%} = 0.69\ T_{bed}$, $T_{bed90\%} = 2.3\ T_{bed}$, and $T_{bed99\%} = 4.6\ T_{bed}$. $T_{bed50\%}$ (year) gives the times to fill 50% of the trench volume.

Waves in shallow water drive strong currents over the entire water column, and sediment transport rates at the seafloor are high. In contrast, in deep water, the seafloor is too far from the surface to be reached by wave orbitals. The definitions of deep and shallow depend on wave period. For short wind waves with a 3 second period, 15 m is deep with almost complete attenuation at the seafloor. In contrast, for long ocean swell with an 18 second period, 15 m is relatively shallow, and velocities at the seafloor are less than 10 percent attenuated from the surface. This vertical attenuation of wave orbital velocities is included in MEMPITS. The model is not valid in the surf zone because wave shoaling, refraction, and breaking are not parameterized.

The equations used to compute T_{bed} are presented in Appendix E.

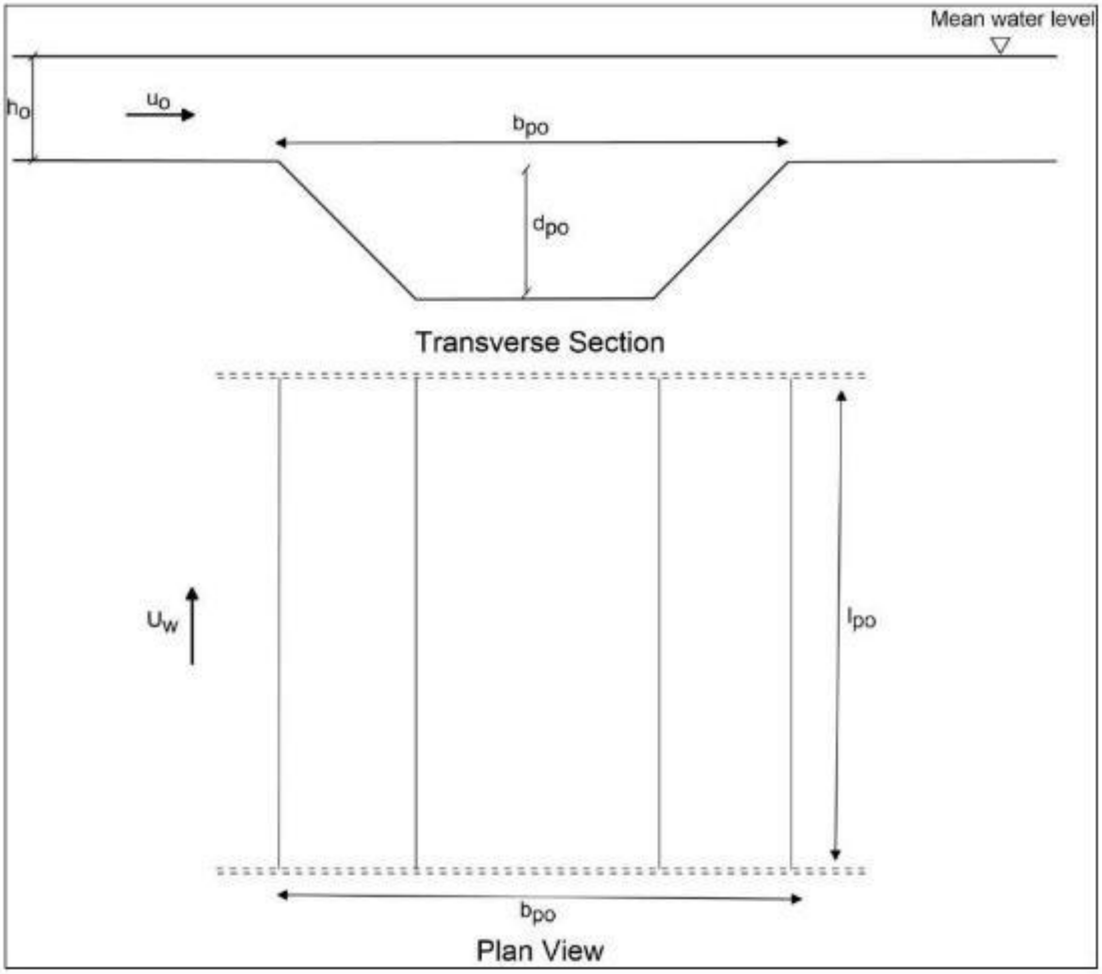

Figure 6-16. Diagram of Trench Transverse Section (Upper) and Plan View (Lower). Variables: ho = Mean Water Depth in Borrow Area; uo = Local Depth-Averaged Velocity; bpo = Mean Width of the Pit; dpo = Mean Dredged Pit Depth; lpo = Mean Length of the Pit in y.

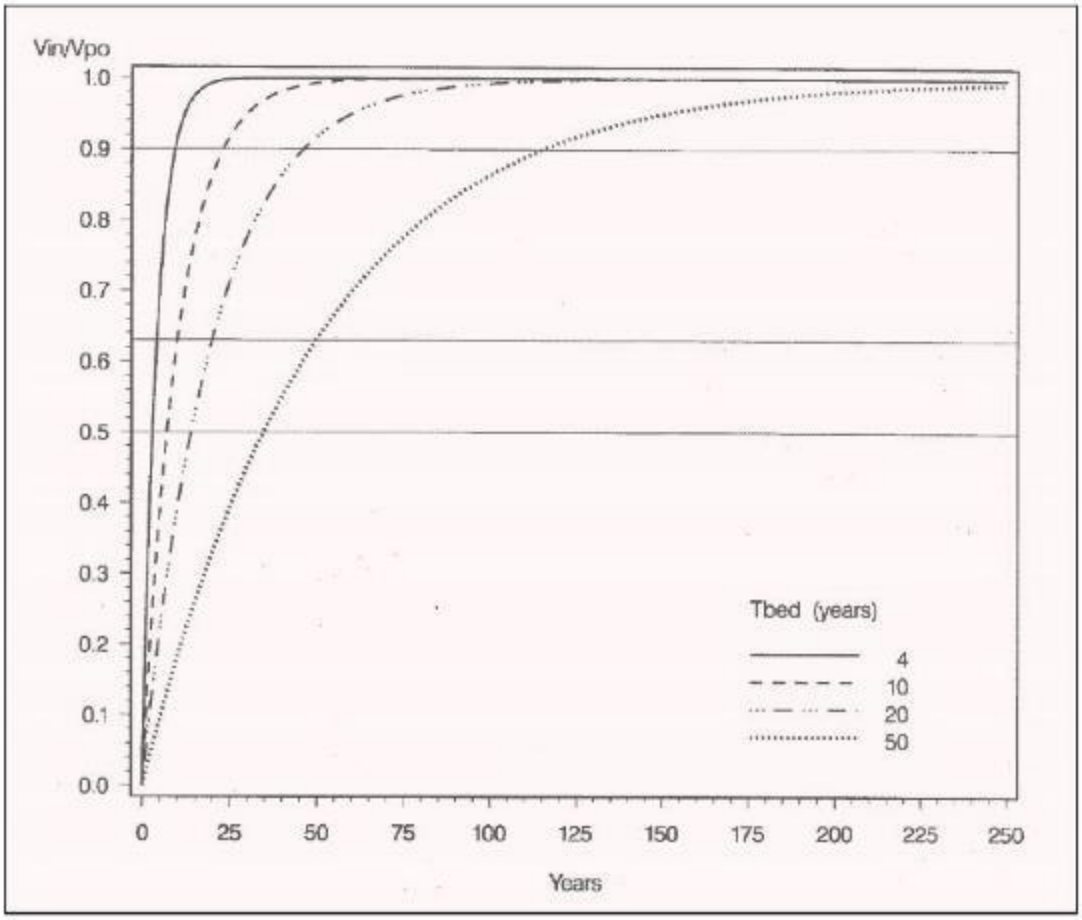

Figure 6-17. The Fraction of the Original Volume Filled (Vin/Vpo) Versus Time for Different Values of Tbed. Solid Horizontal Lines Correspond to 0.9, 0.63, and 0.5. When T=Tbed, the e-folding Time, Vin/Vpo = 0.63.

Observation of Slow Infilling

Infill times can increase dramatically where wave bottom orbital velocities are small. If tidal and wind-driven currents are also weak, T_{bed} is long. For example, T_{bed} = 150 years was predicted by MEMPITS for a dredged trench in 20 m water depth off Refeubix, a town in the Spanish Balearic Islands (Gonzalez et al. 2010). The trench was about 5 m deep, 600 m long, and 160 m wide with a volume of about 500,000 m^3. Median sand grain size was 0.2 mm. Tidal flows are weak in the area, and the usually short-period waves are attenuated at the seafloor. Currents are wind-driven and shift with depth, with annual mean flow about 7 cm/second perpendicular to the trench axis. Maximum monthly currents are as small as 20 cm/second, but can reach 80 cm/second. Near-bottom flows are often below the threshold of no-motion, and transport is episodic. The estimated T_{bed} = 150 years is consistent with the small 9 percent infill observed over 9 years. Note that the 160 m width is much larger than the width of the trenches at SONGS, a difference taken into account by MEMPITS.

The infilling of borrow pits in 13-20 m water depth off Del Mar and Cardiff, about 50 km south of SONGS (Figure 6-18), exemplifies slow pit filling at a water depth of 13 m or deeper. Waves at Del Mar are larger than waves at San Onofre and currents are similar to SONGS. Coastal currents are coherent along the southern California coast (Winant 1983; Elwany 1999). The Del Mar pit showed no infilling in 4 years, and only small infilling was detectable at Cardiff (Figures 6-19 and 6-20). The observations at Del Mar and Cardiff are too short to estimate T_{bed}, but are not inconsistent with $T_{bed} \sim 50$ years.

Observation of Rapid Infilling

Rapid infilling occurs when waves and currents are relatively energetic, as illustrated by a sewer pipeline trench near Scheveningen on the Dutch North Sea coast (Figure 6-21). A volume of about 30,000 m^3 was dredged to form a trench approximately 4 m deep below the water depth of 7-13 m. Sand grain sizes ranged from 0.2-0.3 mm. Trench side slopes were a moderate 10 percent. The trench axis was perpendicular to the shoreline, tidal currents, and wave crests. Peak tidal currents are about 0.6 m/second, and wave heights exceed 1.5 m about 10 percent of the time, creating relatively high sediment fluxes during not-infrequent storms. The calibrated LOMOR model accurately predicted the rapid infilling of the trench. MEMPITS is designed to mimic LOMOR and yields similar agreement with the Scheveningen trench using $T_{bed} = 0.5$yr. SUTRENCH 2000 yielded comparable agreement with the Scheveningen observations, and showed that a constant, representative wave height yields results similar to a time-varying height, as illustrated in Figure 6-22. Waves heights at Scheveningen and SONGS are similar, but tidal currents are much stronger at Scheveningen than at SONGS (60cm/s vs. 10cm/s).

Moulton et al. (2017) investigated the dynamics of flows near single channels excavated across a sandy surf zone in North Carolina. The channel widths were similar to those at SONGS (30 m wide) and the channel floor was 1.5-2.5 m below the water depth. Wave and tidal currents were moderate, similar to SONGS. Wave-breaking was reduced over the trench, and alongshore setup gradients drove feeder currents that converged in strong (up to 1 m/second) rip-current jets (Figure 6-23). A trench with the SONGS dimensions would modify the surf zone flows and sediment transport and create strong rip currents. Circulation details would be sensitive to wave and tide conditions, as well as to the evolving channel geometry (Moulton et al. 2014). Also, rip currents are often created in lab studies by cutting a channel in an alongshore parallel sand bar (Haller et al. 2002; Haas et al. 2003).

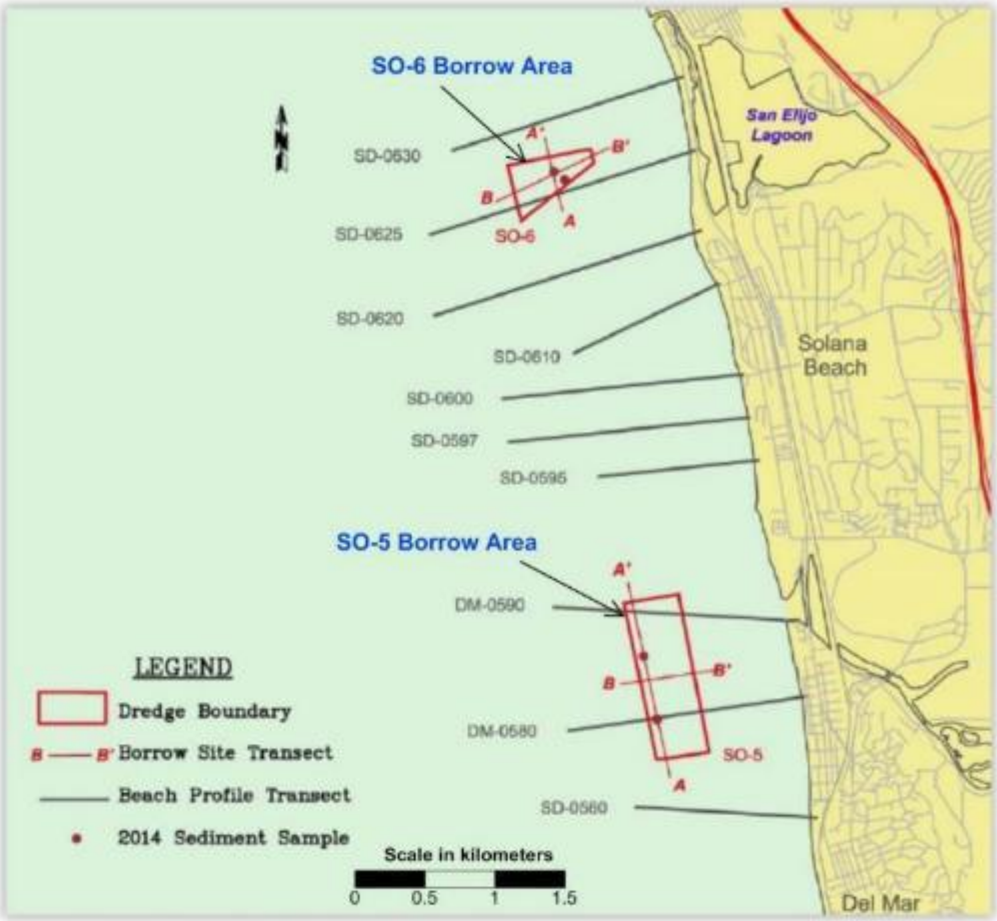

Figure 6-18. Map Showing Del Mar (SO-5) and Cardiff (SO-6) Borrow Pits, Located 50 km South of SONGS, Outlined in Red. From Coastal Frontiers (2017).

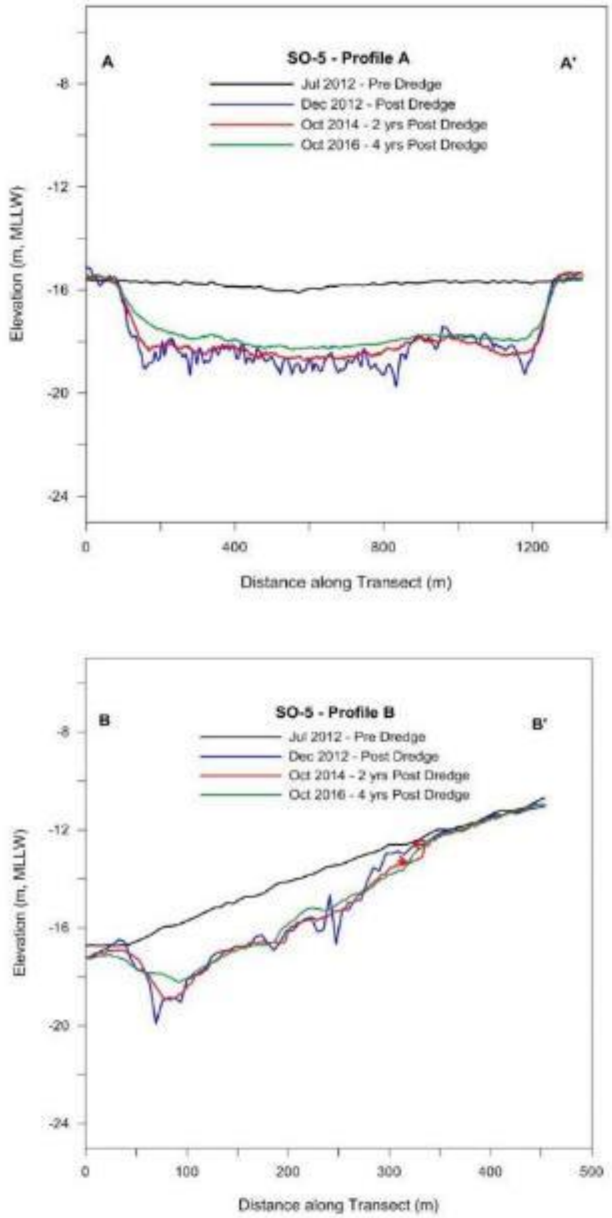

Figure 6-19. Del Mar Borrow Pit (SO-5) Elevation Changes A-A' (Upper), B-B' (Lower) from 2012-2016. Data from Coastal Frontiers (2017).

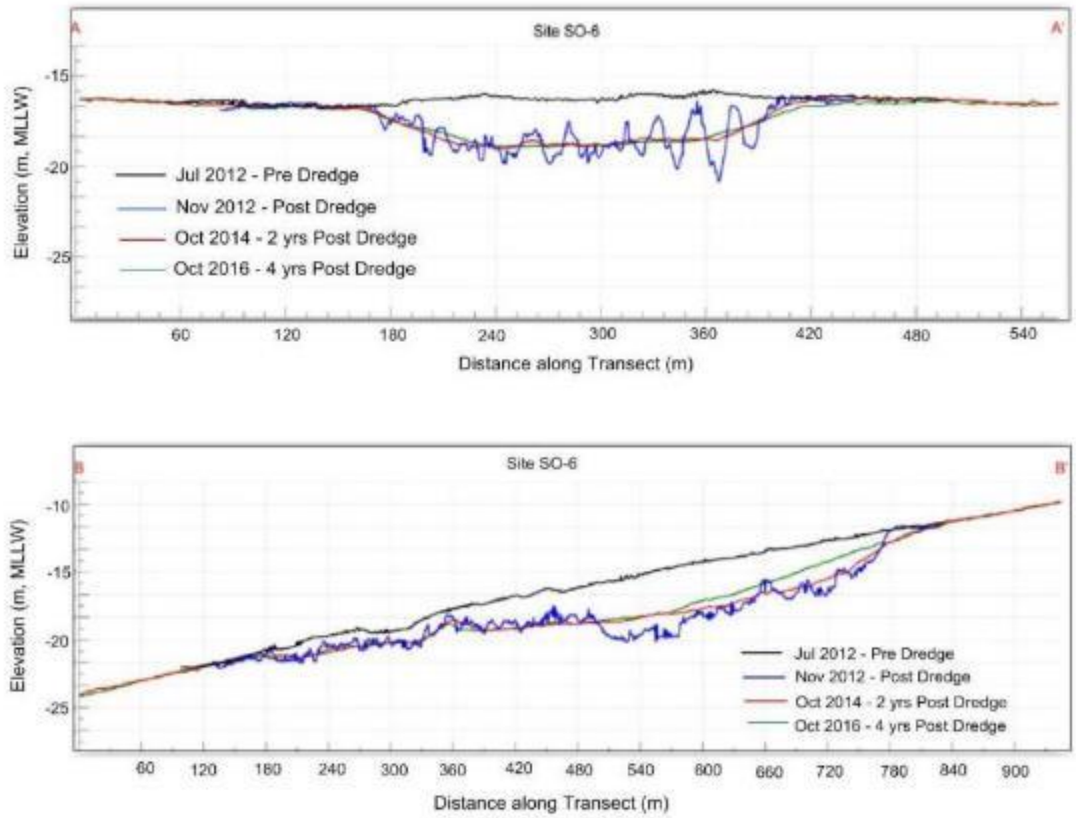

Figure 6-20. Solana Beach Borrow Pit (SO-6) Elevation Changes at Transects A-A' (Upper) and B-B' (Lower) from 2012-2016. Cross-Shore Transect is B-B' (lower). Data from Coastal Frontiers Corporation (2017).

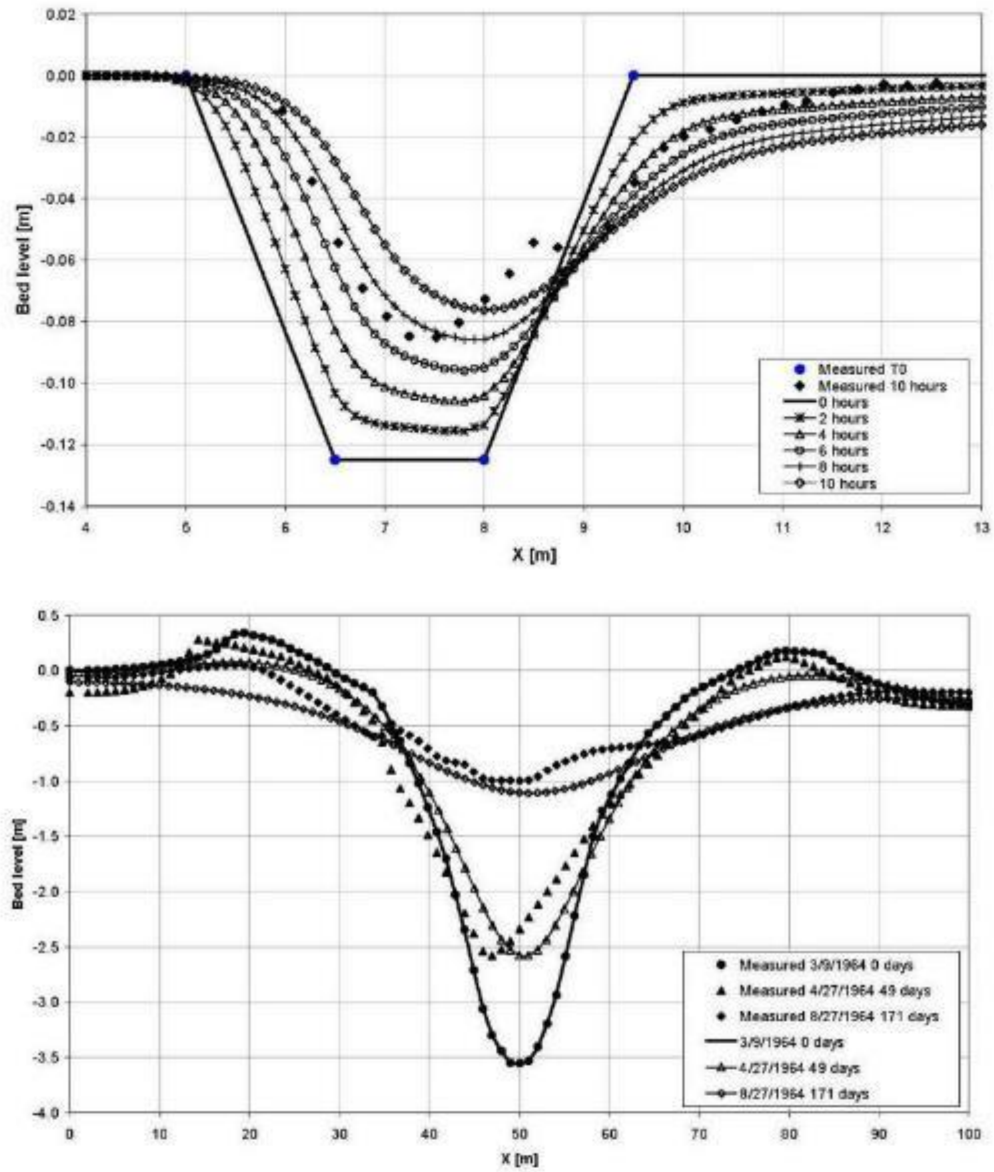

Figure 6-21. Schematic Configuration of a Rapidly Infilled Trench Seaward of the Surf Zone on the Dutch North Sea coast. The 700-m-long Trench was About 4 m Deep in 7 to 13 m Water Depth (A). Observed and LOMOR Model Trench Cross-Section for Laboratory Case (B) and Actual Trench (C) (Ribberink et al. 2005).

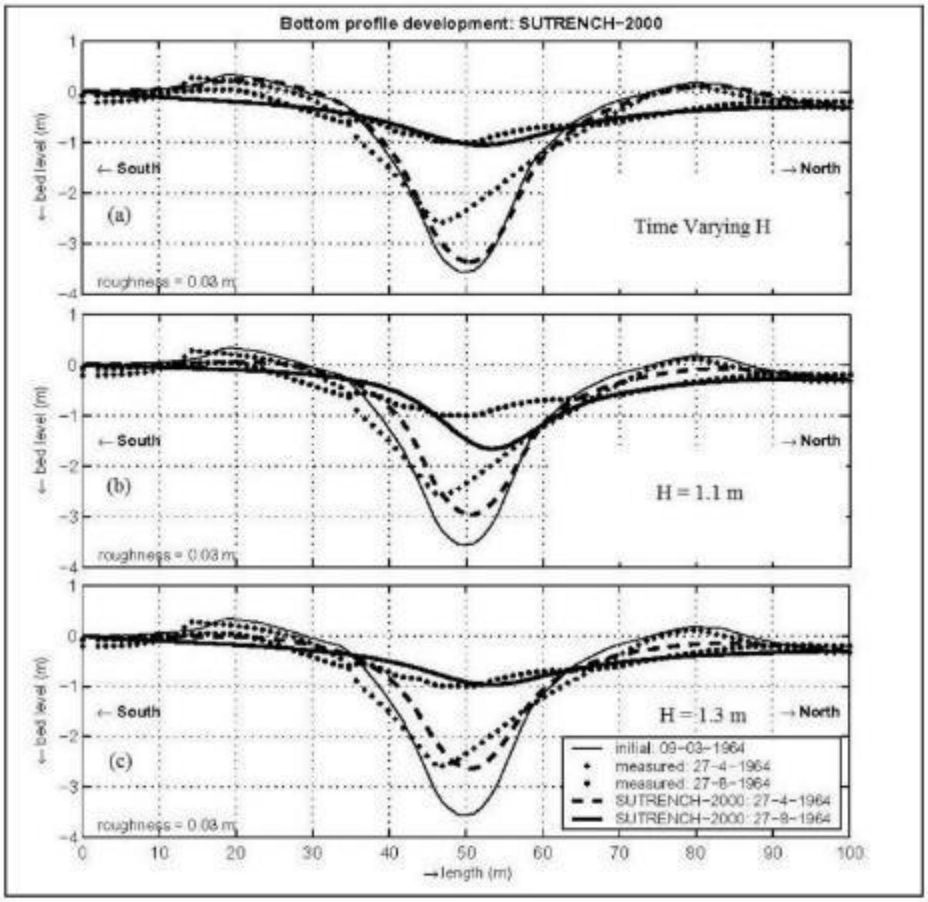

Figure 6-22. Observed and SUTRENCH 2000 Modeled Trench Depth Versus Alongshore Location. Results are Similar with (a) Time-Varying Wave Height H, (b) Constant H = 1.1 m (with Adjusted Friction), and (c) Constant H = 1.3 m (Klein 2004).

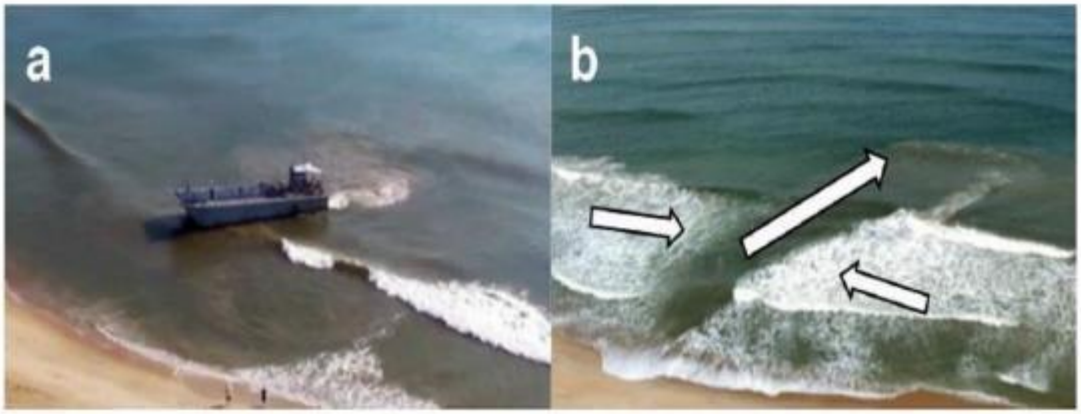

Figure 6-23. Photographs of (a) Landing Craft Excavating Channel About 2 m deep, 30 m Wide (Alongshore), and 75 m Long (Cross-Shore) Across the Surf Zone, and (b) Breaking (White Areas on Channel Sides) and Non-breaking (Dark Areas) Waves Near the Channel. The Arrows Indicate Flow direction. Sediment (Brown) and Foam (White) Carried Offshore of the Surf Zone by the Rip Currents are Visible, Especially to the Right and Offshore of the Large Rip Current Jet (Arrow Pointing Offshore). From Moulton et al. (2014).

6.2.6 Estimated SONGS Trench Infilling Rates

SONGS Trench Infilling

The MEMPITS model constant parameter values used at SONGS include ε_0 = porosity (0.4), φ = angle of repose (32°), α_s= 0.5,α_b = 0.5, $\hat{L}$ = velocity and concentration profile coefficients (0.5), $\varepsilon_b = 0.1$, ε_s = Bailard coefficients [Bailard 1981](0.02), w_s = settling velocity (0.07 m/sec), g = gravity (9.8 m/sec^2), Δ = relative density (1.65), and C_f = friction coefficient (0.001). Infill times were computed for many combinations of water depth, constant wave height and period, mean current, and fall velocities, as well as the bivariate distribution of waves and currents. The results reported below are for a 0.29 mm grain size. The varying spatial distribution of substrate types (hard-bottom, cobbles, shell hash, and sand) within the SONGS project area (Figures 6-24 to 6-25) could lead to greater infill times.

The intake conduits of Units 2 & 3 have a constant inner diameter of 18 feet. The discharge conduits have four cross-sections (A, B, C, and D) with their inner diameters varying from 18 feet (cross-section A) to 10 feet (cross-section D). The widths of the four trench cross-sections increases as the diameter of the conduit increases in order to maintain the stability of the trench slope during removal of the conduits. Appendices B and C give the cross-sections of the SONGS trenches for slopes 1:1 H:V and 1:1.5 H:V, respectively.

In this section, we are presenting the infilling time T_{bed} (infilling time for 63 percent of the trench volume) for two alternatives. In Alternative 1, the slope of the trench sides is 1:1 H:V, and in Alternative 2, the slope of the trench sides is 1:1.5 H:V.

The program input requires information about trench width as well as information about waves (height and period) and currents. A bivariate distribution for wave height, current speed, and percent of time (probability x 100) for occurrence (Table 6-6) was used to input the wave and current conditions to the MEMPITS model. The bivariate distribution of significant wave height Hs versus current speed, u, is shown graphically in Figures 6-24 and 6-25.

MEMPITS requires as input data the values of wave period (T) in association with wave height (Hs) and current speed (u). The corresponding wave period (T) was estimated from the bivariate distribution between Hs vs. T (Table 6-7) based on the available wave data from 1978 to 1994 (Section 6.2.4). Selected values for T in seconds were T = 12 sec for H = < 0.5, T = 14 sec for 0.5 < H < 1 and T = 10 sec for 1.0 < Hs < 1.5 and T = 14 sec for H > 1.5. This approach is referenced here as the bivariate distribution between waves (Hs, T) and currents. The bivariate distribution is used in this study, and provides a better estimate of the trench infilling time than other deterministic approaches.

The ratio between trench depth and water depth is larger than 0.3 and greater than 1 between 0 and 7 m water depth. Therefore, they are considered in this study as deep trenches. The computation of infilling time T_{bed} is based on non-linear analytical approximation for deep trenches (Ribberink 2004).

Table 6-6. Bivariate Distribution Between Significant Wave Height Hs and Current Speed V (m/sec). Numbers in Table Show the Percentage of Time Each Combination of Current Speed and Hs Occurs.

Current (m/second)	Significant Wave Height (Hs) (m)						
	0.25	0.75	1.25	2.75	2.23	3.35	Percentage
0.05	19.17	39.35	2.37	0.24	0.0	0.0	61.13
0.15	7.95	19.51	1.21	0.11	0.0	0.02	28.80
0.25	1.83	6.12	0.54	0.13	0.02	0.0	8.64
0.35	0.30	0.73	0.19	0.06	0.0	0.0	1.27
0.45	0.2	0.11	0.0	0.02	0.0	0.0	0.15
Percentage	29.27	65.82	4.31	0.56	0.02	0.02	100%

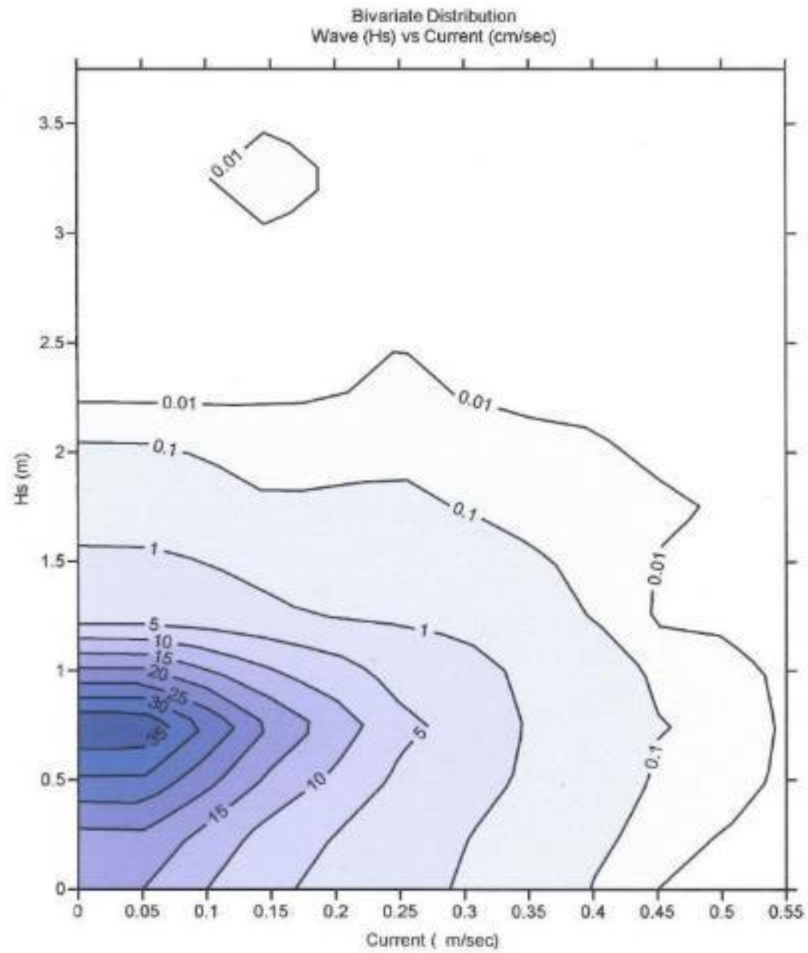

Figure 6-24. Bivariate Distribution of Significant Wave Height (Hs) and Current Speed.

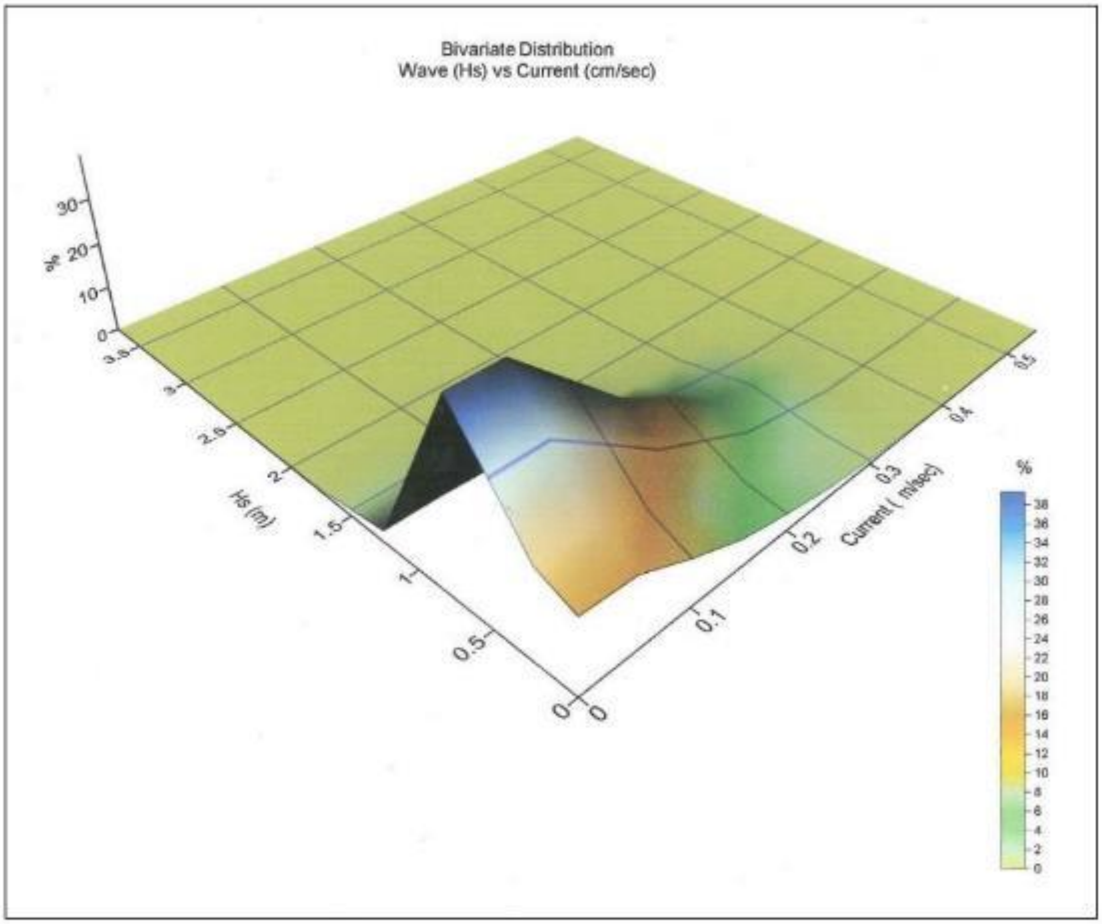

Figure 6-25. Three-Dimensional Plot for Bivariate Between Significant Wave Height Hs and Current Speed.

Table 6-7. Bivariate Distribution Between Significant Wave Height (Hs) and Peak Wave period (T). Numbers in Table Show the Percentage of Time Each Combination of Hs and T Occurs. Percentages were Computed from Wave Data Measurements from 1978 to 1994.

Hs (m)	Wave Period (seconds)										
	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20+	Total
0 < 0.5	0.04	0.41	0.63	1.4	7.5	11.51	6.54	2.14	0.5	0.01	30.68
0.5 < 1.0	0.04	1.27	3.79	4.18	9.4	18.46	17.72	6.92	1.34	0.03	63.15
1.0 < 1.5	0	0.29	1.31	1.12	0.75	0.78	0.59	0.47	0.06	0	5.37
1.5 < 2.0	0	0.02	0.21	0.21	0.08	0.1	0.07	0.02	0	0	0.71
2.0 < 2.5	0	0	0.01	0.01	0	0.02	0.01	0	0	0	0.05
2.5 < 3.0	0	0	0	0	0	0	0	0	0	0	0.01
3.0 < 3.5	0	0	0	0	0	0.01	0	0	0	0	0.01
3.5+	0	0	0	0	0	0	0	0	0	0	0
Total	**0.08**	**1.99**	**5.95**	**6.94**	**17.73**	**30.88**	**24.93**	**9.56**	**1.9**	**0.04**	**100**

The non-linear analytical solution computes the migration velocity C_{bed} and infill time T_{bed} for two basic conditions, namely at the undisturbed sea bed level (= basic state of the original linear analytical model) and at the bottom of the trench. By taking the average value of the two states of migration velocity and the growth rate (=1/T_{bed}).

$$\bar{C}_{bed} = \left(C_{bed_0} + C_{bed_1}\right)/2$$

$$\bar{T}_{bed} = \left\{\left(T_{bed_0}^{-1} + T_{bed_1}^{-1}\right)/2\right\}^{-1}$$

with indices "0" and "1" referring to, respectively, "undisturbed sea bed conditions" and "conditions at the trench bottom."

Tables 6-8 and 6-9 give the T_{bed}, trench width and depth, and water depth values for cross-sections A, B, C, and D. We selected the end-point of each cross-section to be an approximation of the water depth. Calculations of $T_{bed\,50\%}$ and $T_{bed\,90\%}$ are given in Tables 6-10 and 6-11 for Alternatives 1 and 2. Infilling of cross-sections A, B, C and D over time are shown in Appendices F (Alternative 1) and G (Alternative 2). No results are presented for the migration velocity C_{bed} because they are small values varying between 0.02 to 0.06 m/year.

Slow Infilling Between 7 m and 15 m Water Depth

The objective of this section is to discuss the dependence of the results on accurate estimates of wave and current conditions. At San Onofre, measurements of waves were carried out from 1978 to 1994 and for currents from 1997-1986 (Section 6.2.4), decreasing the variability of the results. Other factors affecting the results are: 1) the presence of hard substrate from 2.5 m to 6 m water depth and farther offshore (Figures 4-10 and 4-11); 2) sediment availability, and 3) accurate estimates of model parameter values.

We will discuss the SONGS trench infilling for constant wave height (0.5, 1.5, and 2.5 m) and current speed and compare these values with those computed by the bivariate distribution between Hs and current speed. Figure 6-26 shows the cumulative distribution of significant wave height Hs, and the percentage of time Hs is less than 0.5, 1.5 and 2.5 m for various current speeds. Figure 6-27 shows the cumulative distribution of current speed. Current speed is less than 0.2 m/sec about 92 percent of the time. In 15 m depth, wave orbital velocities of locally generated sea waves are partially attenuated at the seafloor.

For short small waves and weak currents (Hs = 0.5 m, T = 8 seconds, u_o = 0.1 m/second, water depth = 15 m, and trench width = 34.4 m) $T_{bed} = 130$ years. In these conditions, the trenches essentially stay unfilled indefinitely. For long, small waves (Hs = 0.5 m, T = 16 secs, u_o = 0.1 m/s, water depth = 15 m, and trench width = 34.4 m) $T_{bed} = 52$ years.

Trench infilling at SONGS could be limited by sediment availability. Seawards of the 3 m water depth, the trench volume is about 400,000 m^3. The actual layer thickness is between 1 and 2 m. The sediment nearby is limited in volume, but probably sufficient to fill the trench.

Table 6-8. Infilling Time (Tbed) for Units 2 & 3 With Trench Slope 1:1 (Alternative 1) Computed from the Bivariate Distribution.

Cross-Section	SONGS	Water Depth (m, MSL)		Trench Width (m)	Trench Depth (m)	T_{bed}[a] (years)
		Start	End			
A	Unit 2 In surf zone	0	4	34.4	7.6	< 1
A	Unit 2 In surf zone	4	7	34.4	7.6	2.26
A	Unit 2 Outside of surf zone	7	10.06	34.4	7.6	12.9
B	Unit 2	10.06	14.03	22.3	7.6	9.9
C	Unit 2	14.03	14.63	18.6	6.4	7.6
D	Unit 2	14.63	15.8	15	5.2	6.4
A	Unit 3 In surf zone	0	4	34.4	7.6	< 1
A	Unit 3 In surf zone	4	7	34.4	7.6	2.26
A	Unit 3 Outside of surf zone	7	10.06	34.4	7.6	12.9
B	Unit 3	10.06	11.81	22.3	7.6	7.6
C	Unit 3	11.81	12.12	18.6	6.4	5.2
D	Unit 3	12.12	12.50	15	5.2	4.8

[a] T_{bed} depends on trench width and depth plus other parameters indicated in this report.

Table 6-9. Infilling Time (Tbed) for Units 2 & 3 with Trench Slope 1:1.5 (Alternative 2) Computed from the Bivariate Distribution.

Cross-Section	SONGS	Water Depth (m, MSL)		Trench Width (m)	Trench Depth (m)	T_{bed} (years)
		Start	End			
A	Unit 2 In surf zone	0	4	42.1	7.6	< 1
A	Unit 2 In surf zone	4	7	42.1	7.6	2.26
A	Unit 2 Outside of surf zone	7	10.06	42.1	7.6	19.1
B	Unit 2	10.06	14.03	29.9	7.6	17.6
C	Unit 2	14.03	14.63	25	6.4	13.5
D	Unit 2	14.63	15.8	20.1	5.2	10.5
A	Unit 3 In surf zone	0	4	42.1	7.6	< 1
A	Unit 3 In surf zone	4	7	42.1	7.6	2.26
A	Unit 3 Outside of surf zone	7	10.06	42.1	7.6	19.1
B	Unit 3	10.06	11.81	29.9	7.6	13.4
C	Unit 3	11.81	12.12	25	6.4	9.2
D	Unit 3	12.12	12.50	20.1	5.2	7.6

[a] T_{bed} depends on trench width and depth plus other parameters indicated in this report

Table 6-10. Infilling Time in Years for Selected Values of Tbed for Units 2 & 3 for Slope 1:1 (Alternative 1).

Cross-Section		Unit 2					Unit 3			
	Depth (m)	T_{bed} 50%	T_{bed}	T_{bed} 90%	T_{bed} 99%	Depth (m)	T_{bed} 50%	T_{bed}	T_{bed} 90%	T_{bed} 99%
A	0-4	< 0.7	< 1	2.3	4.6	0-4	< 0.7	< 1	2.3	4.6
A	4-7	1.6	2.26	5.2	10.4	4-7	1.0	2.26	5.2	10.4
A	7-10.06	9.0	12.9	30.0	60.0	7-10.06	9.0	12.9	30.0	60.0
B	10.06-14.03	6.9	9.9	23.0	46.0	10.06-11.81	5.3	7.6	17.5	35.0
C	14.03-14.63	5.3	7.6	17.5	35.0	11.81-12.12	3.6	5.2	12.0	24.0
D	14.63-15.8	4.5	6.4	14.7	29.5	12.12-12.50	3.4	4.8	11.0	22.0

Table 6-11. Infilling Time in Years for Selected Values of Tbed for Units 2 & 3 for Slope 1:1.5 (Alternative 2).

Cross-Section		Unit 2					Unit 3			
	Depth (m)	T_{bed} 50%	T_{bed}	T_{bed} 90%	T_{bed} 99%	Depth (m)	T_{bed} 50%	T_{bed}	T_{bed} 99	T_{bed} 99%
A	0-4	< 0.7	< 1	2.3	4.6	0-4	< 0.7	< 1	2.3	4.6
A	4-7	1.6	2.26	5.2	10.4	4-7	1.6	2.26	5.2	10.4
A	7-10.06	13.4	19.1	44.0	88.0	7-10.06	13.4	19.1	44.0	88.0
B	10.06-14.03	12.3	17.6	40.5	81.0	10.06-11.81	9.4	13.4	30.8	61.6
C	14.03-14.63	9.5	13.5	31.1	62.1	11.81-12.12	6.5	9.2	21.2	42.4
D	14.63-15.8	7.4	10.5	24.2	48.3	12.12-12.50	5.3	7.6	17.5	35.0

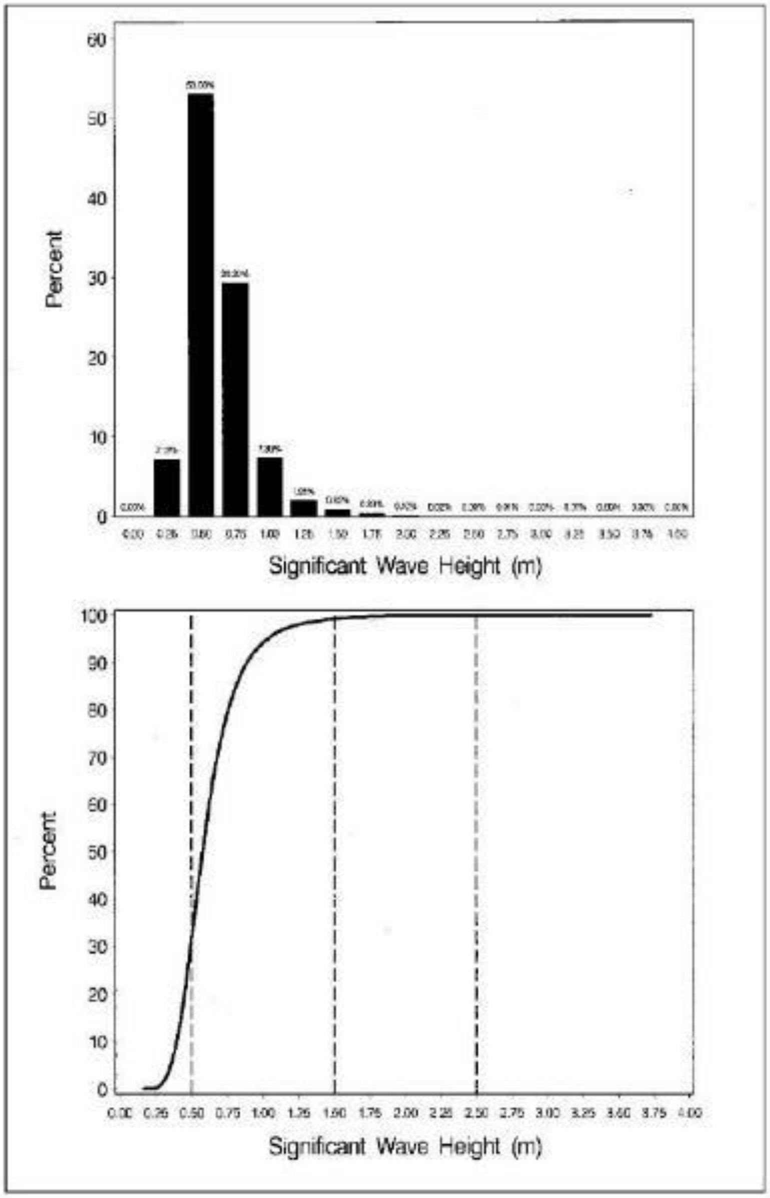

Figure 6-26. Cumulative Distribution of Significant Wave Height Hs from 2000-2016 in 10 m Water Depth at San Onofre. Hs < 1 m, 96% of the Time.

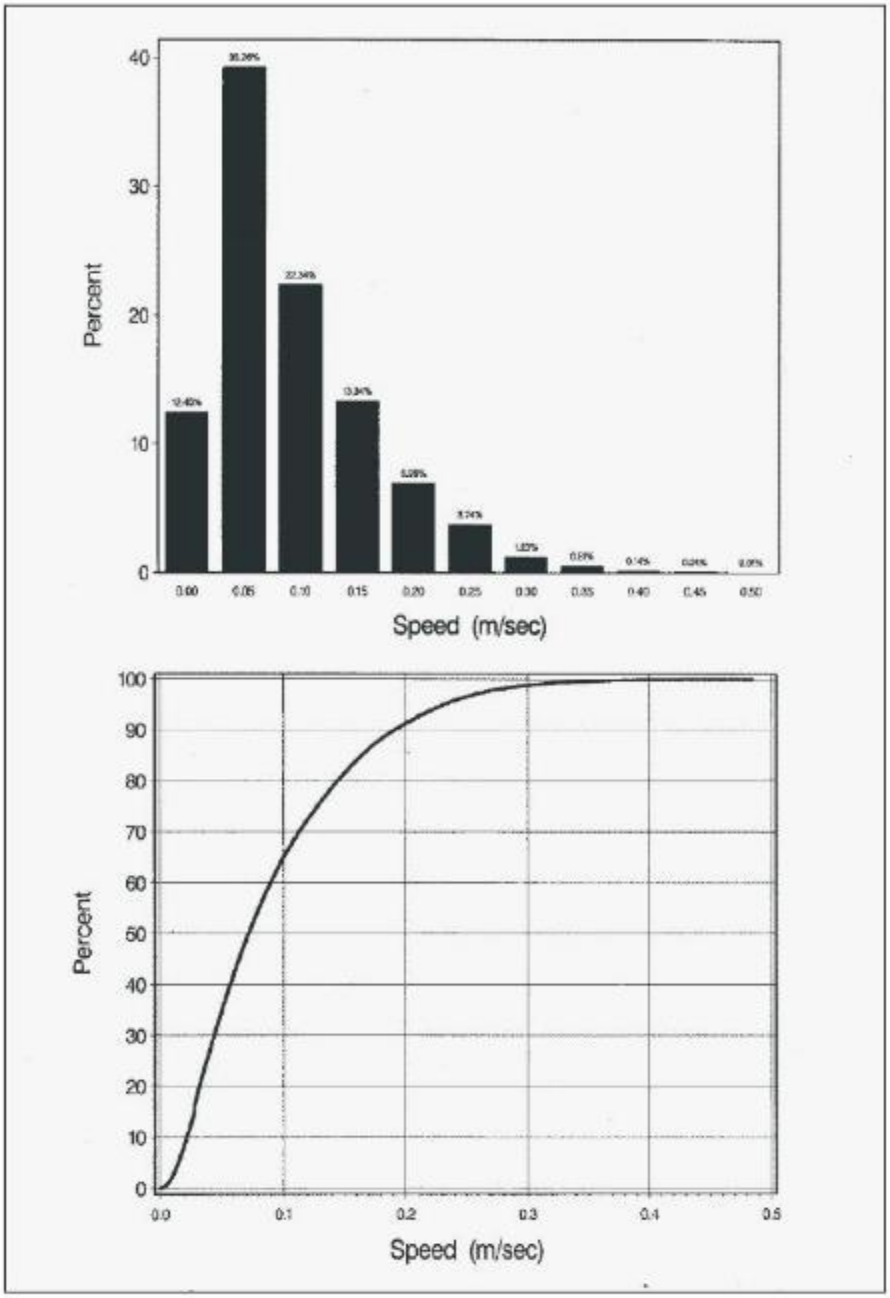

Figure 6-27. Cumulative Distribution of Current Speed in 10 m Water Depth, 3 m Below the Surface at San Onofre. V < 0.2 m/sec, 90% of the Time.

Fast Infilling Between 0-7 M Water Depth

The annual alongshore sediment flux in the surf zone is estimated for comparison with the ~100,000 m^3 of trench infilling between the 7 m depth contour and the shoreline. In coastal engineering design and regional sediment management, it is typically assumed that the breaking- wave-driven alongshore sediment volume flux, Qy, depends on the incident wave significant height, Hs, and the longshore wave radiation stress, Sxy (USACE 1984).

$$Qy = K\ Sxy\ (Hs)\ 0.5 \qquad (6\text{-}1)$$

where K is a dimensional constant. To parameterize Sxy, waves are assumed to be linear, narrow-banded in frequency and direction, and approaching the beach at an angle θ,

$$Sxy = E\frac{C_g}{C}\sin\theta\cos\theta \qquad (6\text{-}2)$$

where C_g and C are the wave group and phase velocities, $E = \rho g Hs^2/8$, ρ is the density of water, and g is the gravity constant.

Elwany et al. (1999, 2017) estimated the gross longshore sediment transport at Oceanside from 1978-1994 as ~500,000 m^3/yr, similar to the estimate of O'Reilly et al. (2016) from 2001-2014 at Camp Pendleton about 20 km south of SONGS. In both studies, the estimated direction of alongshore transport reverses seasonally. Winter waves from the North Pacific drive transport to the south, while summer swell generated in the South Pacific drives northerly transport. Surf zone trenches can be filled by alongshore transport in either direction, so the gross (rather than the net) alongshore flux is relevant.

Based on Moulton et al. (2014, 2017), a plausible scenario on a sandy bottom is that the sides of the 7-meter-deep, 34.4-meter-wide trench will slump over a few weeks (or less), forming a less steep-sided, wider trench. This trench would interrupt a significant fraction of the gross alongshore surf zone transport; sediment may either fall into the trench or move offshore in rip currents. Infilling of ~100,000 m^3 of trench between the 7 m depth contour and the shoreline in over a year or less is likely. The rate of infilling depends on storminess, and during an El Niño winter, the increased shoreline erosion is accompanied by increased offshore accretion (Ludka et al. 2016; Doria et al. 2016). However, at SONGS, a significant part of the conduit trench is on hard bottom. Slumping of side walls would be reduced relative to sand, potentially increasing the infill time. Independent of infill time, a surf zone-spanning trench with SONGS dimensions would strongly modify surf zone flows and sediment transport, and would create notably strong rip currents.

For depths shallower than 4 m, T_{bed} decreases rapidly. T_{bed} = < 1 year, and likely will fill in less than 4 years. However, the trench with SONGS dimensions will strongly modify surf zone flows and sediment transport, and create strong rip currents (Figure 6-23). The circulation details will be sensitive to wave and tide conditions and the evolving channel geometry (Moulton et al. 2014). The impact of SONGS trenches would extend to the beaches north and south due to reduced sand supply to these beaches.

6.2.7 Trench Infilling Conclusions

Using data from the bivariate distribution of waves and currents that best represent the conditions at SONGS as input to the MEMPITS model, estimates of fill time for trench slope 1:1 H:V are about 10 years in water depth less than 7 m and 60 years in 7-15 m water depth. For trench slope 1:1.5 H:V, the filling time is about 10 years in water depth less than 7 m and 90 years or more in 7-15 m water depth.

However, the mixture of sediment types, including sand, cobbles, shell hash, and hard-bottom could cause an unknown and perhaps longer infill time. This is common in sediment transport analysis since the model parameters are estimated in the absence of field measurements. Van Rijn et al. (2005) studied mining pits and trenches worldwide, and concluded that the *"modelling of morphodynamics is not accurate."* The uncertainty margins are relatively large up to factor 3 (Hume et al. 2015). The uncertainties are raised by the lack of field data, which results in possible inaccuracies in estimating the model parameters. These uncertainties also apply to the present SONGS estimates; however, the calculations and the analysis provided represent the best available estimates for the SONGS project.

Consistent with the modeling of Hume et al. (2015), episodic infilling at SONGS is expected to be driven by moderate and large storm conditions occurring frequently during El Niño years. It is also expected that the trench will modify surf zone flows and sediment transport, and create strong and hazardous rip currents that could decrease infill time in less than 7 m water depth.

7 Specific Impacts

7.1 Excavation

During and after excavation, fine-grained sediment (i.e., particles smaller than ~74 microns) would be resuspended in the water column, resulting in high turbidity levels. The finer the sediment, the longer it will remain in suspension; larger particles settle out faster and are deposited closer to the site of disturbance. There are numerous direct and indirect potential impacts of elevated turbidity levels in the marine environment. Turbidity causes light to be scattered and adsorbed rather than transmitted through to the seafloor, therefore, light penetration is reduced, and, as a result, primary production is limited. Lower than average water temperatures may result from the from the cooler, newly suspended sediments that had been buried absorbing heat from the warmer (than the sediments) water and the amount of dissolved oxygen in the water column is often times reduced significantly. While duration of exposure, particle size of the suspended sediment, species type, and life stage of various aquatic biota are determining factors, the reduction in light penetration, warmth, and dissolved oxygen can result in significant detrimental impacts to the aquatic vegetation community. Redistribution of sediment in the water column and deposition on the seafloor is also dependent on current and wave action, depth of water and season. Seagrass beds are present in the shallow zone in the Project Area and the lease area and kelp is present throughout the entire Project Area. These vegetative communities would be affected by elevated turbidity levels in the water column, however, elevated turbidity levels related to excavation activities are typically short lived and, under most scenarios, vegetative communities will be re-established through either recolonization by spores or dormant plants recovering from the turbidity-induced stress.

Turbidity itself can pose significant problems due to limited light penetration, as described above, but can also lead to sedimentation on the hard substrate as the suspended sediment settles to the seafloor. For example, the Barn Kelp, located downcoast of SONGS, was severely impacted during the Marine Review Committee studies to the extent that no surface canopy was observed for several years (Bence et al. 1989). Subtidal surveys at the Barn Kelp found sediment covering the rocky reef habitat preventing recruitment by juvenile algae, such as giant kelp. The sedimentation coincided with terrestrial construction along the coast that resulted in substantial erosion of the coastal bluffs with the eroded sediment, presumably, settling along the coast, including the rocky reef anchoring the Barn Kelp (Bence et al. 1989). This operational experience suggests that increased turbidity, especially of the magnitude likely to result from an excavation, would impact the surrounding vegetation, while excavation was underway. The excavation will be temporary, but the impacts may be significant depending on the length of time and ultimate volume of material excavated.

7.2 Cutting

By cutting the vertical structures at the seafloor height, potential impacts associated with the sediment excavation needed to expose the buried conduit connections would be minimized. There would likely be some as-yet unquantified sediment disruption during the cutting process, but it would reasonably generate less suspended sediment in the water column than excavation. Noise would be generated by use of a diamond wire saw (as a cutting tool example), and prior estimates indicate up to 15 dB of acoustic noise could be generated (Pangerc et al. 2016), suggesting noise from cutting could be difficult to differentiate from ambient noise. Potential impacts from this option would depend on the additional acoustic sources and generation in the area. The length of time needed to cut each vertical structure is unknown at this time, but this is a factor that warrants further investigation if pursued. Alternative cutting methods could be used, but were not analyzed here.

7.3 Shading

Construction and use of a trestle pier, required only for the full conduit removal alternative, would result in shading of the subtidal habitat within the area under the pier (Pardal-Souza et al. 2017). This, in addition to the aforementioned excavation-induced turbidity, will impact vegetative resources in the area surrounding the pier in the shadow of the pier. The trestle pier is only proposed for the full removal option, but construction barges would be used for all three removal options. Temporary shading effects will likely occur as a result of the barge activity, but the impact would be less than it would be associated with the pier. The overall impact from the barges may be negligible depending on the construction pace. No impact was reported associated with the final dispositioning work at SONGS Unit 1; however, the activities associated with dispositioning Units 2 & 3 will occur over a longer time period. In summary, potential shading impacts on the subtidal habitat will vary by alternative, depending on the length of time that construction assets are present at the site. Shading impacts would be associated with both partial abandonment alternatives, but likely substantial with the full removal alternative. Shading impacts to submerged aquatic vegetation would likely be most impacted during periods of high turbidity while the trestle pier and construction barge shadows combine and cover the same area for an extended time.

7.4 Artificial Reef Habitat

Subtidal surveys have shown extensive biological colonization of exposed vertical structures (MBC 2017b). For instance, many of the diffuser ports support giant kelp and associated fish communities (Figure 7-1). The complete removal of all offshore structures or the less invasive removal of just the vertical structures would remove this habitat from the environment. Selective removal of some of the vertical structures could preferentially leave those structures functioning as mature artificial reefs, similar to the Wheeler North Artificial Reef located approximately 8 km northwest of the conduits, which was constructed as a mitigation requirement for impacts to the San Onofre Kelp from SONGS operations. Throughout the SCB, rocky reef habitat (natural or artificial) is relatively rare in comparison to the sandy bottom habitat dominating the seafloor (Pondella et al. 2016). Beyond the rarity of generic rocky reef habitat that can range from very low to high relief, high relief rocky reef habitat is rare, highlighting the value of the mature artificial reef created by the vertical structures (MBC 2017b).

7.5 Habitat Loss for Benthic Organisms

Impacts to benthic organisms will reflect the extent of the area of habitat disturbed. This ranges from the complete loss of the community within the corridor excavated to remove the conduits, to areas covered when the excavated materials are sidecast during excavation, to the habitat lost as a result of the pile driving needed to support the trestle pier. Infaunal organism losses, estimated at 268,700 organisms/m^2, ranged as high as 225.7 million organisms for the surface area excavated to support 1:1.15 H:V slope trenching (per Section 6.2) activities required to completely remove the offshore conduits. The 225.7 million infaunal organism estimate excluded the fish return system discharge conduit and any temporary installations to support the conduit removal such as the trestle pier.

The infaunal habitat available will remain impacted until the trenches have filled in if the complete conduit removal is undertaken. Sidecast sediments will create habitat, but these mounds would likely not be as hospitable to infauna as the sand and cobble material distributed on the surface of the conduit corridors, especially near the diffusers (MBC 2016a). As the trench eventually fills in with sediment, the surrounding infaunal community could be reasonably expected to colonize the habitat. Impacts to the infaunal communities resulting from removing the risers, but abandoning the conduits in place, would likely be proportionally less at a rate commensurate with the differences in disturbed surface area of sediment.

Figure 7-1. Underwater photo of diffuser port D35 showing vegetation including giant kelp and a variety of reef and kelp associated fishes.

7.5.1 Impacts to Mobile Marine Life

Impacts to local fish, mobile macroinvertebrates, sea turtles, and marine mammals resulting from the three conduit disposition options vary widely and reflect the degree of subtidal disturbance created by the deconstruction. Consistent with impact assessments previously carried out, the complete removal of all offshore infrastructure would pose the most significant threat to mobile organisms. The impact mechanisms would include loss of habitat resulting from the excavation, increased turbidity, water quality degradation, and acoustic impacts from generated underwater noise. Underwater noise, in particular, during the active construction poses a threat to marine mammals and other acoustically sensitive marine life (NMFS 2016c). In addition to acoustic impacts, the movement and activity of large marine construction equipment and vessels in the area pose ship strike threats to marine mammals and sea turtles. This threat has been recognized at the regulatory level where similar projects, such as the similar project to set the Unit 1 offshore conduits to their final disposition required marine observers with stop-work authorization on site (MBC 2012).

Habitat loss would be the most pervasive long-term impact and would vary based on the amount of excavation, substrate either buried or removed during excavation, and loss of biogenic habitat (algae and surfgrass) due to either sedimentation or elevated turbidity. Algae, such as giant kelp, and surfgrass provide highly productive biogenic, three-dimensional habitat supporting a wide range of marine life. The high value of this habitat is reflected by its inclusion as HAPC in the Groundfish Fishery Management Plan (PFMC 2017). The cascading effects of losses in biogenic habitat was detailed during the Marine Review Committee studies at SONGS. The Marine Review Committee concluded the operation of SONGS Units 2 & 3 and the turbid discharge plume caused the loss of 150 acres of medium to high density giant kelp (Bence et al. 1989). The potential impacts of construction-induced turbidity as well as physical removal of subtidal features, natural rock, and POISs, AOISs, and diffuser ports that giant kelp or surfgrass attaches to would eliminate anchorage habitat for biogenic habitat. As a result of this estimated biogenic habitat loss, an estimated 28 US tons of kelp bed-associated fish standing stock biomass was lost (Kastendiek and Parker 1989). Various pieces of the infrastructure rising above the seafloor have been colonized by algae and both recreational and commercially important fish and invertebrate species (MBC 2017a; Appendix H). Predicting the range of losses likely to be suffered by the reef ecosystem resulting from the three options is not possible at this time. The total impact of each option will ultimately depend on the construction process and the standing stock of impacted organisms at the time of construction. Conservatively, reef fish, marine mammals (e.g., California sea lions and harbor seals), California spiny lobster, and myriad other invertebrate fauna reliant on the variable relief rocky reef habitat will be displaced or lost due to being buried by side casted sediments or, in some cases, the SONGS structures themselves that could be removed.

Colonization of the area by non-biogenic habitat organisms after construction is complete will depend on a wide range of factors, but the most important will likely be how much rocky reef habitat is exposed above the sandy bottom when the infrastructure removal work is complete and how quickly biogenic habitat recolonizes the area. A potential benefit to the rocky reef community resulting from the full removal option would be the trestle pier pilings that would create new, high-relief, vertical habitat for the more mobile organisms like fish and marine mammals. Presumably these pilings would be in place long enough to develop the beginnings of a biofouling community of barnacles, mussels, and similar fauna common to pier pilings throughout the SCB. Eventually, however, these pilings would likely be removed or cut at the seafloor and left in place once the project is over, thereby minimizing their long-term environmental benefit.

8 Conclusion

The full removal option for the Units 2 & 3 offshore conduits and associated vertical structures has the greatest potential to impact the Project Area's ecology (Table 8-1). Cutting the selected vertical elements at the seafloor height would reduce the excavation impacts, but possibly increase acoustic impacts. Full removal would include the disruption of the seafloor, which would be necessary to insert the pilings needed to support the trestle pier, and major excavation to expose the buried conduits. Excavation will also be required for the partial removal (such as vacuum dredging sediment from around MAPS to expose the collars), but not to the extent that would be required to remove the buried conduits. No trestle pier is needed for the partial removal options. As described earlier, exposing and removing the buried conduits would result in an open trench. Expected lengths of time for the trench to fill in (naturally) to two-thirds full ranges from up to 10 years in the shallow (up to 7 m) to 120 years at the deeper (more than 15 m deep) portions of the discharge conduits. Marine life colonization rates of the trench as it fills in are unknown—a scientific literature search returned no information that would lend support to describe colonization of sandy seafloor trenches. With the exception of high energy waves or currents moving larger cobble- and boulder-sized material into the trench, sand and smaller material will be the primary source of backfill sediments. These materials would support a lower productivity community, if any, with minimal habitat variation to support more complex communities associated with even low-relief rock reefs. The light penetration to the bottom of the trench has not been modeled or quantified as it will be dependent on the slope used for the trench in addition to total trench depth, but a conservative estimate of less light and less ambient water circulation should be expected, which would contribute to poorer water quality conditions in the trench relative to the surrounding unaltered seafloor. Losses of both artificial reef habitat and the biogenic habitat it supports would reduce the overall production of the Project Area resulting in fewer mobile marine animals, less acreage of desirable fishing locations associated with highly productive and preferred fish habitat. (giant kelp and rocky reef) in the Project Area, and temporarily increased acoustic impacts to sensitive marine mammals.

Table 8-1. Summary of Qualitative Assessment of the Severity of Impacts Resulting from Each Disposition Option.

Impact	Full Removal	Remove all POIS, AOIS, MAPS, Diffusers	Selective Removal POIS, AOIS, and Maps
Excavation/Turbidity	High	Medium	Low
Cutting	NA	Low	Low
Shading	High	Low	Low
Resulting Artificial Reef	High	Medium	Low
Benthic Habitat Loss	High	Medium	Low
Impacts to Mobile Marine Life	High	Medium	Low

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A

Appendix A: Cross-Sections of Nearshore Survey Area

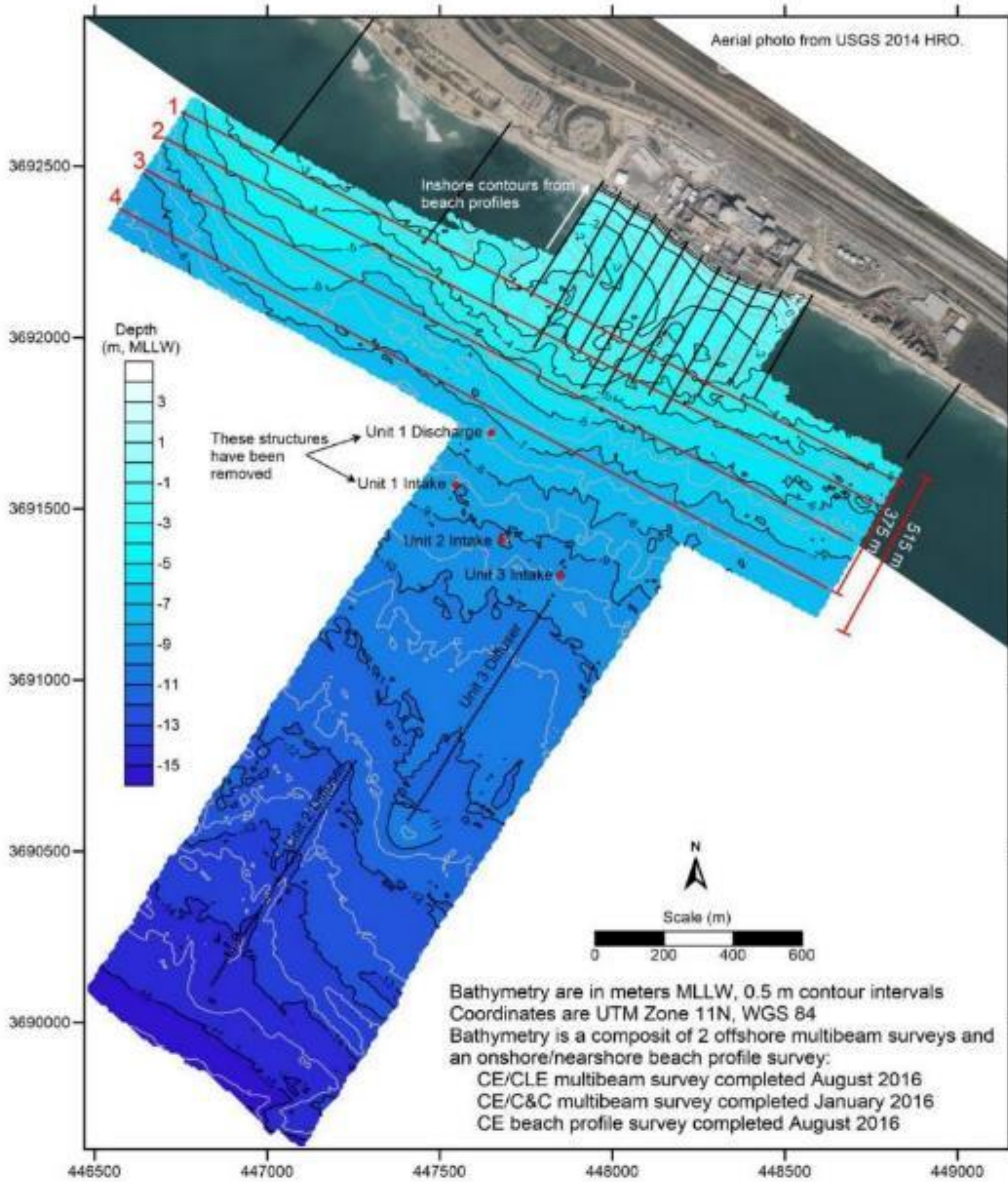

Figure A-1. Four alongshore transects (1, 2, 3, and 4) across the nearshore survey area. The Units 2 & 3 diffuser port structures are labeled by the broken lines. Each black dot in the diffuser port line represents an individual diffuser port.

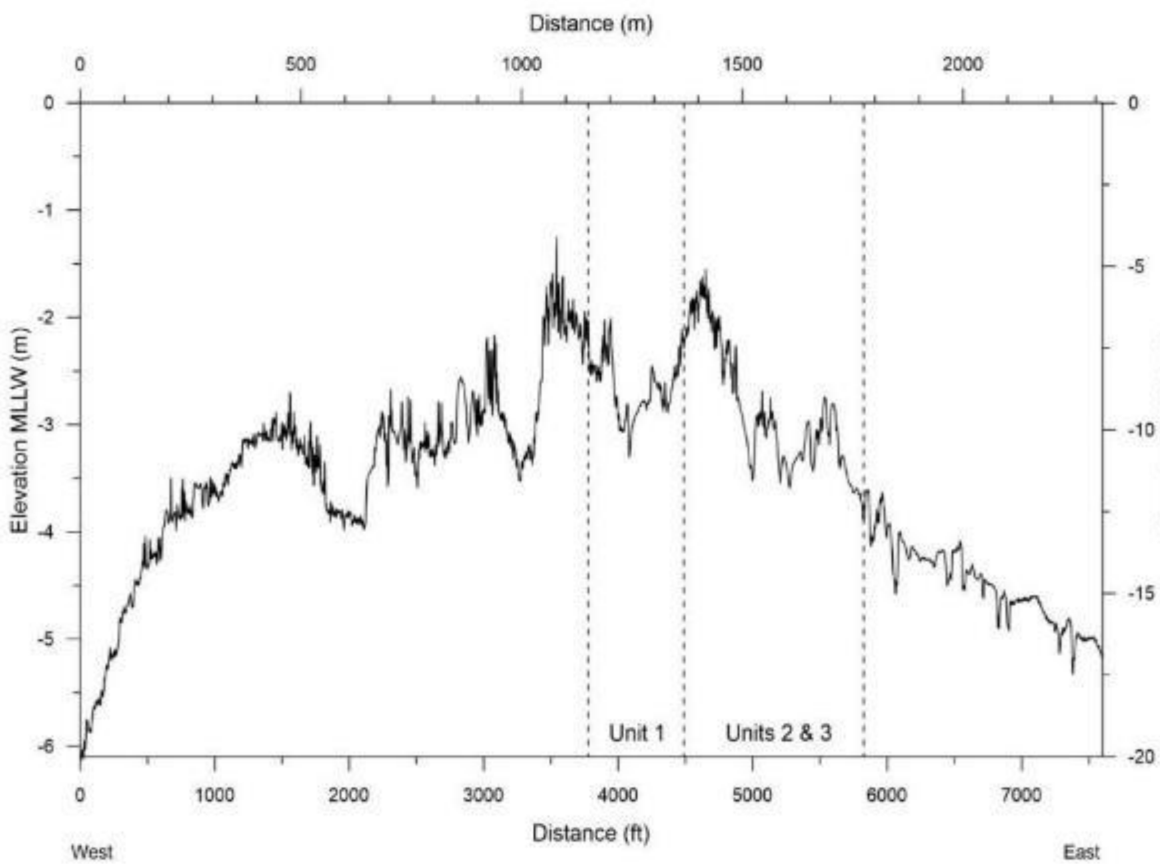

Figure A-2. Alongshore Cross-section 1.

San Onofre Nuclear Generating Station Units 2 & 3 Conduits Dispositioning Alternatives

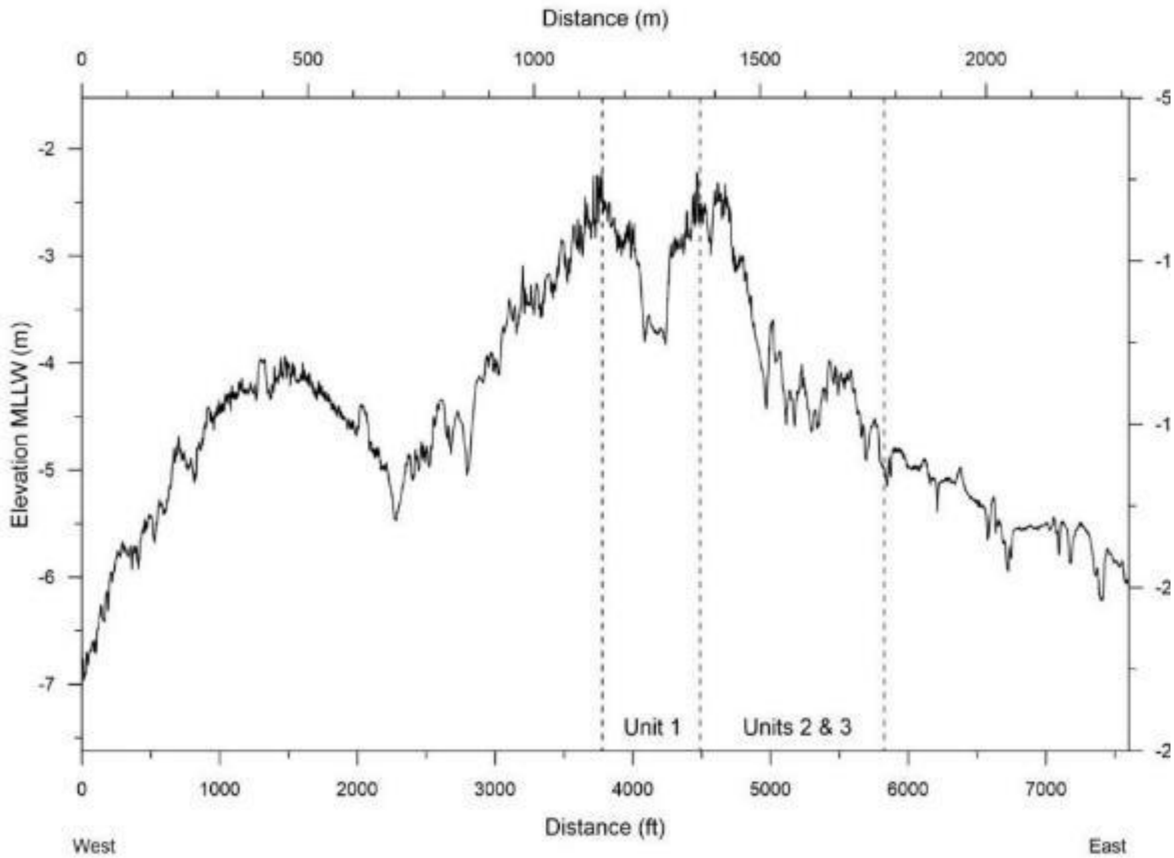

Figure A-3. Alongshore Cross-section 2.

San Onofre Nuclear Generating Station Units 2 & 3 Conduits Dispositioning Alternatives FDR

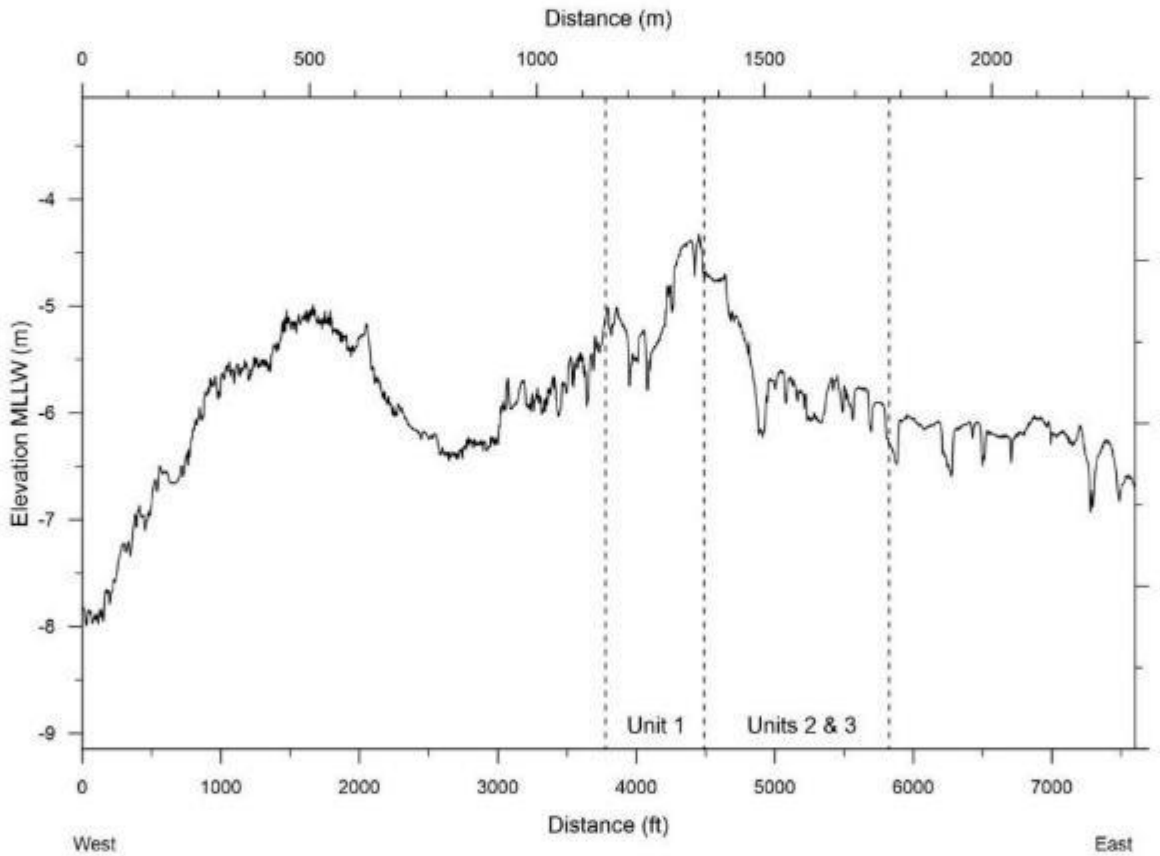

Figure A-4. Alongshore Cross-section 3.

San Onofre Nuclear Generating Station Units 2 & 3 Conduits Dispositioning Alternatives

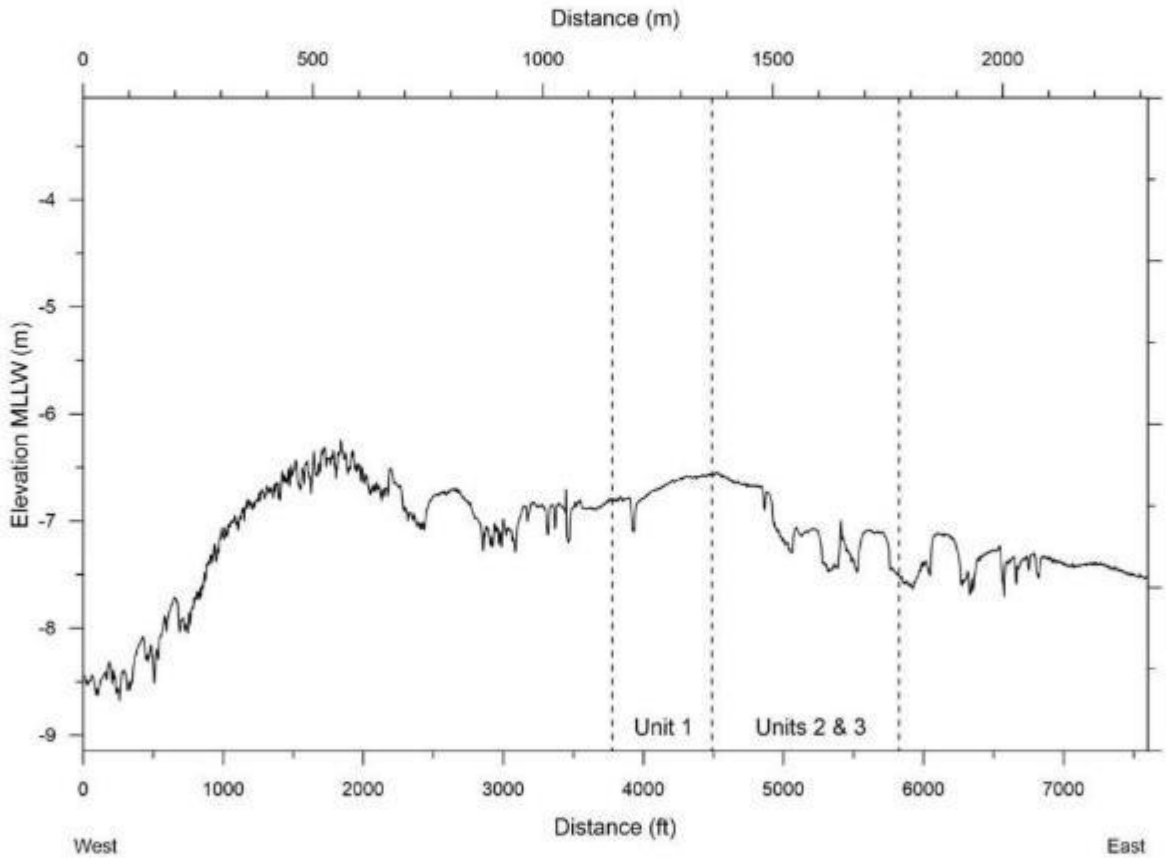

Figure A-5. Alongshore Cross-section 4.

San Onofre Nuclear Generating Station Units 2 & 3 Conduits Dispositioning Alternatives

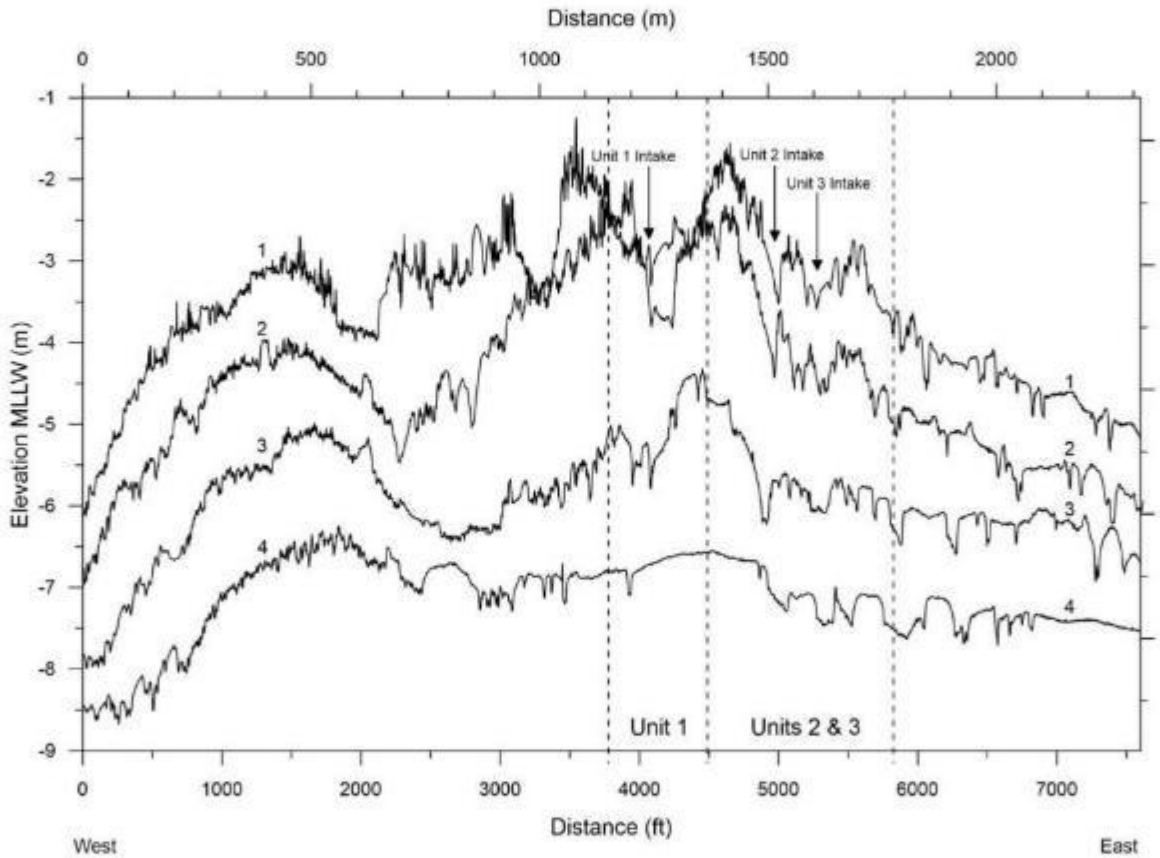

Figure A-6. Cross-sections 1 through 4.

B

Appendix B: Cross-Sections A, B, C, and D

Side Slope 1:1

(Alternative 1)

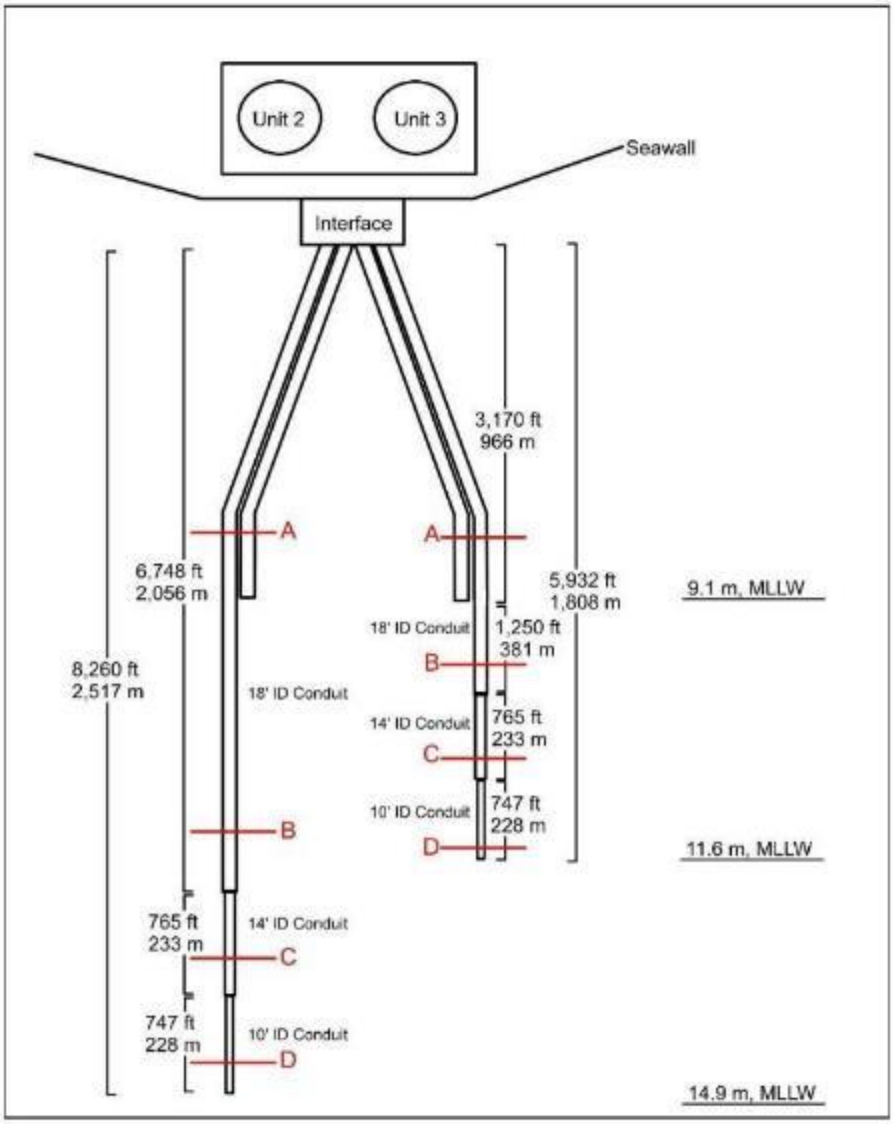

Figure B-1. **Intake and discharge conduits for Units 2 & 3. Water depth is referenced to MLLW (Appendix A).**

San Onofre Nuclear Generating Station Units 2 & 3 Conduits Dispositioning Alternatives

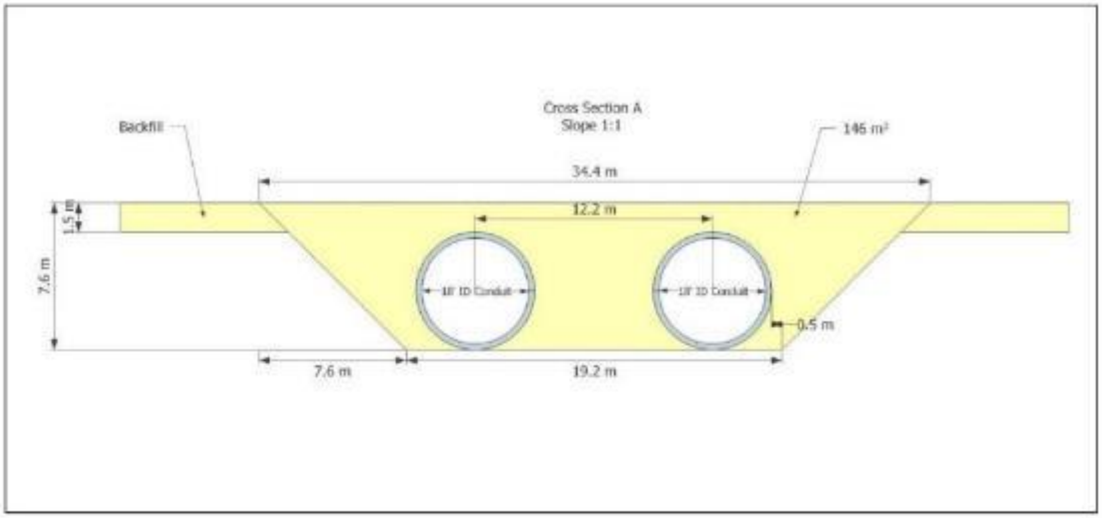

Figure B-2. Cross-section A showing trench for removal of 18-ft (6-m) ID intake and discharge conduits with side slope 1:1.

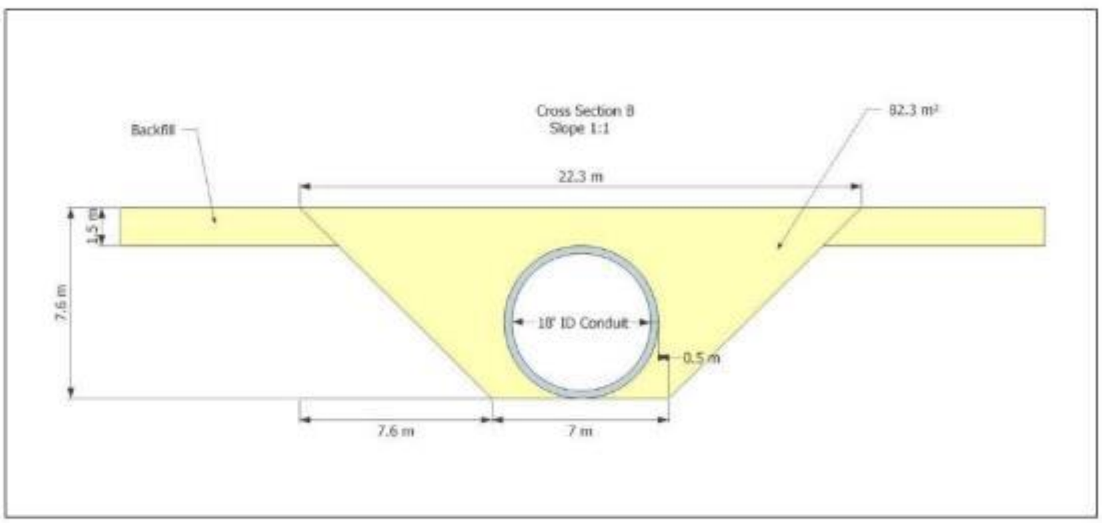

Figure B-3. Cross-section B showing trench for removal of 18-ft (6-m) ID discharge conduit with side slope 1:1.

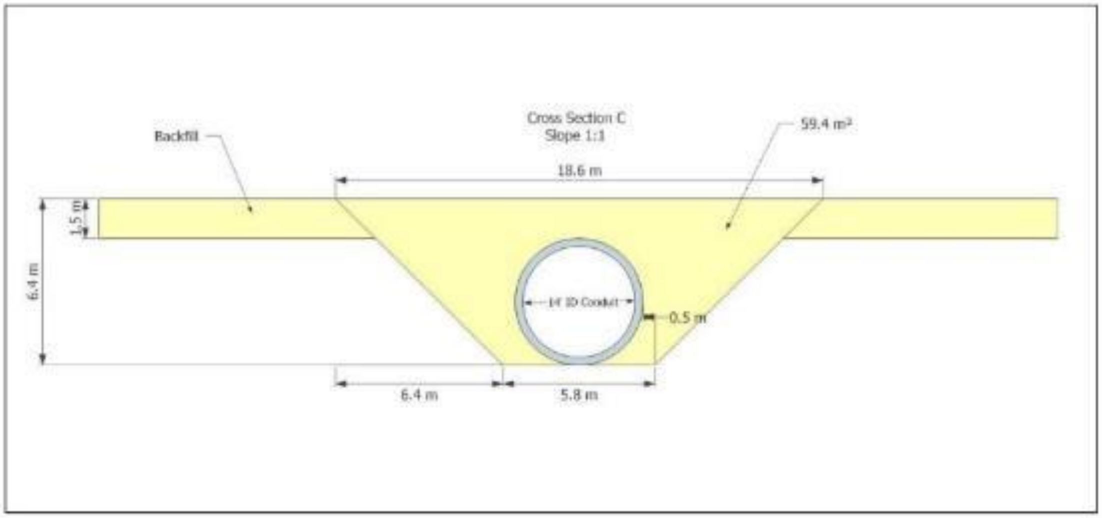

Figure B-4. Cross-section C showing trench for removal of 14-ft (4-m) ID discharge conduit with side slope 1:1.

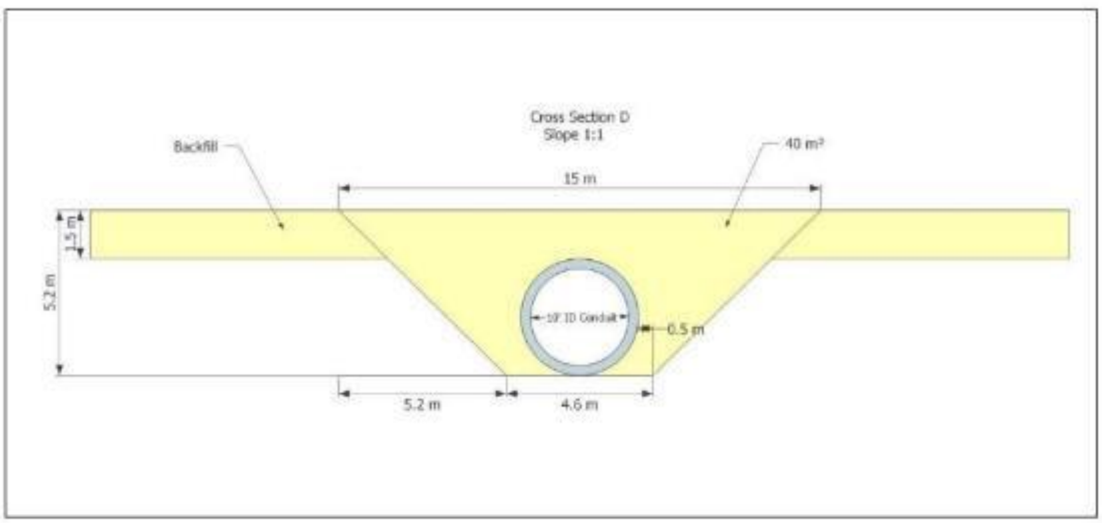

Figure B-5. Cross-section D showing trench for removal of 10-ft (3-m) ID discharge conduit with side slope 1:1.

C

Appendix C: Cross-Sections A, B, C, and D

Side Slope 1:1.5

(Alternative 2)

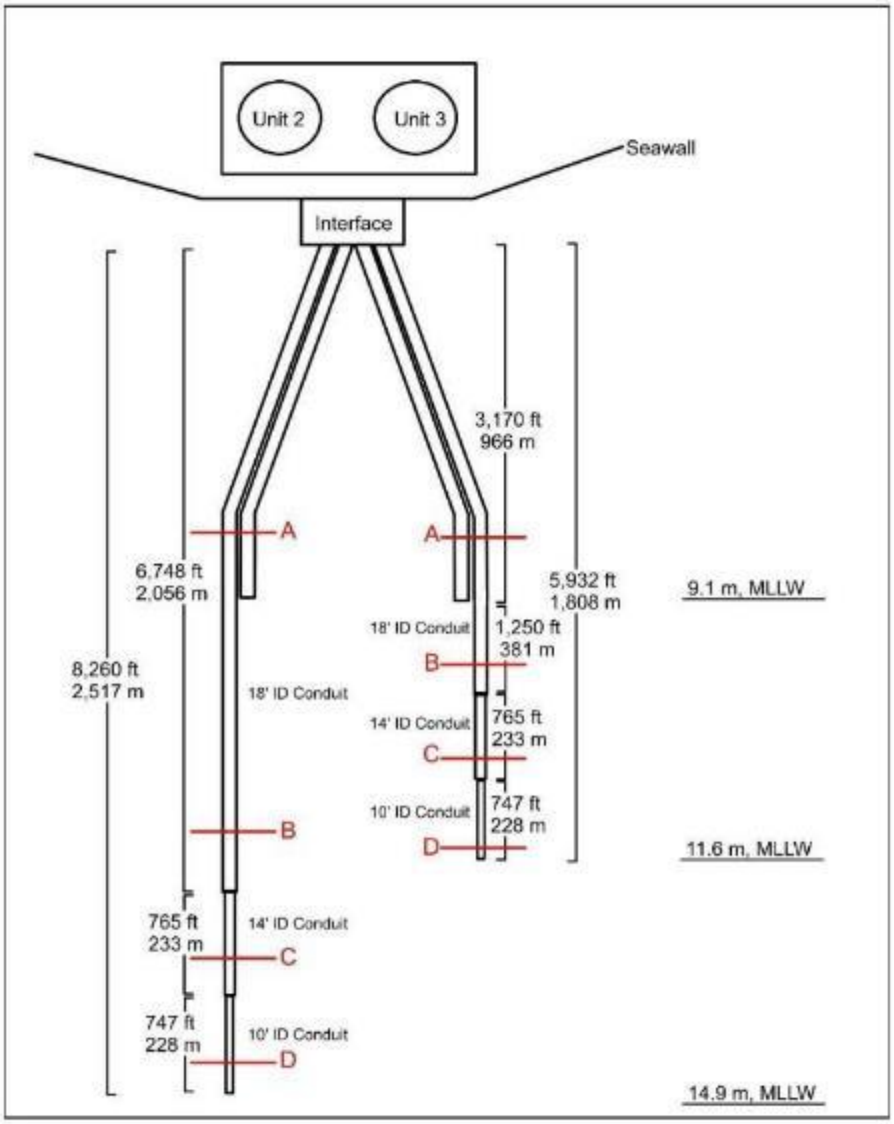

Figure C-1. **Intake and discharge conduits for Units 2 & 3. Water depth is referenced to MLLW (Appendix A).**

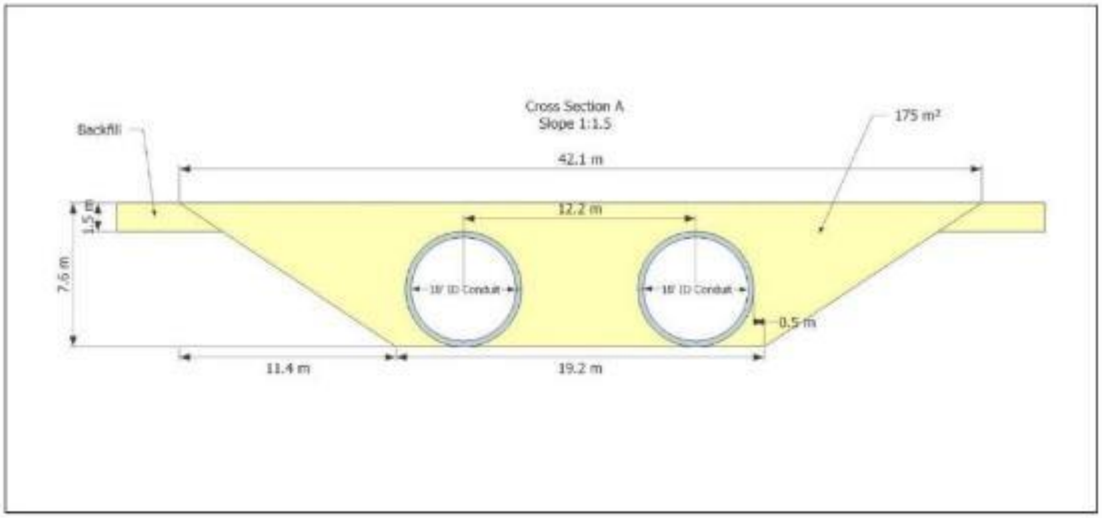

Figure C-2. Cross-section A showing trench for removal of 18-ft (6-m) ID intake and discharge conduits with side slope 1:1.5.

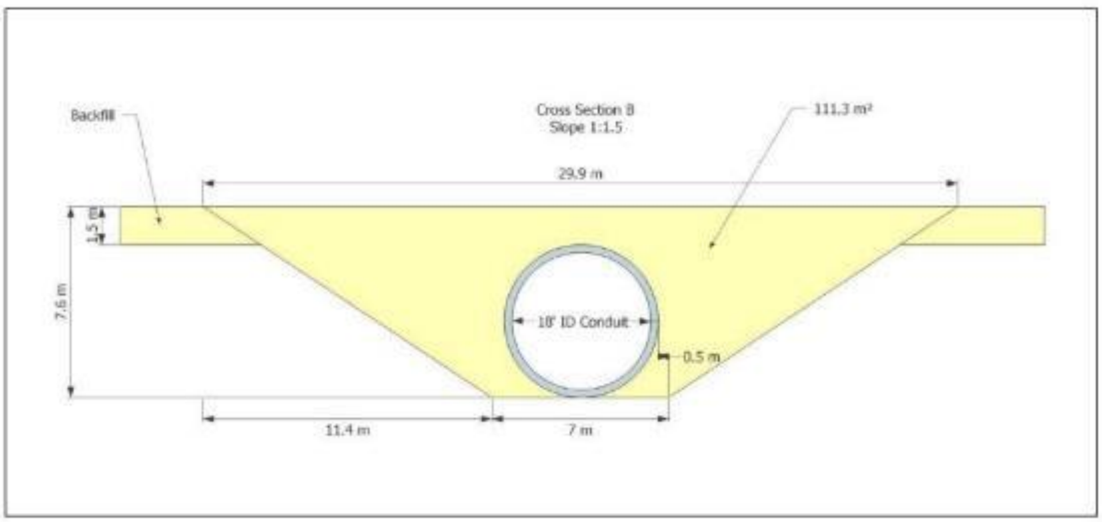

Figure C-3. Cross-section B showing trench for removal of 18-ft (6-m) ID discharge conduit with side slope 1:1.5.

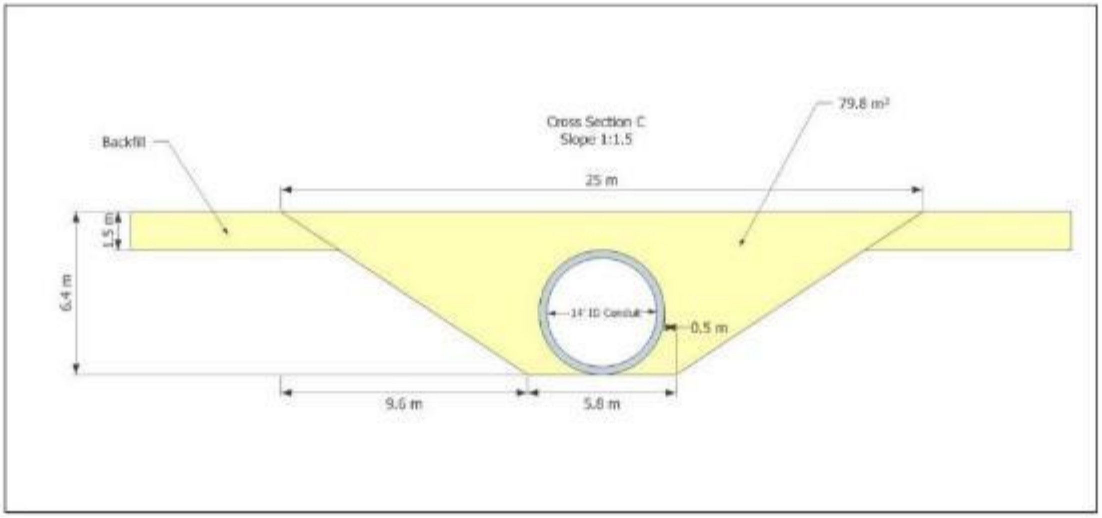

Figure C-4. Cross-section C showing trench for removal of 14-ft (4-m) ID discharge conduit with side slope 1:1.5.

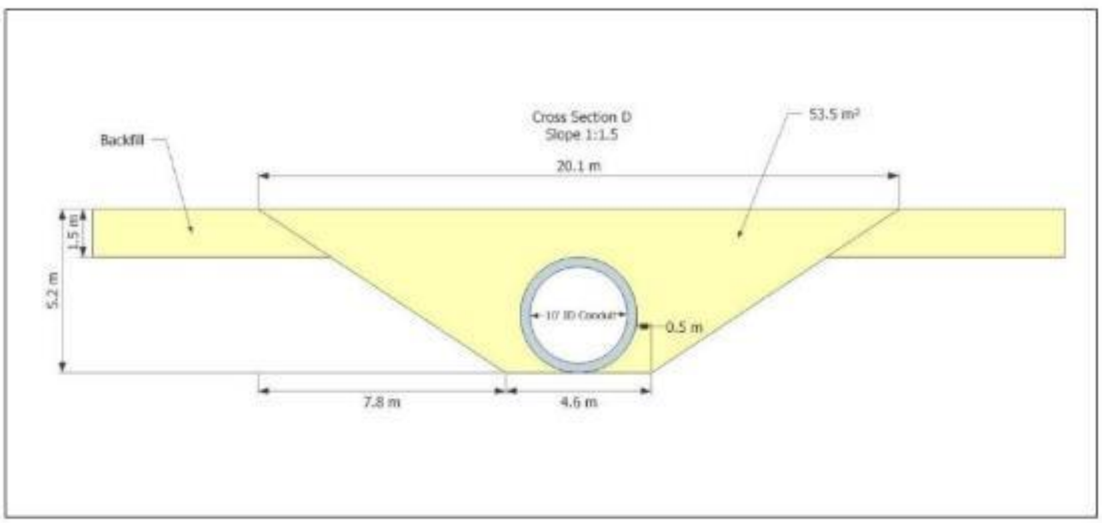

Figure C-5. Cross-section D showing trench for removal of 10-ft (3-m) ID discharge conduit with side slope 1:1.5.

D

Appendix D: Trench Volumes

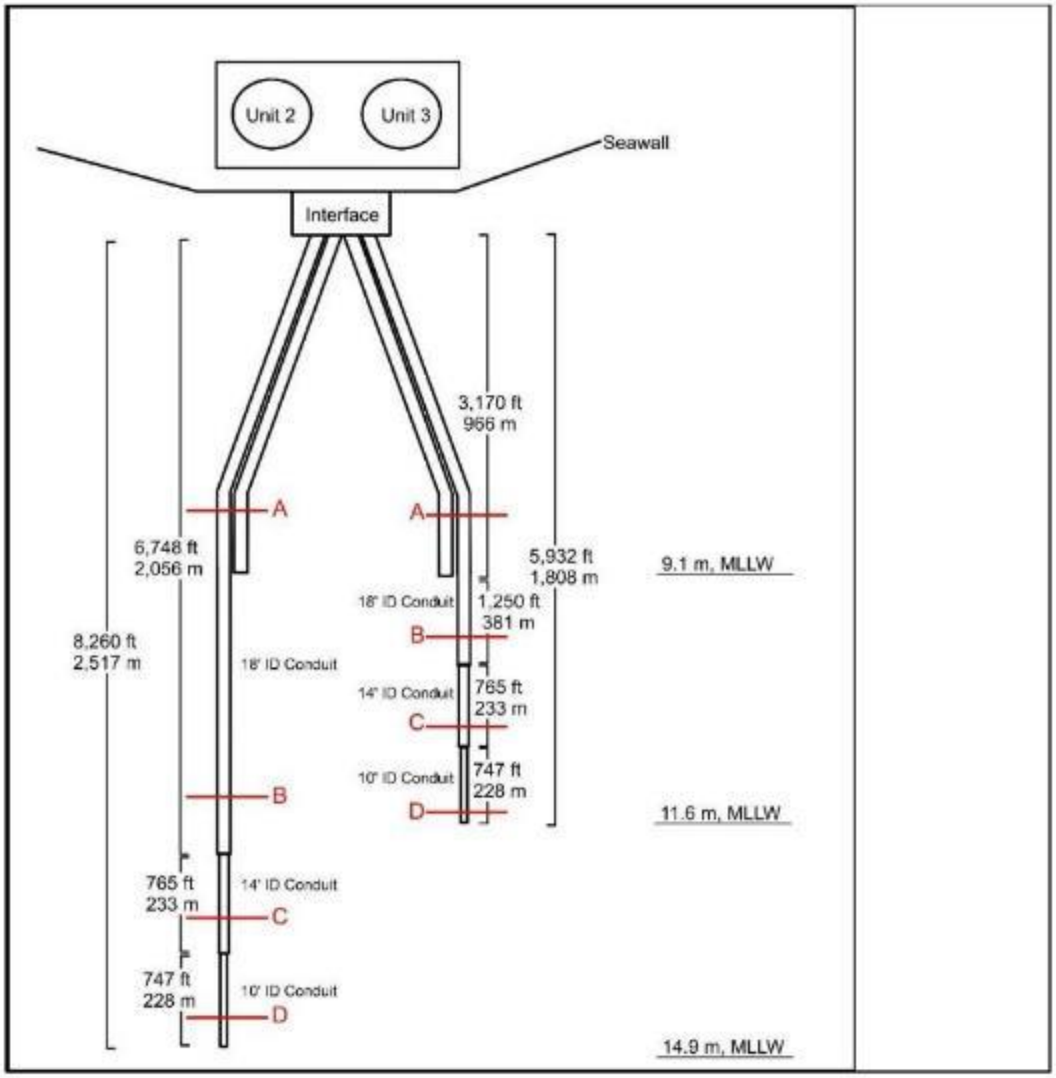

Figure D-1. **Plan view of Units 2 & 3 offshore conduits and locations of 4 separate cross-sections (A, B, C, and D) used to estimate the dredge volume of sand required to remove Units 2 & 3 offshore conduits.**

Table D-1. Dredge volume of sand for removal of offshore conduits given side slope 1:1.

UNIT 2	Cross-Sectional Area		Length		Volume	
	ft^2	m^2	ft	m	ft^3	m^3
Both 18' ID Conduits	1,572	146	3,170	966.2	4,983,240	141,110
18' ID Conduit	886	82	3,578	1090.6	3,170,108	89,768
14' ID Conduit	639	59	765	233.17	488,835	13,842
10' ID Conduit	431	40	747	227.7	321,957	9,117
		Total	**8,260**	**2,517**	**8,964,140**	**253,836**

UNIT 3	Cross-Sectional Area		Length		Volume	
	ft^2	m^2	ft	m	ft^3	m^3
Both 18' ID Conduits	1,572	146	3,170	966.2	4,983,240	141,110
18' ID Conduit	886	82	1,250	381	1,107,500	31,361
14' ID Conduit	639	59	765	233.2	488,835	13,842
10' ID Conduit	431	40	747	227.7	321,957	9,117
		Total	**5,932**	**1,808**	**6,901,532**	**195,430**

UNITS 2 & 3	Volume	
	ft^3	m^3
Total	**15,865,672**	**449,266**

Table D-2. Dredge volume of sand for removal of offshore conduits given side slope 1:1.5.

UNIT 2	Cross-Sectional Area		Length		Volume	
	ft^2	m^2	ft	m	ft^3	m^3
Both 18' ID Conduits	1,884	175	3,170	966.2	5,972,280	169,116
18' ID Conduit	1,199	111	3,578	1,090.6	4,286,444	121,379
14' ID Conduit	859	80	765	233.17	657,365	18,615
10' ID Conduit	576	54	747	227.7	429,869	12,173
		Total	**8,260**	**2,517**	**11,345,957**	**321,282**

UNIT 3	Cross-Sectional Area		Length		Volume	
	ft^2	m^2	ft	m	ft^3	m^3
Both 18' ID Conduits	1,884	175	3,170	966.2	5,972,280	169,116
18' ID Conduit	1,199	111	1,250	381	1,497,500	42,405
14' ID Conduit	859	80	765	233.2	657,365	18,615
10' ID Conduit	576	54	747	227.7	429,869	12,173
		Total	**5,932**	**1,808**	**8,557,013**	**242,308**

UNITS 2 & 3	Volume	
	ft^3	m^3
Total	**19,902,970**	**563,589**

Table D-3. Location, distance, and depth of Units 2 & 3 offshore conduits.

UNIT 2		
Location	**Distance from Interface (m)**	**Depth (m)**
Interface	0	0.00
Intake End	966	8.53
Diffuser Start	1753	11.89
End Diffuser	2510	14.02
End	2518	14.02

UNIT 3		
Location	**Distance from Interface (m)**	**Depth (m)**
Interface	0	0.00
Intake End	966	8.53
Diffuser Start	1043	9.75
End Diffuser	1801	10.36
End	1808	10.36

E

Appendix E: MEMPITS Equations

COMPUTATION OF AMPLITUDE DECAY TIME Tbed

E-1. PROCEDURE

Each combination of wave height, wave period, water depth and vertically averaged current (H_so, T_po,h_o, U^_o) is either wave or current dominated, depending on the relative sizes of the wave orbital velocity U_o= 〖 〖πH〗 _so/ (T_po sinh⁡(k_wo h_o) 〗 _ ^ and the near-bottom mean current, u_bo=0.5 u_o.

A detailed description of these relationships can be consulted in Ribberink (2004) and Ribberink, Roos, and Hulsater (2005).

T_bed=(1-ε_o) h_o [L_A k^2 (4q_so^c+2q_so^wc (1+f))/(L_A^2 k^2+1)+(k^2 h_o)/tanφ (|q_bo^c |+3/2 |q_bo^wc |)]^(-1) current-dominated,

T_bed=(1-ε_o) h_o [L_A k^2 (q_so^w (1+3f)+α_s q_so^wc (3+f))/(L_A^2 k^2+1)+(k^2 h_o)/tanφ (|q_bo^w |+3/2 |q_bo^cw |)]^(-1) wave-dominated,

where the dominant condition is a relationship between the near-bed wave orbital flow and the near-bed current:
Wave-dominant condition: u_bo<U^_o or [u_o<(α_b πH_so)/(T_po sin⁡h (k_wo h_o))]
Current-dominant condition: u_bo>U^_o or [u_o>(α_b πH_so)/(T_po sin⁡h (k_wo h_o))]

U^_o= π H_so/T_po 1/(sin⁡h (k_wo h_o)) (near-bed wave orbital flow)

u_bo=α_b u_o (near-bed flow velocity with u_o as the water depth-averaged current velocity)

q_bo^c=m_b α_b^3 u_o^3

q_bo^wc=1/2 m_b α_b U^_o^2 u_o (bedload transport: current and wave contributions)

f=(k_w∞ h_o sin⁡h (2k_wo h_o))/(2k_wo h_o+sin⁡h (2k_wo h_o) tan⁡ 〖h^2 (k_wo h_o)〗) (parameters associated with surface waves)

q_so^c=m_s α_s^4 u_o^4 q/|q| q=u_o h_o (current-dominated)

q_so^wc= 〖3/4 m〗 _s α_s^2 U^_o^2 u_o^2 q/|q| (suspended-load: current and wave contributions)

q_so^w=m_s 4/3π U^_o^3 α_s u_o (wave-dominant)

q_so^cw= 〖3/π m〗 _s α_s^2 U_o u_o^3

q_bo^w=m_b 4/3π U^_o^3 (wave-dominant)

$q_{bo}^{cw} = \left(\frac{2}{\pi} m\right)_b \alpha_b^2 \hat{U}_o u_o^2$

$D_{ib} = (|q_{bo}^{c}| + 3/2\,|q_{bo}^{wc}|)/((1-\varepsilon_o)\tan\varphi)$ (current-dominant)

$D_{ib} = (q_{bo}^{w} + 3/2\, q_{bo}^{wc})/((1-\varepsilon_o)\tan\varphi)$ (wave-dominant)

$D_{is} = 0$ (wave and current-dominant)

$L_A = \bar{L}\,(u_o h_o)/w_s$ (suspended sediment adjustment length)

$C_b^c = (3q_{bo}^c)/((1-\varepsilon_o) h_o)$ (sediment bedload in a steady current, no waves)

$T_{ho} = h_o/(C_b^c)$ (time to transport C_b^c a horizontal distance equal to h_o)

$k = 2\pi/L = 2\pi/(2b_{po})$ (L = bed wavelength, b_{po}= pit width)

$m_b = (C_f \varepsilon_b)/(\Delta g \tan\varphi)$; $m_s = (C_f \varepsilon_s)/(\Delta g w_s)$; $\varepsilon_b = 0.1$; $\varepsilon_s = 0.02$ (Bailard coefficients [Bailard, 1981])

$C_f = 0.5 f_w$ (f_w = wave friction coefficient [Swart, 1976; Johnsson, 1980])

A discussion of the application of this coefficient is presented in De Groot (2004). ε_o= porosity (0.4), φ= angle of repose (standard value = 32°), α_s, α_b, $\bar{L}$= velocity and concentration profile coefficients (standard value = 0.5), K_{wo}= local wave number of waves (undisturbed bed zones not affected by the pit), $K_{w\infty}$= wave number in deep waters, Δ= relative density of sediment, and W_s= settling velocity of sediment.

All notations used in MEMPITS are defined in Section E-2.

E-2. NOTATIONS

a initial sandpit amplitude

b_{po} mean width of the pit

C advection velocity of the seabed (C_b+C_s)

C_b migration velocity due to bedload

C_s migration velocity due to suspended-load

C_f friction coefficient

C_{bed} migration velocity of the sand pit

C_b^c sediment bedload in a steady current without waves

D diffusion coefficient

D_50 median grain size

D_90 grain size such that 90% of the material in the sample is finer

D_ib diffusion coefficient due to bed-slope effect

d_po mean dredged pit depth

F_ro Froude number

f_w wave friction coefficient

g acceleration of gravity

h_o mean water depth in borrow area

H_s significant wave height

H_so significant wave height in borrow area

k bottom wave number of the pit (= 2π/L)

K_wo wave number of waves in borrow area

K_w∞ wave number of waves in deep waters

L bottom wavelength of the pit

L^ concentration profile coefficient

L_A adjustment length for suspended sediment

l_po mean length of the pit in y-

MD migration-damping ratio

q_b bedload sediment transport rate

q_s suspended-load sediment transport rate

q_t total sediment transport rate

T tidal period

t time

T_bed amplitude decay time or e-folding time of the pot

T_p wave peak period

T_po local wave peak period in borrow areas

U^_o local near-bed horizontal orbital wave velocity

u_o local depth-averaged velocity

u_baxo baroclinic currents in x- in borrow area

u_bo near-bed horizontal flow velocity in x- in borrow area

u_tixo tidal currents in x- in borrow area

u_so suspended horizontal flow velocity in x- borrow area

u_wxo wind-induced currents in x- borrow area

V_m flow velocity

V_p0 initial pit volume

V_p1 final pit volume

V_w wind velocity

W_s settling velocity of sediment

x position along the pit

x_c position of the centroid of the pit volume in x-

x- pit axis parallel to the direction of the steady currents

y- principal pit axis normal to the direction of the steady currents

F

Appendix F: MORPHOLOGICAL CHANGES FOR SONGS TRENCHES

UNITS 2 & 3 COOLING SYSTEM CONDUITS

SLOPE 1:1

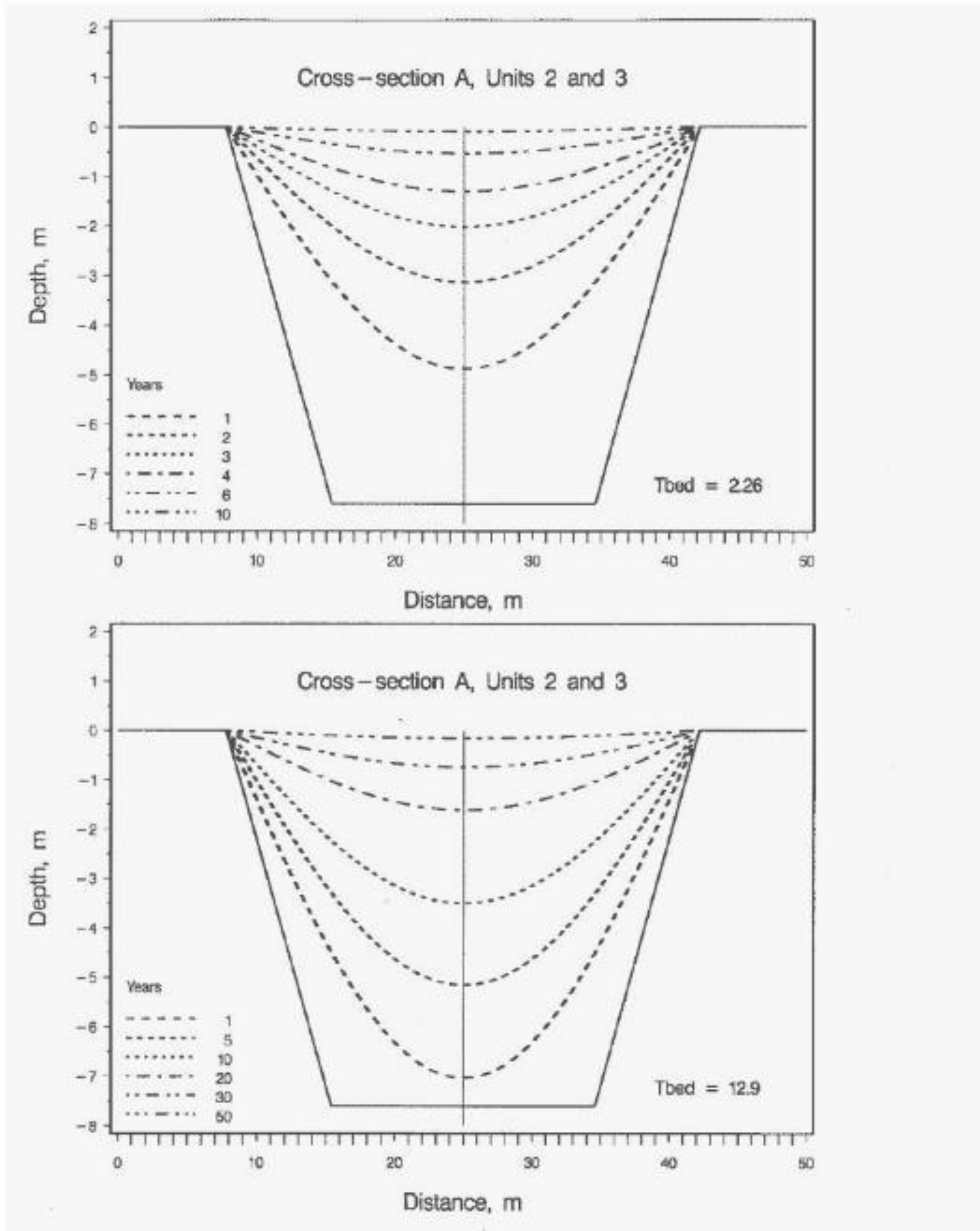

Figure F-1. Estimated trench infill over time for cross-section A with 1:1 slope.

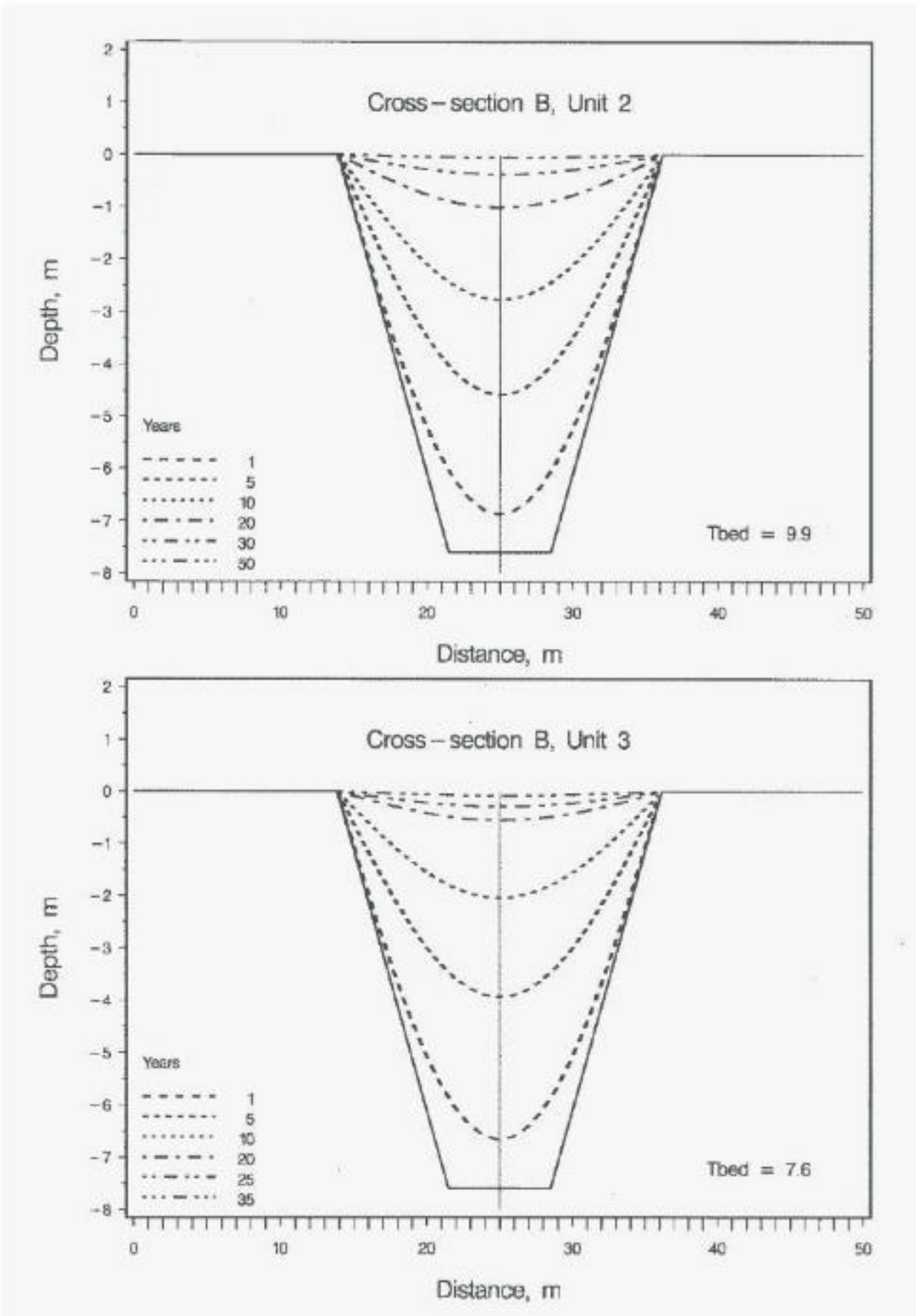

Figure F-2. Estimated trench infill over time for cross-section B with 1:1 slope.

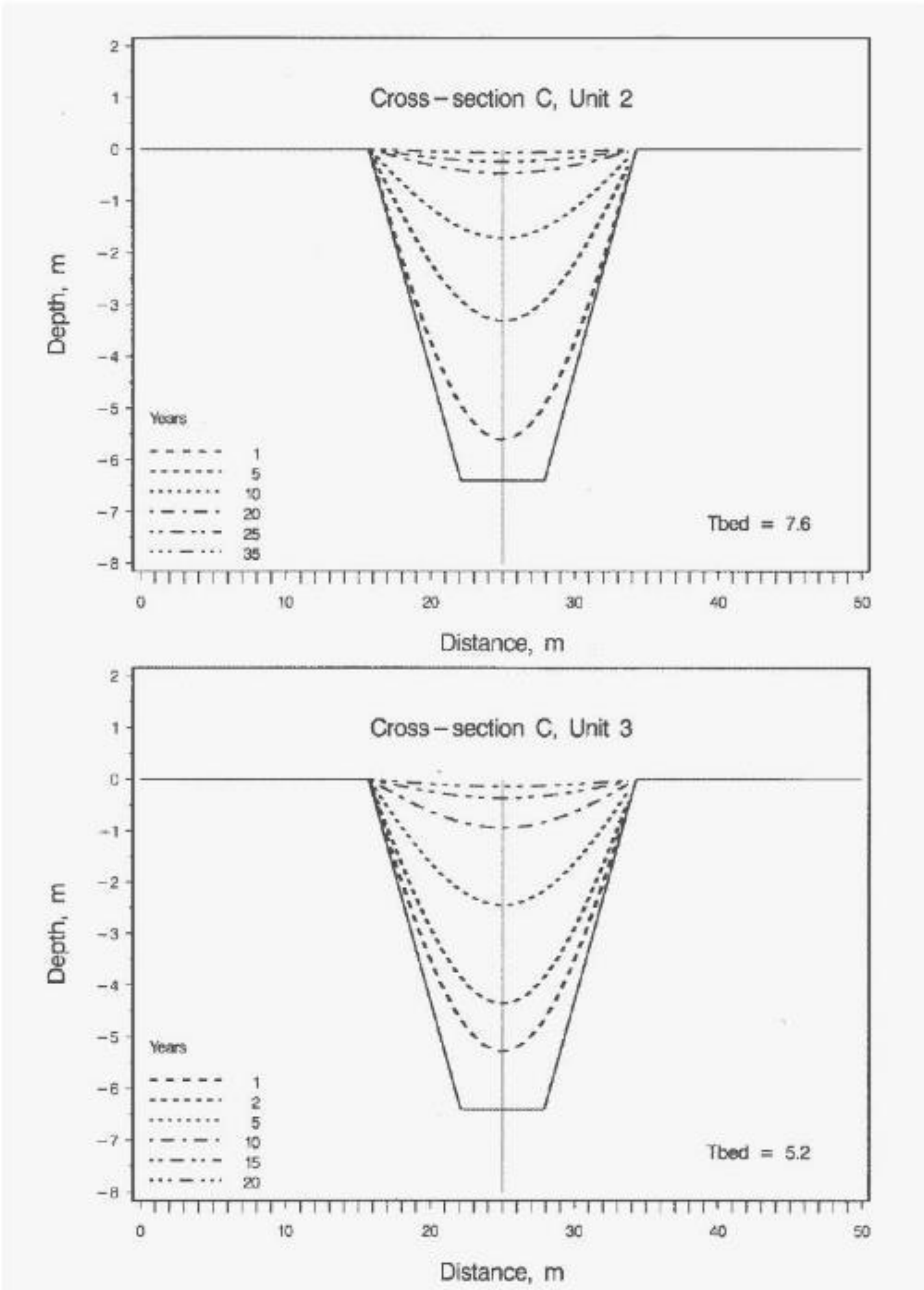

Figure F-3. Estimated trench infill over time for cross-section C with 1:1 slope.

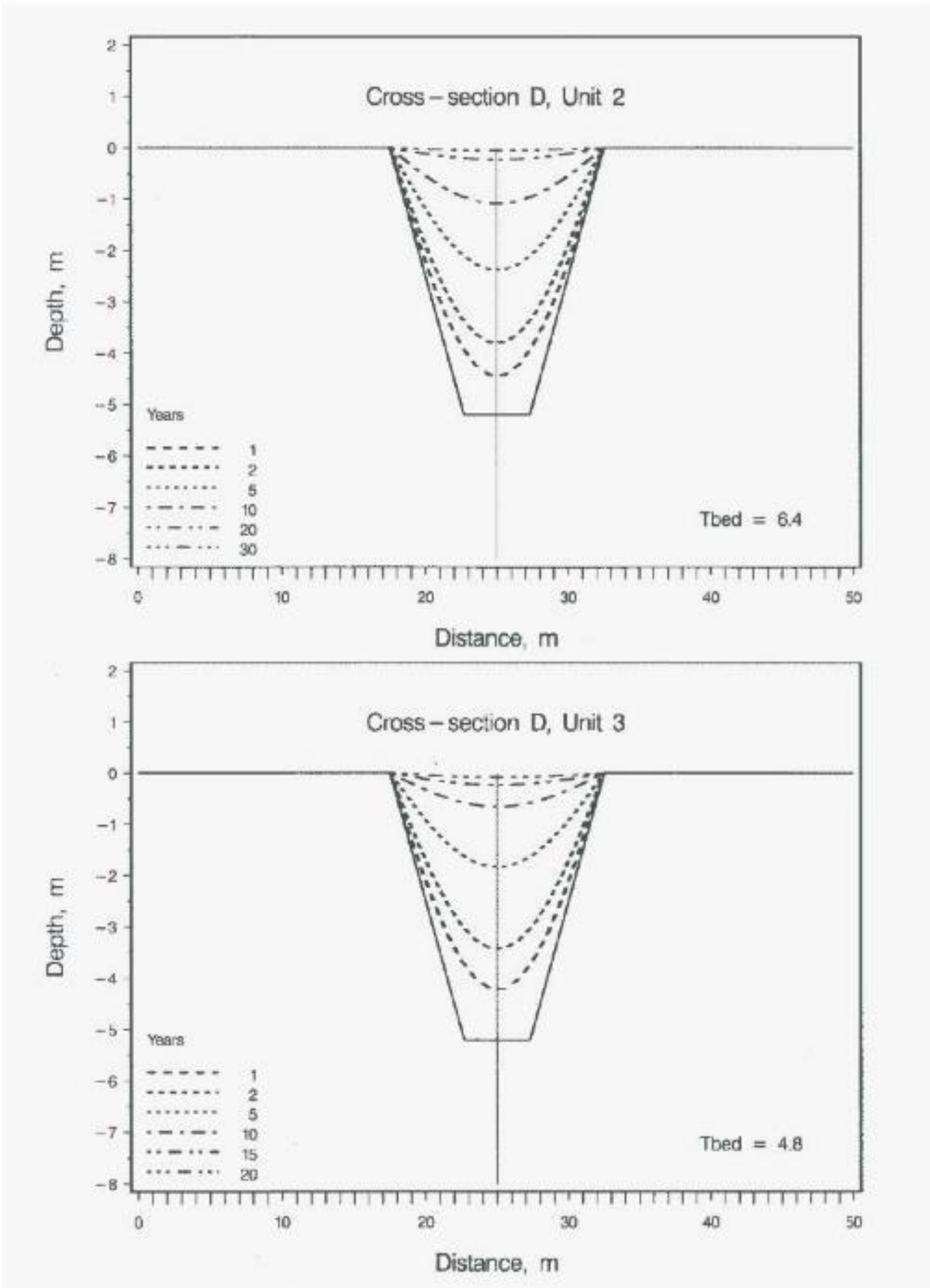

Figure F-4. Estimated trench infill over time for cross-section D with 1:1 slope.

G

Appendix G: MORPHOLOGICAL CHANGES FOR SONGS TRENCHES

UNITS 2 & 3 COOLING SYSTEM CONDUITS

SLOPE 1:1.5

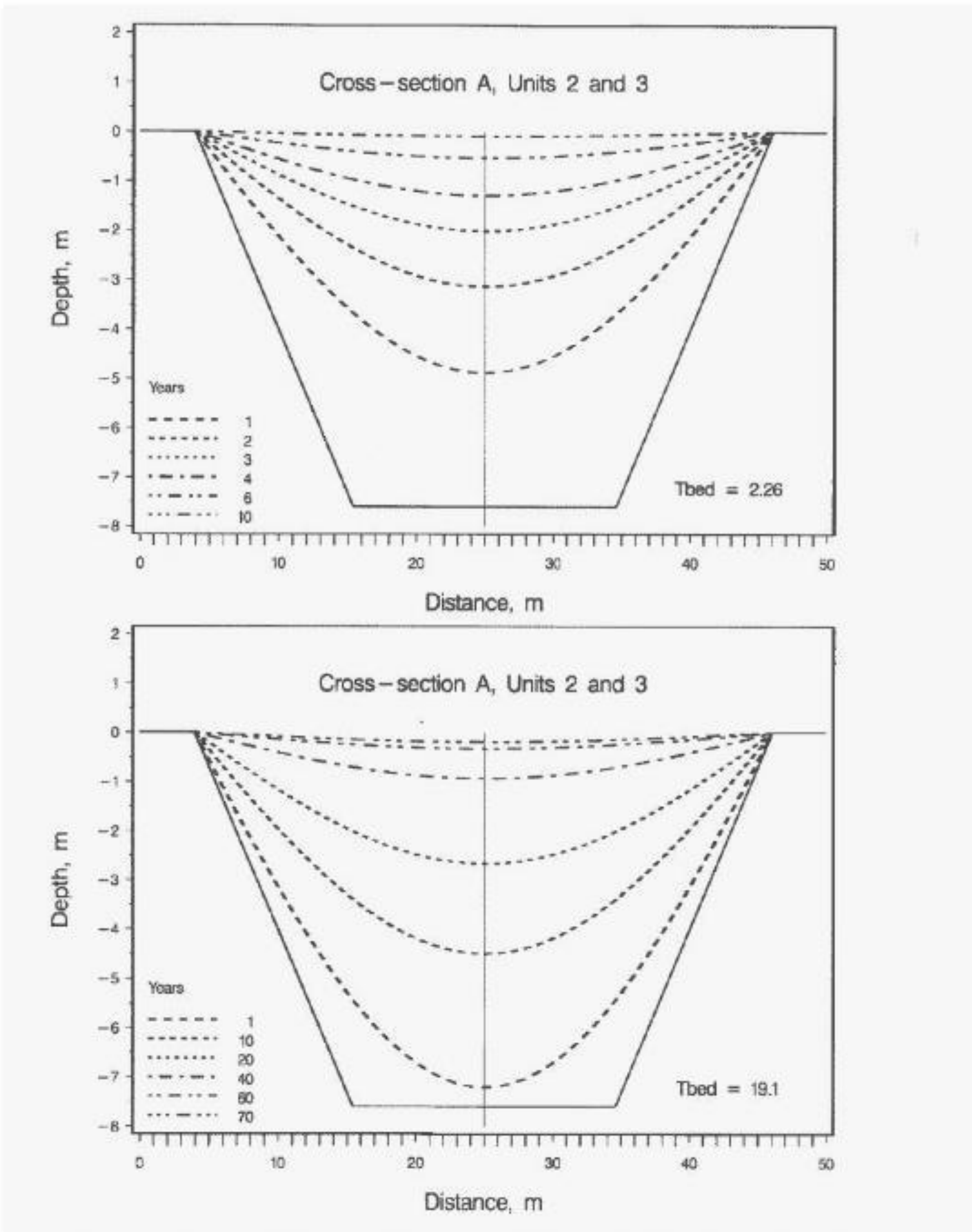

Figure G-1. Estimated trench infill over time for cross-section A with 1:1.5 slope.

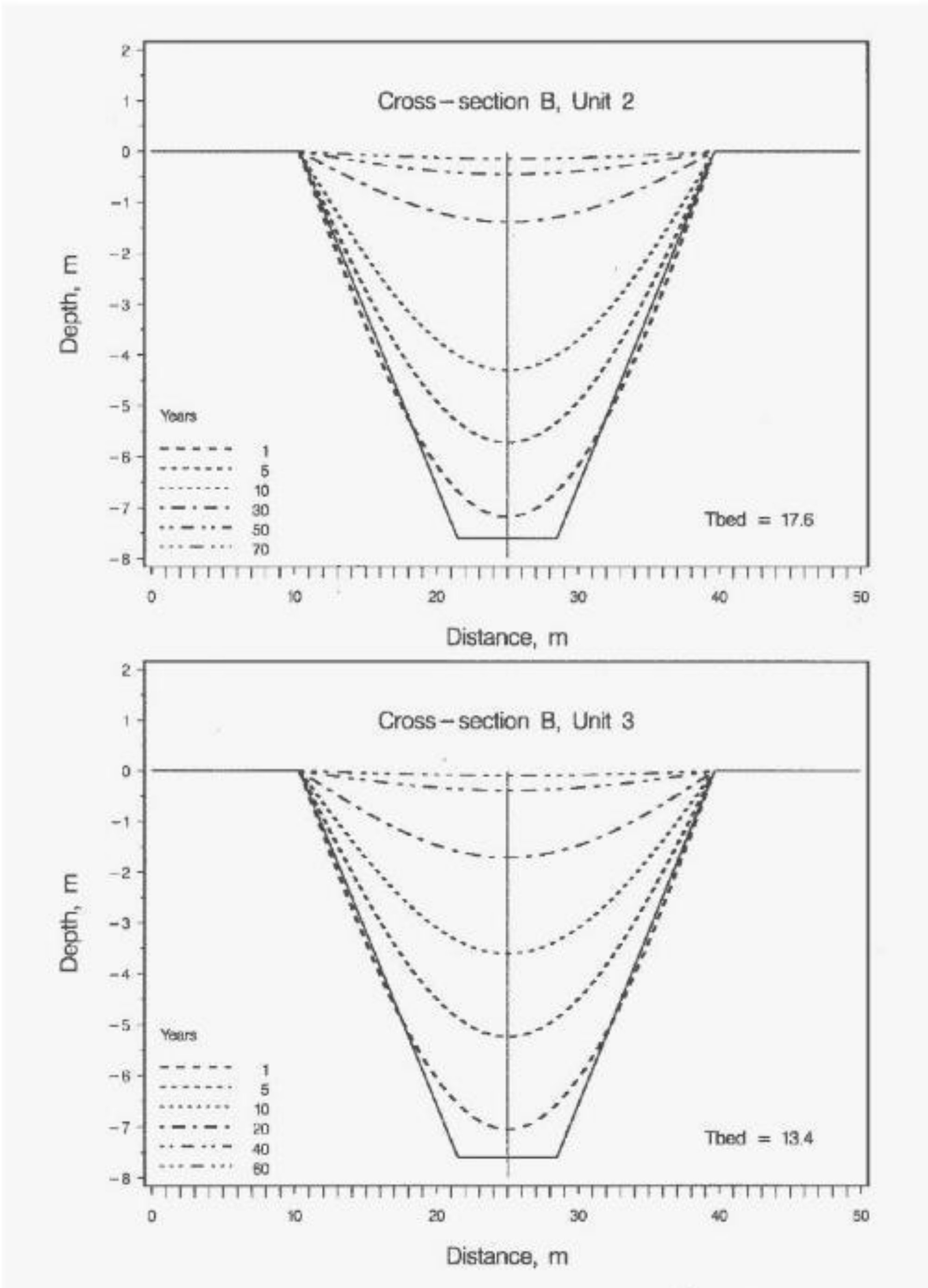

Figure G-2. Estimated trench infill over time for cross-section B with 1:1.5 slope.

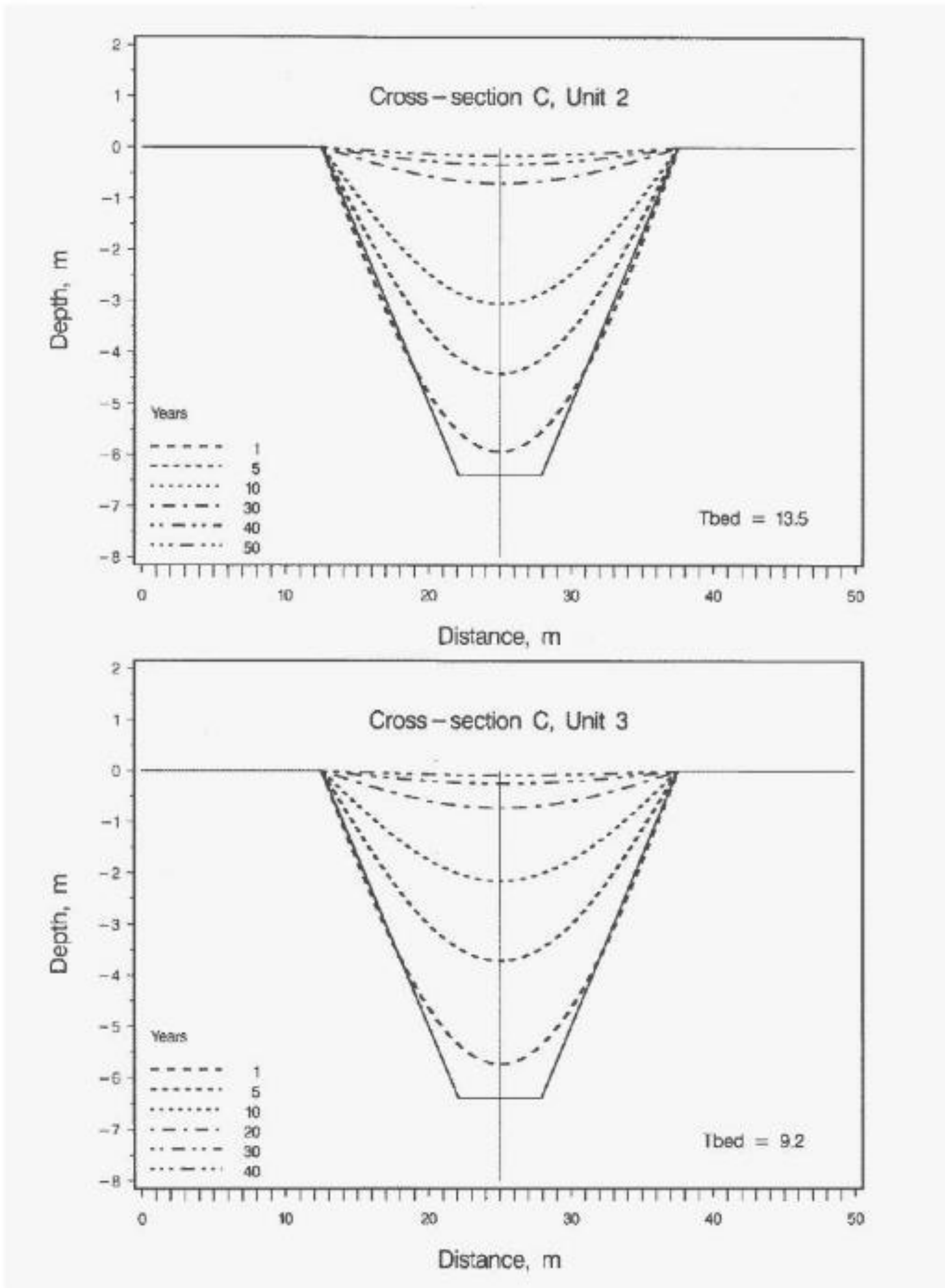

Figure G-3. Estimated trench infill over time for cross-section C with 1:1.5 slope.

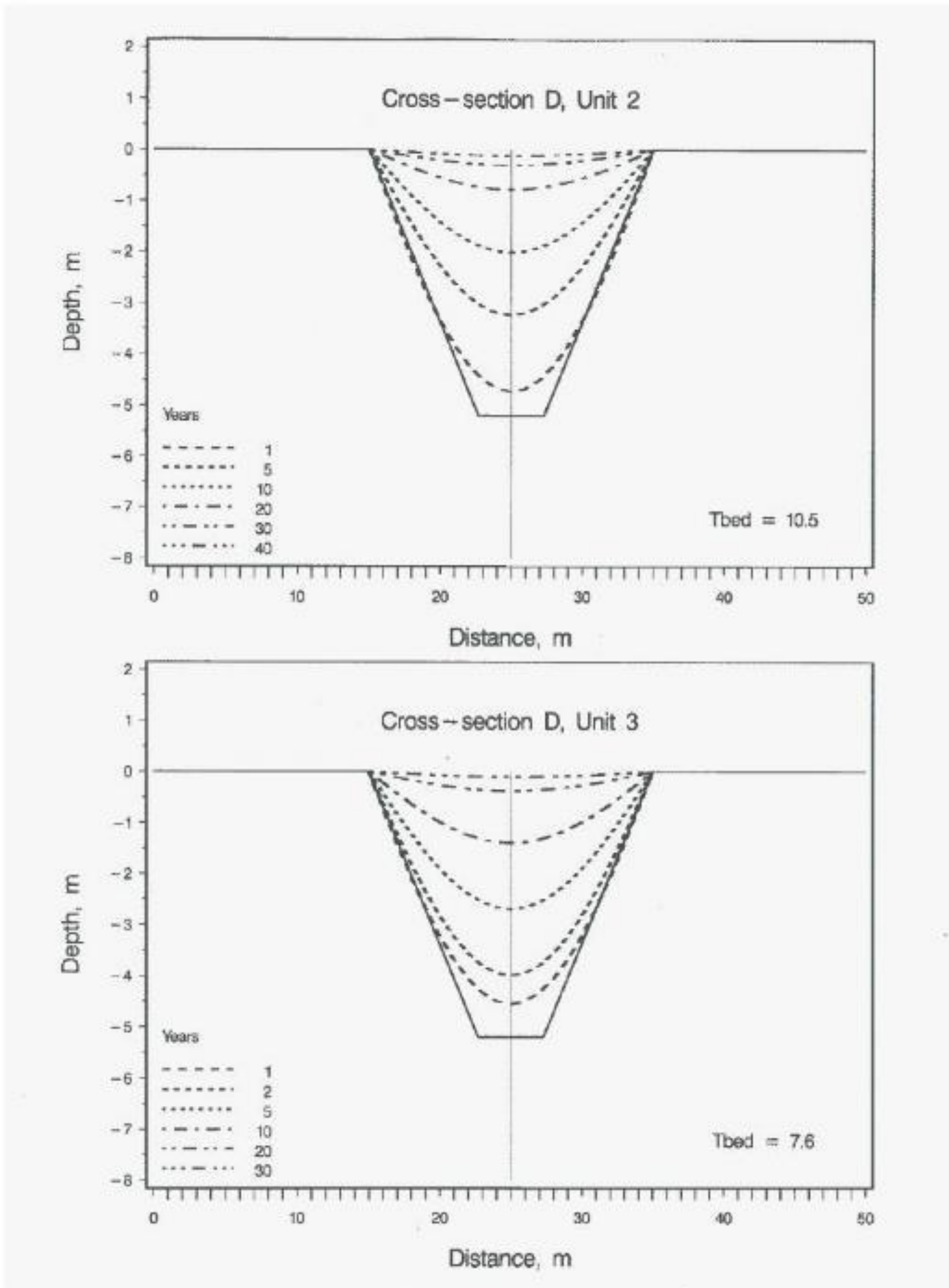

Figure G-4. Estimated trench infill over time for cross-section D with 1:1.5 slope.

H

Appendix H: MBC Applied Environmental Sciences. 2017. San Onofre Nuclear Generating Station Units 2 & 3 Diffuser Corridor Characterization Survey