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Al Bates
Manager
Regulatory Affairs

10 CFR 50, Appx. I

May 12, 2022

ATTN: Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Subject: **Docket Nos. 50-206, 50-361, 50-362 and 72-41**
2021 Annual Radiological Environmental Operating Report
San Onofre Nuclear Generating Station (SONGS), Units 1, 2 and 3 and Independent Spent Fuel Storage Installation

In accordance with the San Onofre Nuclear Generating Station (SONGS) Licensee Controlled Specification 5.7.1.2, Southern California Edison (SCE) is submitting the 2021 Annual Radiological Environmental Operating Report (AREOR) for SONGS Units 1, 2 and 3. The AREOR covers the operation of SONGS during January 1, 2021 through December 31, 2021 and includes summaries, interpretations, and analyses of trends of the results of the Radiological Environmental Monitoring Program (REMP).

In addition, the AREOR includes the results for direct radiation monitoring near the Independent Spent Fuel Storage Installation.

There are no commitments in this letter or the enclosure.

If you have any questions, please contact me at (949) 368-7024.

Sincerely,

Enclosure: 2021 San Onofre Nuclear Generating Station Annual Radiological Environmental Operating Report

cc: S. A. Morris, Regional Administrator, NRC Region IV
A. M. Snyder, NRC Project Manager, SONGS Units 1, 2 and 3
R. K. Lupo, California Department of Public Health

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ENCLOSURE

2021 San Onofre Nuclear Generating Station
Annual Radiological Environmental Operating Report

San Onofre Nuclear Generating Station
2021
Annual Radiological Environmental Operating Report

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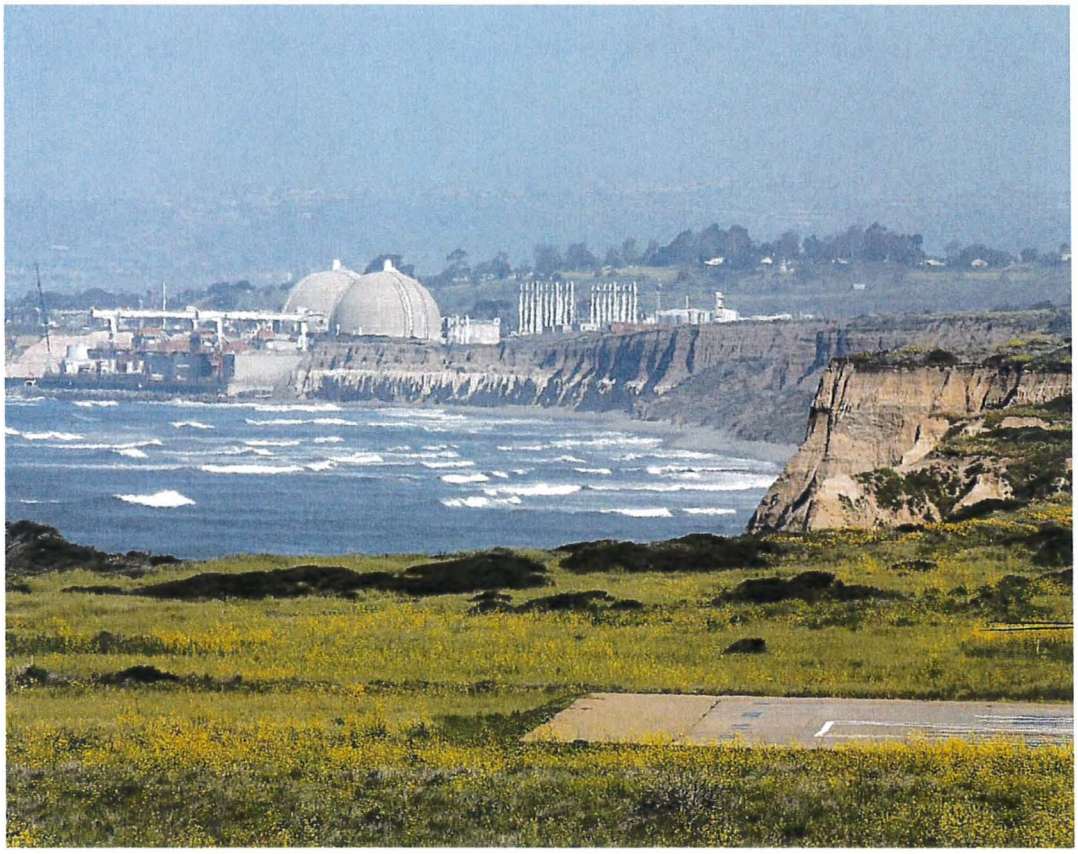

This 2021 Annual Radiological Environmental Operating Report (AREOR) for the San Onofre Nuclear Generating Station (SONGS) fulfills the requirements of the SONGS Licensee Controlled Specification 5.7.1.2 and the Independent Spent Fuel Storage Installation (ISFSI) facility. The 2021 AREOR covers the results of the environmental monitoring performed around SONGS during the time period January 1, 2021 through December 31, 2021.

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Acronyms

AREOR	Annual Radiological Environmental Operating Report
ARERR	Annual Radioactive Effluent Release Report
CDPH	California Department of Public Health
CEAL	Contracted Environmental Analysis Laboratory
DOE	Department of Energy
EAB	Exclusion Area Boundary
EPA	U.S. Environmental Protection Agency
ISFSI	Independent Spent Fuel Storage Installation
LCS	Licensee Controlled Specifications
LLD	Lower Limit of Detection
LUC	Land Use Census
MDC	Minimum Detectable Concentration
ND	Not Detectable
NEI	Nuclear Energy Institute
NRC	U.S. Nuclear Regulatory Commission
ODCM	Offsite Dose Calculation Manual
QA	Quality Assurance
QC	Quality Control
REMP	Radiological Environmental Monitoring Program
TLD	Thermoluminescent Dosimeter

1 Executive Summary

On June 12, 2013, Southern California Edison notified the Nuclear Regulatory Commission (NRC) that it had permanently ceased operation for both Units 2 & 3 on June 7, 2013. While all power operations have ceased, spent fuel remains stored on site. San Onofre Nuclear Generating Station (hereafter referred to as San Onofre or SONGS) continues to fulfill its regulatory commitment to monitor the environment and potential exposure pathways. The Radiological Environmental Monitoring Program (REMP) supports the conclusion that San Onofre has had an inconsequential radiological impact on the environment and that it is well within applicable state and federal regulations.

The REMP includes the sampling of environmental media and measuring radiation levels in the environment surrounding SONGS. Its purpose is to identify any levels of radioactivity or radiation associated with SONGS that have a potential exposure to a member of the general public. This is accomplished through the measurement of direct radiation and by the sampling and analysis of various environmental media, including:

- air particulate
- direct radiation (TLDs)
- local crops
- ocean water
- non-migratory marine species
- shoreline sediment (beach sand)
- ocean bottom sediments

Samples are analyzed for both naturally occurring and SONGS plant-related radionuclides. A detailed description of the 2021 sample types and locations are included in Appendix A of this report.

The California Department of Public Health (CDPH) Drinking Water and Radiation Laboratory participated in an inter-laboratory split sampling program with SONGS, including ocean water tritium samples and gamma isotopic samples from various environmental media. The results are discussed in Appendix C. The CDPH also conducted a direct radiation (TLD) monitoring program in conjunction with SONGS. Refer to Appendix G.

This report describes the REMP as conducted at SONGS during the period from January 1, 2021 through December 31, 2021. The REMP produces scientifically defensible data indicating SONGS had no significant radiological environmental impact in 2021. This report fulfills applicable license commitments, as described in the Offsite Dose Calculation Manual (ODCM).

Beyond the immediate area of the ISFSI, the REMP data collected during 2021, as in previous years, continues to be representative of background levels. The data is summarized in the Statistical Summary of REMP Data found in Appendix B. As in previous years, cesium-137 (Cs-137) was identified in soil and fish. Cs-137 in soil is attributable to fallout from nuclear weapons testing and sources external to SONGS, such as the Chernobyl accident. The Cs-137 in fish is consistent with concentrations detected in other West Coast marine species and may be attributable to the legacy Pacific Ocean discharges from Fukushima. Cs-137 has been detected at indicator locations, as well as at control locations, in past years. Naturally occurring radionuclides, including beryllium-7 (Be-7), potassium-40 (K-40), thorium-228 (Th-228) and thorium-230 (Th-230) were detected in both control and indicator locations at similar concentrations and are not related to SONGS.

Background radiation includes both natural and manmade contributions. Natural background is comprised of the terrestrial and cosmic radiation sources while manmade background results from past weapons testing fallout and routine medical applications. Prior to the construction of SONGS Units 2 & 3, environmental samples and measurements were collected and analyzed to determine the baseline radiation levels. The results from the indicator stations are compared to this pre-operational data, as well as control samples, to evaluate if changes in any radiation levels can be attributed to SONGS or other causes such as natural variations in the environment or manmade contributions external to SONGS.

In summary, the environmental monitoring data collected during 2021 supports a conclusion of no adverse effect on the population or the environment from SONGS. The radiation exposures to people living in the surrounding area from SONGS remain less than the detection level, and are a small fraction of the radiation exposures in the environment from the natural background from terrestrial and cosmic radiation.

2 Radiological Environmental Monitoring Program

Program Overview

The purpose of the REMP is to characterize the radiological environment outside of the Site Boundary and to detect potential radiological impacts resulting from activities at SONGS Units 2 & 3. The REMP monitors credible pathways of exposure to the public and fulfills the radiological environmental monitoring requirements of the ODCM.

Exposure pathways are the different routes by which people can potentially be exposed to radiation or radioactive materials. The pathways may be characterized into four general types, shown below along with a brief description of the monitoring as performed at SONGS:

- **AIRBORNE**. The airborne pathway represents the inhalation intake of airborne radioactive materials. This pathway is sampled in areas around SONGS by continuously drawing air through specialized filters 24 hours a day, 7 days a week. Although both units at SONGS ceased operation in June 2013, these air samples continue to be collected on a weekly basis.
- **WATERBORNE**. The waterborne pathways include the exposure to radioactive materials accumulated in surface water, ocean bottom sediment, and shoreline sediments. Ocean water is monitored through the collection of monthly samples in the environment around the plant. Sediment samples are collected to evaluate any long-term buildup in the environment.
- **INGESTION**. The ingestion pathways include both terrestrial and marine categories.

  The terrestrial ingestion pathway includes broadleaf vegetation, agricultural products, and food products. Atmospheric releases from the plant can deposit on these food products, representing an intake exposure pathway through the consumption of these food products. Semiannual samples of crops (e.g., tomato, lettuce, sorrel) are collected from the local area around the plant to evaluate any impact on the terrestrial ingestion pathway.

  The marine ingestion pathway includes marine biota (fish, shellfish). Liquid waste discharges can be incorporated into these biota. Semiannual fish and invertebrate samples are used to evaluate any impact on the marine ingestion pathway.
- **DIRECT RADIATION**. The direct radiation pathway represents external exposure from sources on the plant site and directly from any radioactive effluents released to the air or water. This direct environmental radiation dose is measured through the use of direct measurement dosimeters, such as thermoluminescent dosimeters (TLDs) that are placed around the plant site and in the local environment.

Site Area and Description

San Onofre Nuclear Generating Station is located next to San Onofre State Beach, adjoining Camp Pendleton Marine Corps Base, in San Diego County, 64 miles south of Los Angeles, California. At this time there are no operating reactors, but in the past, there were three operating pressurized water reactors with a total rated capacity of 2664 net megawatts electrical.

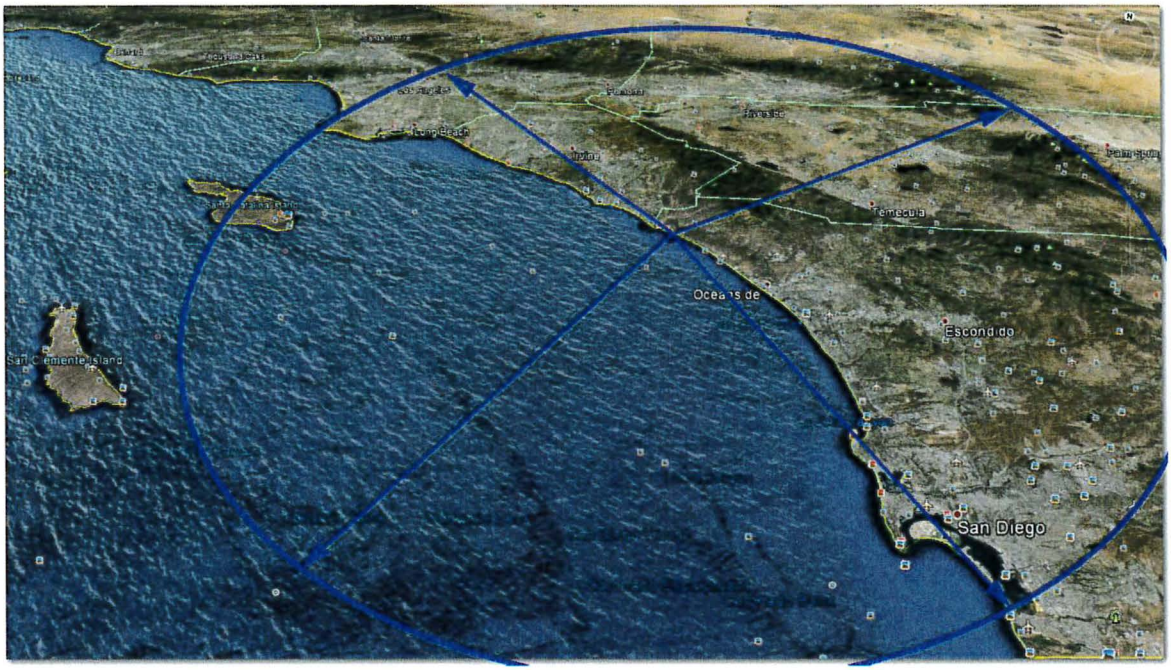

Figure 1 - SONGS 45 mile REMP Radius

Unit 1, rated at 410 net megawatts electrical, was supplied by Westinghouse Electric Company. Unit 1 began commercial operation on January 1, 1968. The unit was permanently shut down on November 30, 1992, and all above-ground structures have been dismantled. By August 31, 2004, all fuel was transferred to the ISFSI. By November 29, 2006, all remaining monitored effluent pathways were permanently removed from service or routed to Unit 2 discharge to the outfall. The remaining portions of Unit 1 are owned by Southern California Edison (80%) and San Diego Gas and Electric (20%).

Unit 2 and Unit 3 were supplied by Combustion Engineering, Inc., with turbine generators supplied by G.E.C. Turbine Generators, Ltd., of England. The units began commercial operation in August 1983, and April 1984, respectively, and were rated at 1127 net megawatts electrical each. The twin units are owned by Southern California Edison (78.21%), San Diego Gas and Electric (20%), and the City of Riverside (1.79%).

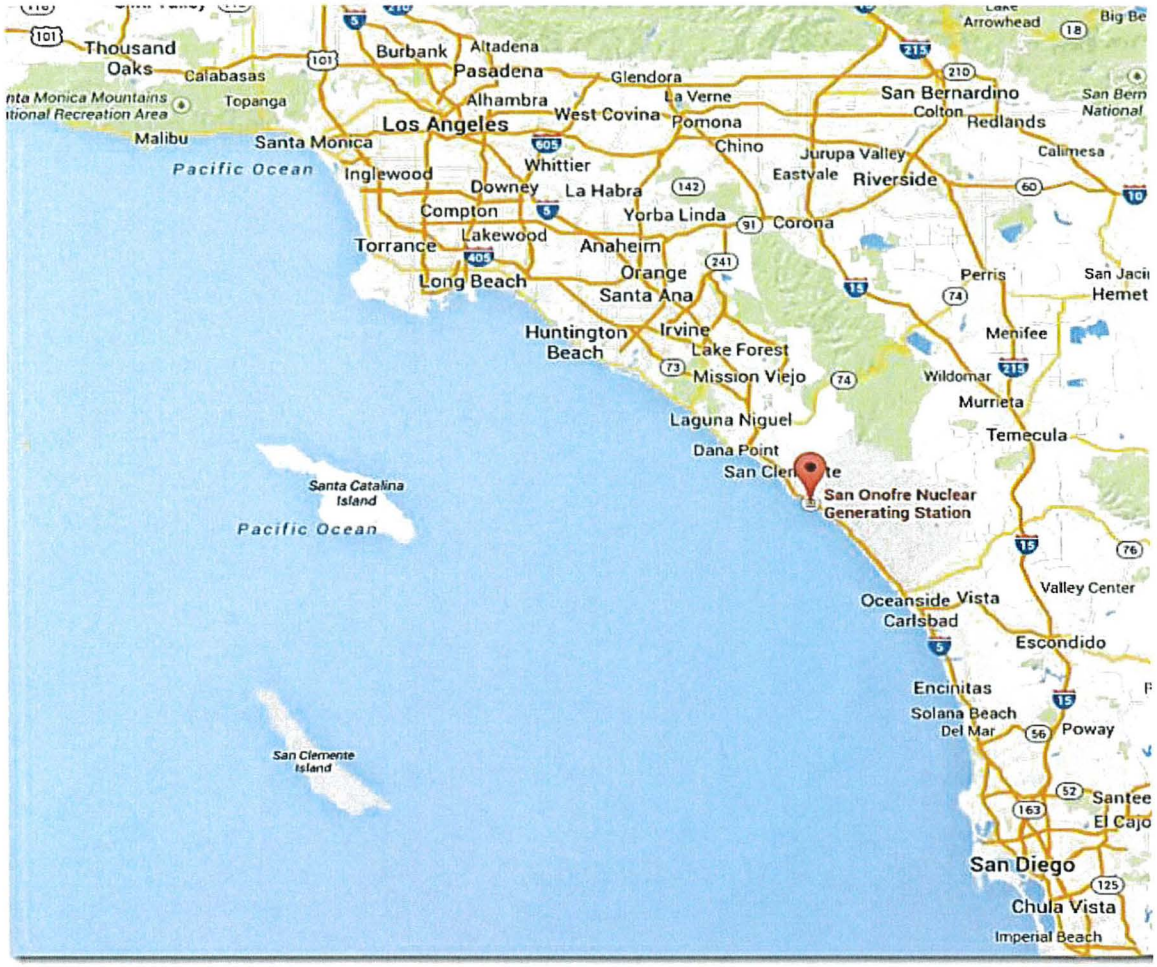

Figure 2 - SONGS Location

Effective December 29, 2006, the City of Anaheim transferred its ownership interests in San Onofre Units 2 & 3 and the entitlement to the Units 2 & 3 output to Southern California Edison Company, except that it retains its ownership interests in its spent nuclear fuel and the ISFSI for Units 2 & 3 located on the facility's site. In addition, the City of Anaheim retains financial responsibility for its spent fuel and for a portion of the Units 2 & 3 decommissioning costs. The City of Anaheim remains a licensee for purposes of its retained interests and liabilities. Southern California Edison notified the NRC on June 12, 2013, that it had permanently ceased operation of Units 2 & 3 on June 7, 2013. The NRC notification, called a Certification of Permanent Cessation of Power Operations, set the stage for SCE to begin preparations for decommissioning. In a letter to the NRC dated August 7, 2020, SCE certified that all spent fuel had been removed from the Spent Fuel Pools of Units 2 & 3 and on August 10, 2020 SCE had put in place programmatic changes that were previously approved by the NRC for ISFSI-Only operation. SCE continues to monitor environmental conditions in accordance with 10 CFR 50, Appendix I.

Sample Collection and Analyses

Samples of environmental media were obtained in accordance with the requirements of the ODCM to meet the regulatory requirements. Refer to Appendix A for a complete list of REMP sample locations as described in Table 5-4 of the ODCM.

Indicator samples close to SONGS are compared to control samples located in areas that are beyond the measurable influence of San Onofre. The control sample results are considered representative of background levels with no potential contribution from releases and sources at SONGS. The control stations also serve as indicators of radioactive sources unrelated to activities at SONGS, such as remote sewage plant discharges of nuclear medicine applications or radioactive material attributable to external sources (legacy fallout from nuclear weapons, the nuclear accident at Chernobyl, and the nuclear accident at Fukushima). The indicator location samples are used to detect environmental radioactivity attributable to SONGS. Indicator sample locations can be located either onsite or offsite.

The SONGS REMP is conducted in accordance with a Quality Assurance Program, meeting the requirements of NRC Regulatory Guide 4.15, Rev. 1. Samples are collected using approved methods; radiochemical analyses of these samples are performed using standardized analytical methods. The Contracted Environmental Analysis Laboratory (CEAL) participates in an inter-laboratory comparison program in partial fulfillment of the quality assurance requirements for environmental monitoring. The CEAL participated in cross check programs which meet the intent of Reg. Guide 4.15. See Appendix C for additional details.

Detection Limit Terminology

The NRC requires that equipment and analytical methods used for radiological monitoring must be able to detect specified minimum limits for the type sample and the radionuclide of the analysis. The *a priori* detection capability for the analytical system used for the measurement is referred to as the Lower Limit of Detection (LLD). This LLD ensures that radiation measurements are sufficiently sensitive to detect any levels of concern and small changes in the environment. Samples with no detectable radiation levels are typically referred to as less than the Minimum Detectable Concentration (MDC). The MDC is evaluated for each sample and is used to ensure that the specific analysis has sufficient sensitivity to detect levels consistent with the requirements for analysis by the system LLD. For a more thorough discussion, refer to NUREG/CR-4007.

- **Lower Limit of Detection (LLD)** - The LLD is the *a priori* (before the fact) lower limit of detection for the method used for the analysis. It is a measure of the detection capability for the analytical method and not for any single sample analysis. This value is calculated for each isotope and every matrix based on typical or expected values of decay time, sample size, counter efficiency, etc. The required LLD values are listed in the ODCM and represent the detection capability that the analytical methods must meet for each of the specified sample media.

- **Minimum Detectable Concentration (MDC)** - The MDC is the *a posteriori* (after the fact) lower limit of detection based on actual decay time, measured sample size, and counting efficiency for an individual sample analysis. The MDC is compared to the LLD to verify that the measurement met the ODCM requirements for the maximum value of the LLD for the listed radionuclides. Values flagged by the CEAL as being confirmed above the MDC are presumed to be valid detected levels of radioactivity.

- **Not Detected (ND)** - The term ND refers to TLD data analyzed per ANSI N13.37-2014 (Environmental Dosimetry-Criteria for System Design and Implementation) that is less than the ANSI calculated detection limit above a specific location's baseline. A baseline is calculated per ANSI methods for each specific location because the direct radiation signal is a strong function of very local conditions. If the TLD data for a specific location is less than that specific location's baseline plus the ANSI calculated detection limit, then the value is "ND" for that specific measurement.

The sampling and analyses for the REMP are conducted in accordance with the ODCM and the applicable regulatory requirements.

Regulations and Guidance

10 CFR 50, Appendix I

10 CFR 50, Appendix I establishes the per unit limits on releases of radioactivity to the environment and the resulting dose to the public. These limits are more restrictive than the 10 CFR 20 limits. The 10 CFR 50, Appendix I limits are:

Source	NRC Limits for SONGS
Liquid Effluent	Less than or equal to 3 mrem/yr to whole body from all pathways of exposure
	Less than or equal to 10 mrem/yr to any organ from all pathways of exposure
Gaseous Effluents – Noble Gases	Less than or equal to 10 mrad/yr gamma air dose
	Less than 20 mrad/yr beta air dose
Tritium and particulates with half-life greater than 8 days	Less than or equal to 15 mrem to any organ for an offsite individual from all pathways of exposure

40 CFR 190

The Environmental Protection Agency (EPA) has established environmental radiation protection standards in 40 CFR 190 for the uranium fuel cycle that includes nuclear power plants. These limits are applicable to the sum of liquid effluent, gaseous effluents and direct radiation.

The dose limits from all applicable pathways to any offsite individual are:

- 25 mrem/year to the whole body
- 75 mrem/year to the thyroid
- 25 mrem to any other organ

As discussed in the 2021 SONGS ARERR, the calculated dose to a member of the public as a result of SONGS is a small fraction of the dose standard established by the EPA. This conclusion is supported by the results of the REMP, as reflected by the absence of measurable levels of radiation or radioactive materials in the offsite environment attributable to SONGS.

Other Guidance

The following regulatory and industry guidance has been identified as applicable to the SONGS REMP.

- US NRC Regulatory Guide 4.1, Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants, 1975
- US NRC Regulatory Guide 4.2, Preparation of Environmental Reports for Nuclear Power Stations, 1976
- US NRC Regulatory Guide 1.109, Calculation of Annual Doses to Man from Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I, 1977
- NUREG-1301, Offsite Dose Calculations Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors, Generic Letter 89-01, Supplement No. 1, 1991
- US NRC Regulatory Guide 4.13, Revision 2, June 2019, Environmental Dosimetry Performance Specifications, Testing, and Data Analysis
- ANSI/HPS N13.37, "Environmental Dosimetry – Criteria for System Design and Implementation", 2014
- US NRC Regulatory Guide 4.15, Rev. 1, Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment, 1979
- NUREG-1576, Multi-agency Radiological Laboratory Analytical Protocols
- NUREG/CR-4007, Lower Limit of Detection: Definition and Elaboration of a Proposed Position for Radiological Effluent and Environmental Measurements, 1984

NRC Reporting Limits

The NRC has established required reporting levels that represent thresholds above which an investigation is needed to evaluate and ensure compliance with radiation safety standards for the public. Licensed nuclear facilities must prepare a special report if any environmental sample value exceeds the corresponding reporting limit. SONGS did not submit any special reports to the NRC in 2021 as no reporting limits were exceeded.

Summary of Analysis of Results and Trends

The 2021 SONGS REMP was conducted in accordance with 10 CFR 50, Appendix I, the SONGS LCS and Section 5.0 of the SONGS ODCM. The REMP sample data have been summarized in the format specified in NUREG-1301. Data have been evaluated to identify the levels of any plant-related environmental radioactivity above background levels (i.e., plant-related contributions that are distinguishable from background). For data distinguishable from background, a comparison has been made between current environmental monitoring results and pre-operational or previous operational data as appropriate, for trending environmental radioactivity.

To conform with 10 CFR 50, Appendix I, Section IV B.2, data on measurable levels of radiation and radioactive materials in the environment are provided to allow for a comparison to the predicted (calculated) values in the environment from radioactive material released in effluents.

The tabulated means, ranges, and standard deviations are presented in Appendix B. Comparisons with background and pre-operational baseline data are presented in Appendix D.

The REMP data are reviewed for accuracy and are compared against NRC reporting levels. Measurements exceeding the administrative levels (10% of the NRC reporting levels) are flagged. Analyses are performed using instrumentation and methods that provide analytical results with a level of detection as required by the ODCM. The *a posteriori* MDC is compared to the maximum value for the *a priori* LLD specified in the ODCM. This ensures that regulatory limits for the maximum LLD are met.

Table 1 - Maximum LLDs as Specified in SONGS ODCM

Analysis	Water (pCi/L)	Airborne Particulate or Gases (pCi/m^3)	Marine Animals (pCi/kg, wet)	Local Crops (pCi/kg, wet)	Sediment (pCi/kg, dry)
Gross beta	4	1E-02			
H-3	3000				
Mn-54	15		130		
Co-58, 60	15		130		
Zn-65	30		260		
Cs-134	15	5E-02	130	60	150
Cs-137	18	6E-02	150	80	180

The impact of SONGS on the surrounding environment is assessed through a series of analyses. These analyses include: comparisons of indicator to control locations (Appendix B); comparison of 2021 REMP data to historical environmental data (Appendix D); and the summary of deviations from sampling requirements and corrective actions taken (Appendix E).

A detailed discussion of the 2021 analytical results is presented in this report. Analytical values from offsite indicator sample stations continue to trend with the control stations. The data indicate that SONGS had no significant radiological impact on the environment during 2021. In addition, dose to members of the public attributable to SONGS-related radiological activities remain well below regulatory limit of 100 mrem per year, as specified in 10 CFR 20.1301 and in keeping with the philosophy of "as low as is reasonably achievable" (ALARA), as specified in 10 CFR 20.1101(b).

The data are summarized in the Statistical Summary of REMP Data found in Appendix B. The level of Cs-137 found in control and indicator samples is consistent with historical and expected data. The Cs-137 is attributable to fallout from legacy atmospheric nuclear weapons testing, to fallout from Chernobyl, and to the legacy Fukushima discharges into the Pacific Ocean. Naturally occurring radionuclides, including beryllium-7 (Be-7), potassium-40 (K-40), thorium-228 (Th-228) and thorium-230 (Th-230) were detected in both control and indicator locations at similar concentrations and are not related to SONGS. Refer to Appendix B for a more detailed discussion.

3 Land Use Census Results

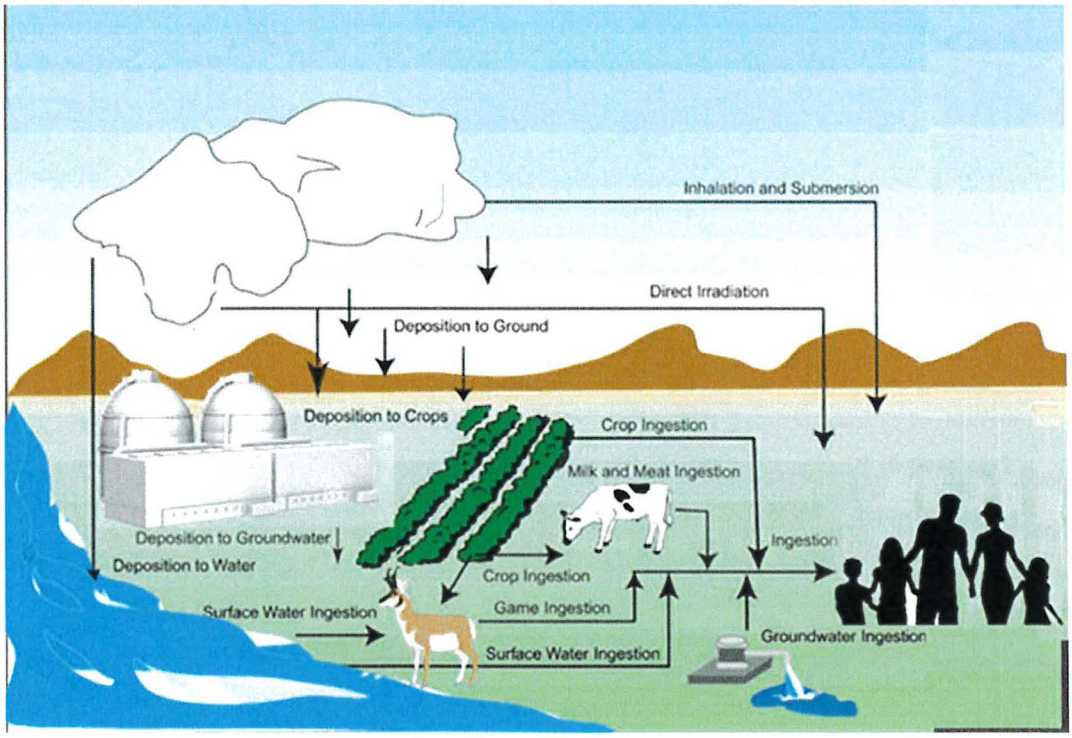

Figure 3 - Examples of Exposure Pathways

In accordance with the ODCM, each year a Land Use Census (LUC) is performed to identify any changes in the use of areas at and beyond the site boundary. Modifications to the monitoring program may be made if the LUC identifies either new pathways of exposure, or significant changes to the existing pathways around the plant. The 2021 LUC did not identify any new pathways.

Summary of Changes to the LUC:

The 2021 LUC did identify minor changes to the occupancy and location of some existing receptors. The critical receptor and critical locations for each exposure pathway remained the same as those from 2020.

Land Use Changes identified in the 2021 LUC report:

- The Camp San Onofre wastewater treatment plant (LUC # O-10) was not operational for all of 2021. This facility has been placed in long term standby and is no longer an employment location. It is being retained in the data pending possible future use.
- A new host location was established in the San Onofre State Park campground. Two hosts occupy the area for six months each - although not at a permanently assigned location. The location is variable because this host does not have hookups. Since a permanent specific site has not been established for this employment location the occupancy is conservatively included in the occupancy for the San Onofre State Park camper location, 1.8 mi SE (LUC # O-2).
- The Endless Summer Surf Camp was open from June 7 until September 20, 2021. It was not open in 2020.

4 Quality Assurance

A portion of REMP sampling activity is devoted to quality assurance. All REMP activities, including support contractors, are assessed as defined in Regulatory Guide 4.15, Rev. 1. The quality assurance program's main aspects include process quality control, instrument quality control, comprehensive data reviews, cross-check analyses, and audits. Routine REMP assessments ensure that the program, procedures and personnel are performing satisfactorily. Samples are collected using approved methods; radiochemical analyses of these samples are performed using standardized analytical methods. Quality audits and independent technical reviews help determine areas that need attention. These areas are addressed in accordance with the station's Corrective Action Program. See Appendix C for detailed QA measurement data.

The CDPH participates in a split sampling program in accordance with the site's REMP procedures. Duplicate radiological split sampling is performed by SONGS to demonstrate repeatability of the sample collection, preparation, and analysis process. Split sample analysis is performed for the evaluation of the precision and bias trends of the method of analysis without the added variables introduced by sampling. The 2021 CDPH data resulted in similar conclusions to the 2021 SONGS REMP data.

GEL Laboratories, LLC (GEL) performs the radiochemistry analysis of samples noted within this report. GEL performs the requested analysis under its Quality Assurance Program, which meets the requirements of 10 CFR 50, Appendix B, ASME NQA-1 and Regulatory Guide 4.15 Revision 1. The measurement capabilities of the radiological laboratory are demonstrated by participating in an inter-laboratory measurement assurance program and performing duplicate and split sample analyses. Approximately 10% of the analyses performed are quality control samples, consisting of inter-laboratory measurement assurance program samples, duplicate samples, and split samples. The inter-laboratory measurement assurance program provides samples that are similar in matrix and size to those sampled and measured by the REMP. This program assures that equipment calibrations and sample preparation methods accurately measure radioactive material in samples.

Stanford Dosimetry performs the environmental TLD analyses noted in this report. Stanford Dosimetry performs the requested analyses under its Quality Assurance Program which meets the requirement of 10 CFR 50, Appendix B, ASME NQA-1, Regulatory Guide 4.15 Revision 1 and Regulatory Guide 4.13 Revision 2 (Environmental Dosimetry – Performance Standards, Testing and Data Analysis).

5 Program Deviations

Any deviation in the conduct of the program as required, either in terms of sample collection or analysis, requires an investigation as to the cause and identification of measures to prevent recurrence. Deviations from the sampling program or sensitivity requirements are acknowledged and explained in Appendix E to this report.

6 Conclusion

Radiological environmental data collected throughout 2021 have been evaluated to determine if SONGS had any measurable impact on the surrounding environment.

The Cs-137 detected in soil and fish is due to factors external to SONGS. The Cs-137 in soil is attributable to the legacy fallout from nuclear weapons testing and to the fallout from the Chernobyl accident. The Cs-137 in fish is attributable to the legacy discharges to the Pacific Ocean from Fukushima. The work process at SONGS during 2021 had no significant radiological impact on the environment.

7 References

1. SONGS Offsite Dose Calculation Manual (ODCM), Section 5.0.

2. SONGS Radiological Monitoring (RM) Procedures established for the Radiological Environmental Monitoring Program.

3. NUREG/CR-4007, "Lower Limit of Detection: Definition and Elaboration of a Proposed Position for Radiological Effluent and Environmental Measurements," August 1984.

4. The Procedures Manual of the Environmental Measurements Laboratory (US DOE HASL-300)

APPENDIX A. SAMPLE TYPE AND SAMPLING LOCATIONS

Notes used for Table 2 through Table 10:

a Distance (miles) and Direction (sector) are measured relative to Units 2/3 midpoint as described in the ODCM. Direction determined from degrees true north.

b Distances are within the Units 2/3 Exclusion Area Boundary (EAB)

c Soil samples are not required by the SONGS ODCM.

d Kelp samples are not required by the SONGS ODCM.

MCB = Marine Corps Base (Camp Pendleton)

Table 2 - Direct Radiation Measuring Locations

DIRECT RADIATION MEASURING LOCATION		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
1	City of San Clemente (Former SDG&E Offices) (Control)	5.7	NW
2	Camp San Mateo – (MCB, Camp Pendleton)	3.6	N
3	Camp San Onofre – (MCB, Camp Pendleton)	2.8	NE
4	Camp Horno – (MCB, Camp Pendleton)	4.4	E
6	Old El Camino Real (AKA Old Highway 101)	3.0	ESE
8	Noncommissioned Officers' Beach Club	1.4	NW
10	Bluff	0.7	WNW
11	Former Visitors' Center	0.4[b]	NW
12	South Edge of Switchyard	0.2[b]	E
13	Southeast Site Boundary (Bluff)	0.4[b]	ESE
15	Southeast Site Boundary (Office Building)	0.1[b]	SSE
16	East Southeast Site Boundary	0.4[b]	ESE
19	San Clemente Highlands	4.9	NNW
22	Former US Coast Guard Station - San Mateo Point	2.7	WNW
23	SDG&E Service Center Yard (Control)	8.1	NW
31	Aurora Park - Mission Viejo (Control)	18.6	NNW
33	Camp Talega – (MCB, Camp Pendleton) (Control)	5.9	N
34	San Onofre School – (MCB, Camp Pendleton)	1.9	NW
35	Range 312 – (MCB, Camp Pendleton)	4.8	NNE
36	Range 208C – (MCB, Camp Pendleton)	4.1	NE
38	San Onofre State Beach Park	3.4	SE
40	SCE Training Center – Mesa	0.7	NNW
41	Old Route 101 – East	0.3[b]	E
44	Fallbrook Fire Station (Control)	17.7	E
46	San Onofre State Beach Park	1.0	SE

DIRECT RADIATION MEASURING LOCATION		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
47	Camp Las Flores – (MCB, Camp Pendleton) (Control)	8.6	SE
49	Camp Chappo – MCB (Control)	12.9	ESE
50	Oceanside Fire Station (Control)	15.6	SE
53	San Diego County Operations Center (Control)	44.2	SE
54	Escondido Fire Station (Control)	31.8	ESE
55	San Onofre State Beach (U1 West)	0.2[b]	WNW
56	San Onofre State Beach (U1 West)	0.2[b]	W
57	San Onofre State Beach (Unit 2)	0.1[b]	SW
58	San Onofre State Beach (Unit 3)	0.1[b]	S
59	SONGS Meteorological Tower	0.3[b]	WNW
61	Mesa - East Boundary	0.7	N
62	MCB - Camp Pendleton	0.7	NNE
63	MCB - Camp Pendleton	0.6	NE
64	MCB - Camp Pendleton	0.6	ENE
65	MCB - Camp Pendleton	0.7	E
66	San Onofre State Beach	0.6	ESE
67	Former SONGS Evaporation Pond	0.6	NW
68	Range 210C – (MCB, Camp Pendleton)	4.4	ENE
73	South Yard Facility	0.4[b]	ESE
74	Oceanside City Hall (Backup Control)	15.6	SE
75	Gate 25 MCB	4.6	SE
76	Former El Camino Real Mobil Station	4.6	NW
77	Area 62 Heavy Lift Pad	4.2	N
78	Horno Canyon (AKA Sheep Valley)	4.4	ESE

Table 3 - Airborne Radioactivity Sampling Locations

AIRBORNE (AP) SAMPLING LOCATION		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
1	City of San Clemente (City Hall)	5.1	NW
7	AWS Roof	0.18[b]	NW
9	State Beach Park	0.6	ESE
10	Bluff	0.7	WNW
11	Mesa EOF	0.7	NNW
12	Former SONGS Evaporation Pond	0.6	NW
13	Marine Corp Base (Camp Pendleton East)	0.7	E
16	San Luis Rey Substation (Control)	16.7	SE

Table 4 - Soil Sampling Locations

SOIL SAMPLING LOCATION [c]		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
1	Camp San Onofre	2.8	NE
2	Old Route 101 – (East Southeast)	3.0	ESE
3	Basilone Road / I-5 Freeway Off ramp	2.0	NW
5	Former Visitors Center	0.4[b]	NW
7	Prince of Peace Abbey – Oceanside (Control)	15	SE

Table 5 - Ocean Water Radioactivity Sampling Locations

OCEAN WATER (SW) SAMPLING LOCATION		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
A	Station Discharge Outfall - Unit 1	0.6	SW
B	Outfall - Unit 2	1.5	SW
C	Outfall - Unit 3	1.2	SSW
D	Newport Beach (Control)	30.0	NW

Table 6 - Shoreline Sediment Radioactivity Sampling Locations

SHORELINE SEDIMENT (SSA) SAMPLING LOCATION		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
1	San Onofre State Beach (Southeast)	0.6	SE
2	San Onofre Surfing Beach	0.8	WNW
3	San Onofre State Beach (Southeast)	3.5	SE
4	Newport Beach North End (Control)	29.2	NW

Table 7 - Local Crops Sampling Locations

LOCAL CROPS SAMPLING LOCATION		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
2	Oceanside (Control)	15 to 25	SE to ESE
6	SONGS Garden Mesa EOF	0.7	NNW

Table 8 - Non-Migratory Marine Animal Sampling Locations

MARINE ANIMAL (MOA) SAMPLING LOCATION		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
A	Unit 1 Outfall	0.9	WSW
B	Units 2/3 Outfall	1.5	SSW
C	Laguna Beach (Control)	20 to 25	WNW to NW

Table 9 - Kelp Sampling Locations

KELP SAMPLING LOCATION [d]		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
A	San Onofre Kelp Bed	1.5	S
B	San Mateo Kelp Bed	3.8	WNW
C	Barn Kelp Bed	6.3	SSE to SE
E	Salt Creek (Control)	11 to 13	WNW to NW

Table 10 - Ocean Bottom Sediment Sampling Locations

OCEAN BOTTOM (SEB) SAMPLING LOCATION		DISTANCE[a] (miles)	DIRECTION[a] (Sector)
B	Unit 1 Outfall	0.8	SSW
C	Unit 2 Outfall	1.6	SW
D	Unit 3 Outfall	1.2	SSW
E	Laguna Beach (Control)	20-25	NW
F	SONGS Up-coast	0.9	WSW

Table 11 - Sector and Direction Designations

DEGREES TRUE NORTH FROM SONGS 2 & 3 MIDPOINT			NOMENCLATURE	
Sector Limit	**Center Line**	**Sector Limit**	**22.5° Sector**	**Direction**
348.75	0 & 360	11.25	A	N
11.25	22.5	33.75	B	NNE
33.75	45.0	56.25	C	NE
56.25	67.5	78.75	D	ENE
78.75	90.0	101.25	E	E
101.25	112.0	123.75	F	ESE
123.75	135.0	146.25	G	SE
146.25	157.0	168.75	H	SSE
168.75	180.0	191.25	J	S
191.25	202.5	213.75	K	SSW
213.75	225.0	236.25	L	SW
236.25	247.5	258.75	M	WSW
258.75	270.0	281.25	N	W
281.25	292.5	303.75	P	WNW
303.75	315.0	326.25	Q	NW
326.25	337.5	348.75	R	NNW

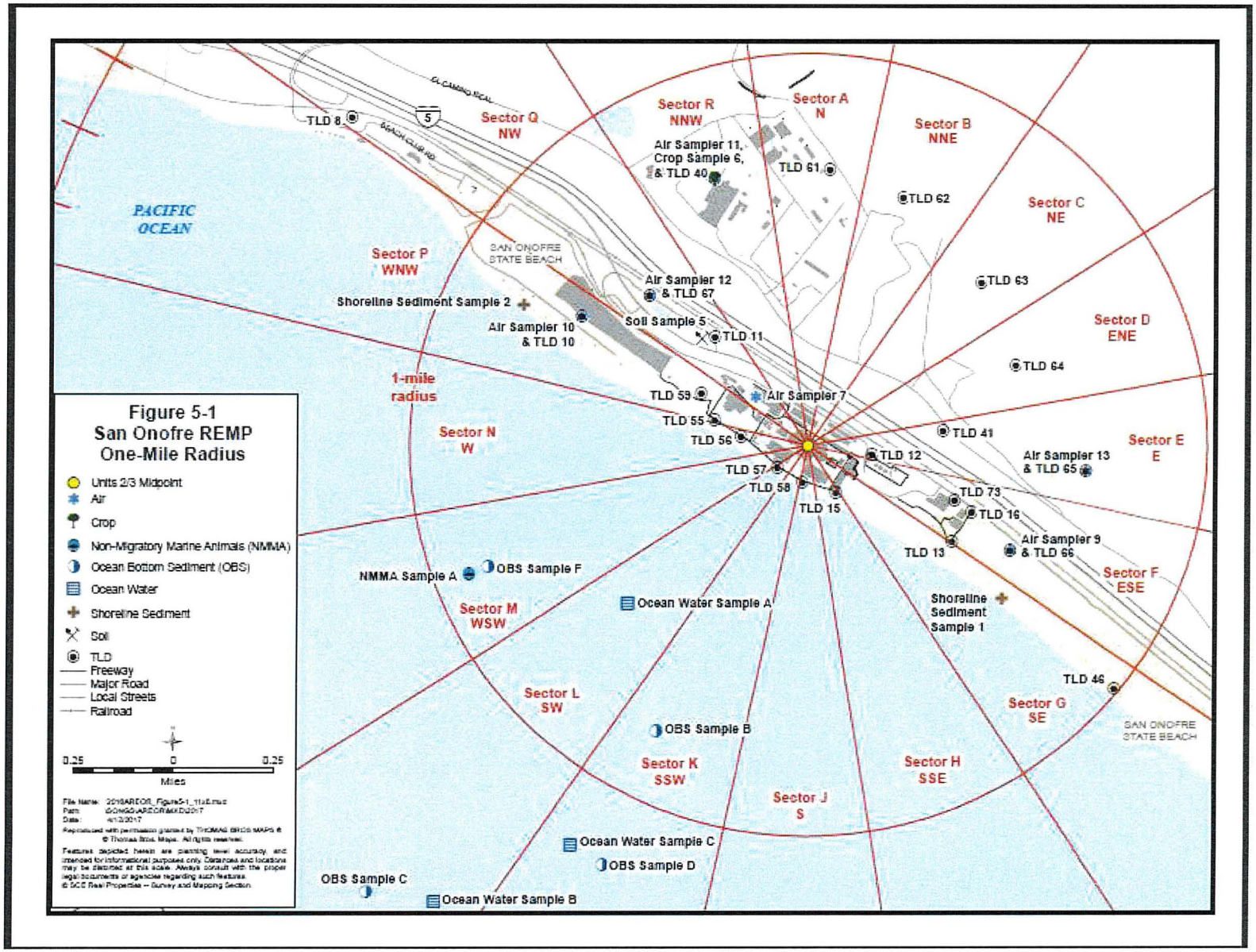

Figure 4 - SONGS REMP One Mile Radius

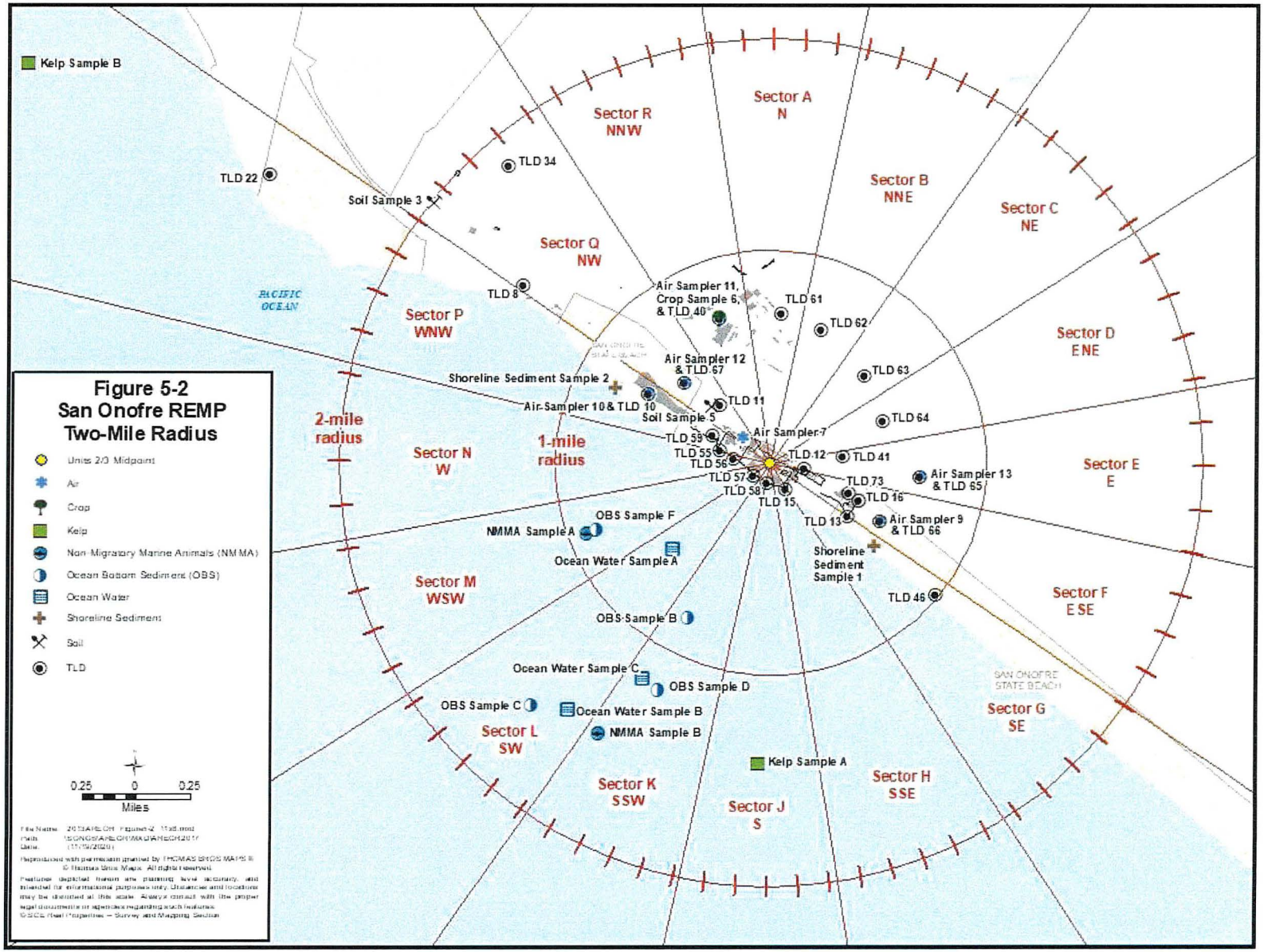

Figure 5 - SONGS REMP Two Mile Radius

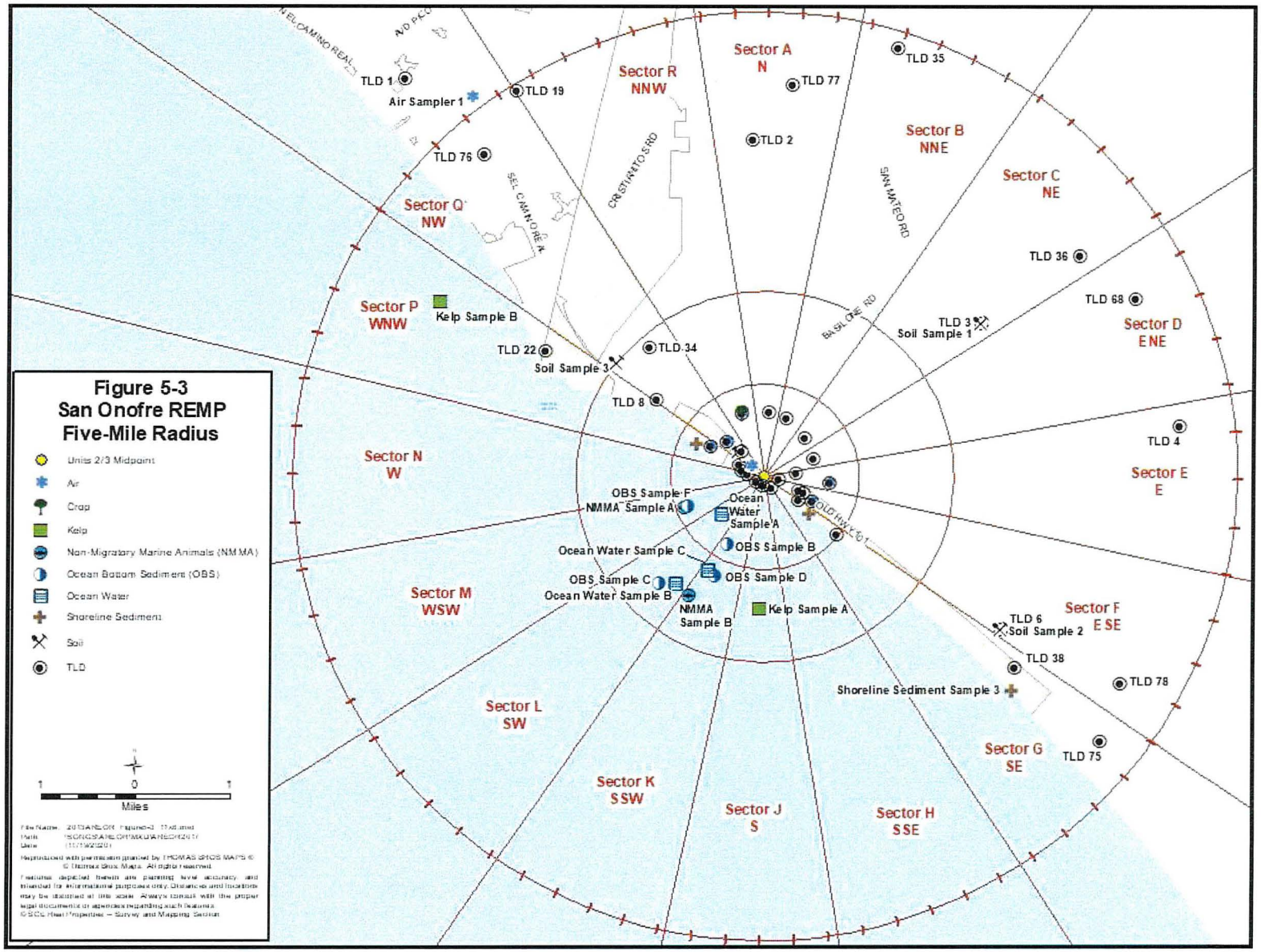

Figure 6 - SONGS REMP Five Mile Radius

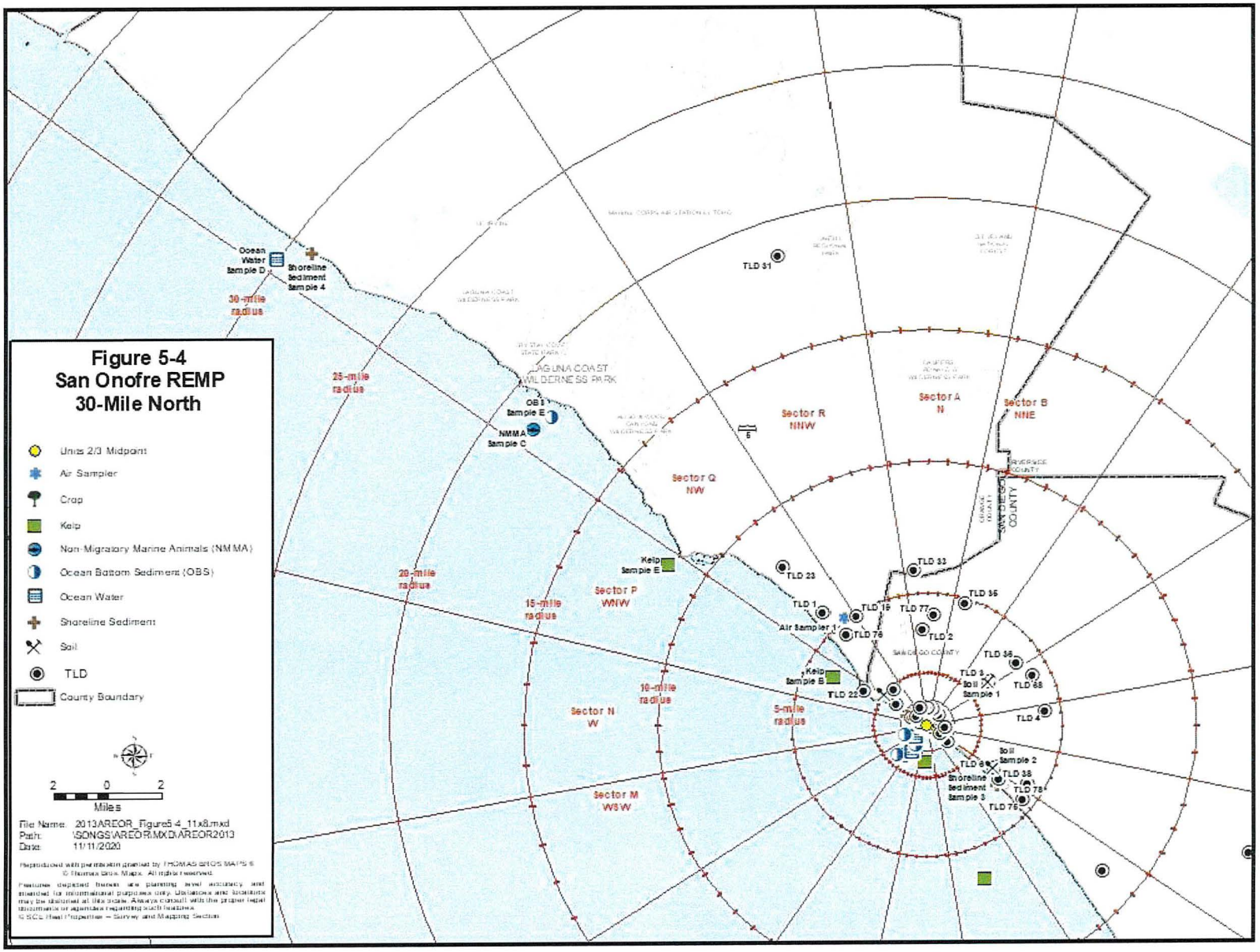

Figure 7 - SONGS REMP 30-mile Radius North

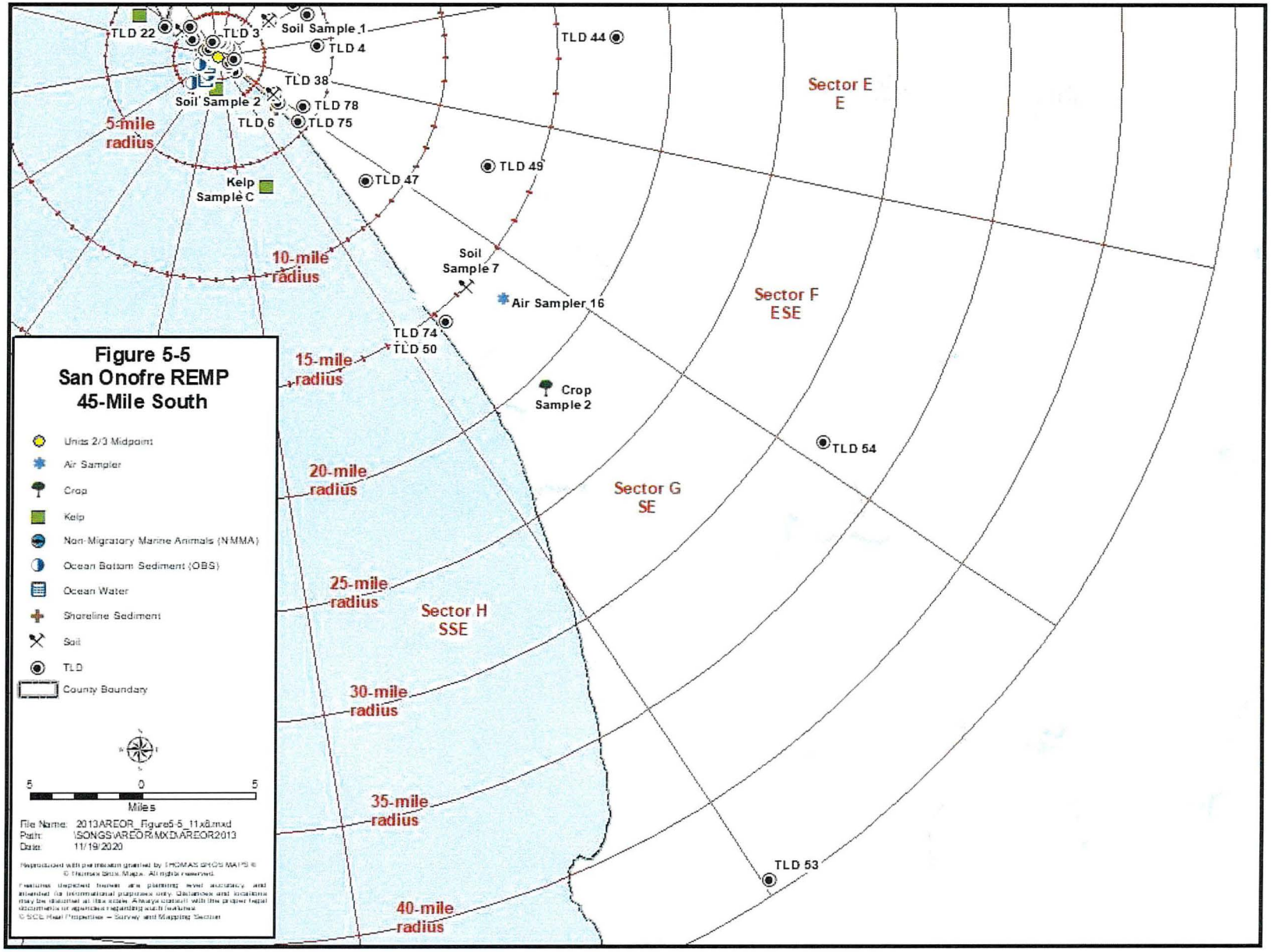

Figure 8 - SONGS REMP 45-mile Radius South

APPENDIX B. RESULTS AND DISCUSSIONS OF 2021 ENVIRONMENTAL DATA

Summary

The 2021 REMP analysis results support the conclusion that the measured levels of radioactivity in samples collected are attributable to sources external to SONGS (fallout and ongoing liquid discharges to the Pacific Ocean from the nuclear accident at the Fukushima Daiichi Nuclear Power Station, Chernobyl, and residual fallout from legacy atmospheric nuclear weapons testing). Cs-137 has been intermittently detected in the indicator and in the control soil samples in past years and no correlation between Cs-137 level in soil and proximity to the plant has been observed. The Cs-137 detected in both indicator and control samples of non-migratory marine animals is attributable to sources external to SONGS. The direct radiation results (from TLD data) are ND (not detected) outside the immediate area of the ISFSI.

Results and Discussions of 2021 Environmental Data

Direct Radiation

Direct gamma radiation is monitored in the environment by calcium sulfate ($CaSO_4$) TLDs placed at 49 locations and analyzed quarterly per the methodology described in Regulatory Guide 4.13 revision 2 (based on ANSI/HPS N13.37-2014, "Environmental Dosimetry – Criteria for System Design and Implementation"). The Annual Public Dose, as referenced in Table 12, is based on the potential exposure for member of the public at the listed locations. For onsite locations, at or near the EAB, the occupancy factor is determined per site procedure for Direct Radiation Exposure Controls and Monitoring. The hypothetical maximum associated exposure to a member of the general public, adjusted for occupancy, is less than the minimum detectable dose as calculated using the ANSI method.

The 2021 quarterly dose measurements (accounting for background) at all TLD locations outside the SONGS EAB were ND. The criteria for establishing a detectable dose, in accordance with Reg. Guide 4.13, is 5 mrem per quarter above the quarterly baseline and 10 mrem per year above the annual baseline for that location. Dose measurements less than these values are reported as ND. In accordance with ANSI N13.37, the annual facility-related dose is calculated using the sum of the four quarterly dose measurements and subtracting the annual baseline. If quarterly data is missing, then the average of the available quarters is substituted for the missing data to determine the annual dose. If occupancy adjustment of a facility-related dose results in < 1 mrem then dose to a member of the public is reported as ND, per ANSI/HPS N13.37-2014, Section 7.3.5. Refer to Table 12 for a summary of all 2021 SONGS REMP TLD data.

The 2021 REMP quarterly dose measurements within the EAB were detectable at TLD 55. REMP TLD 55, (located on the beach walkway between the ISFSI and the ocean), is readily accessible to the general public and had detectable quarterly dose measurements during the last two quarters of 2021. REMP TLD 55 data includes the estimated neutron dose. Elevated doses at TLD 55 may be due to both different background dose characteristics and elevated dose rates due to the ISFSI. Environmental dose determined using TLDs is variable depending on the types of rock and building material near the monitoring location and a long-term background dose cannot be accurately determined for TLDs along the seawall or ISFSI due to potential dose contributions from the site and ISFSI.

The annual dose measurements at TLDs 55, 56, 59, and 73 were also detectable. The detectable dose measurement at TLD 73 (located close to TLD 13) is attributable to the transport, loading and storage of radioactive materials at SONGS. The detectable dose measurements at TLDs 56 (located close to 55) is also attributable to the operation of the ISFSI and possibly increased background due to rocks in the area. The measured dose rates at TLD 59 can be attributed to a locally elevated baseline dose rate at this location. There are no SONGS-related activities near TLD 59 that could account for the elevated dose rate observed here. The area around TLD 59 is not accessible to members of the general public.

Separate TLDs are used to compensate for transit dose and a fade TLD is used to evaluate for the time and temperature dependent "fade" that may affect dosimeter data. After the samples were analyzed, the measured doses were corrected for pre and post field-exposure times.

A neutron dosimeter package was co-located with REMP TLD 55 and at selected ISFSI TLD locations around the ISFSI. Any detected neutron dose was added to the gamma dose to report a total dose for each station with a neutron package. The maximum detected neutron dose at a SONGS ISFSI location in any quarter of 2021 was 3.1 mrem.

The first quarter 2021 data for TLD 55 was not available. In accordance with the ANSI guidance, a normalized annual dose to members of the general public was calculated for TLD 55 based on the three quarters of available data. In addition, two supplemental dosimeters were deployed at two locations between TLD 55 and 56 along the seawall. Data from the supplemental locations was available for all of 2021. The empirical data gathered from these four locations immediately adjacent to the ISFSI indicate that dose to a member of the general public was less than one millirem per year based on the estimated occupancy at this location as per the ANSI guidance.

Direct Radiation baseline evaluation and estimation of natural background

An in-depth baseline exposure analysis of the environmental radiation results for the period of 2001 through 2010 was completed for all the REMP TLD monitoring locations. It was determined that if the standard deviation was low and no additional exposure above background was identified at a particular station, the average of that station's radiation exposure results should be equal to natural background (baseline) at that location. The baseline results for REMP TLDs have been summarized with the annual and quarterly values in Table 12.

Natural background radiation is variable and a minor shift in location can yield a measurable change in background radiation, depending on concentrations of natural radioactive materials in the area such as rocks and soil or building materials. Therefore, if a TLD is moved, the baseline (background) for that location may be affected. The natural direct gamma radiation varies according to location because of differences in the natural radioactive materials in the soil, soil moisture content, buildings, and other factors.

The baseline environmental exposure analysis included an assessment of the standard deviation of the quarterly results and annual totals at each location. This is an appropriate methodology to determine the ability to detect radiation exposure above background, described in ANSI/HPS N13.37-2014. The 2021 quarterly and annual results expressed in Table 12 are positive exposures if they exceed either 5 mrem above the baseline quarterly or 10 mrem above the baseline annually. If not, the measurement is noted as ND.

In 1980 the Department of Energy (DOE) conducted an Aerial Radiological Survey of SONGS and the surrounding area. The currently used baseline/background value of 15.8 mrem per standard quarter within the SONGS EAB is consistent with the 1980 gamma exposure rates reported by the DOE for the areas immediately north and south of SONGS, taking into account the reduction in environmental radioactivity and background dose rates caused by the decay of atmospheric nuclear weapons testing fallout since 1980.

An empirical determination of the baseline background dose for stations within the EAB is not possible due to the known plant-related radiological activities (e.g., storage and transport of radioactive materials) that occurred during the baseline calculation study period. The average of nearby proxy locations outside the EAB was used to estimate the baseline within the EAB. A value of 15.8 mrem per quarter was determined as the appropriate baseline for the REMP stations located within the EAB. However, local baseline variations within the EAB are possible because the baseline study period did not predate the introduction of licensed material to the REMP TLD locations within the EAB.

Table 12 - SONGS REMP TLD Data

TLD (SCE-##)	Location	Distance (miles)	Qtr. Baseline (mrem)	2021 Quarterly Results (mrem)				Baseline Adjusted Quarterly Results (mrem)				Ann. Baseline (mrem)	Annual Total (mrem)	Annual Facility Dose (mrem)	Annual Public[e] Dose (mrem)
				1	2	3	4	1	2	3	4				
1	City of San Clemente	5.7	18.4	**18.9**	**17.7**	**17.9**	**19.8**	**ND**	**ND**	**ND**	**ND**	73.6	**74.3**	**ND**	**ND**
2	Camp San Mateo – MCB	3.6	19.6	**19.1**	**18.8**	**19.4**	**21.5**	**ND**	**ND**	**ND**	**ND**	78.2	**78.9**	**ND**	**ND**
3	Camp San Onofre – MCB	2.8	17.2	**17.3**	**16.3**	**17.4**	**18.5**	**ND**	**ND**	**ND**	**ND**	69.0	**69.4**	**ND**	**ND**
4	Camp Horno – MCB	4.4	19.0	**17.7**	**17.3**	**18.0**	**19.5**	**ND**	**ND**	**ND**	**ND**	76.1	**72.6**	**ND**	**ND**
6[f]	Old Route 101 (ESE)	3.0	12.0	**11.4**	**-**	**11.4**	**14.5**	**ND**	**ND**	**ND**	**ND**	47.9	**49.7**	**ND**	**ND**
8	Noncommissioned Officers' Beach Club	1.4	16.2	**15.6**	**15.1**	**15.1**	**16.8**	**ND**	**ND**	**ND**	**ND**	64.8	**62.6**	**ND**	**ND**
10	Bluff	0.7	17.2	**16.0**	**16.3**	**16.7**	**18.2**	**ND**	**ND**	**ND**	**ND**	69.0	**67.1**	**ND**	**ND**
19	San Clemente Highlands	4.9	18.7	**17.8**	**18.3**	**18.8**	**20.9**	**ND**	**ND**	**ND**	**ND**	74.8	**75.9**	**ND**	**ND**
22	Former US Coast Guard Station	2.7	18.8	**19.8**	**18.0**	**19.1**	**21.0**	**ND**	**ND**	**ND**	**ND**	75.3	**77.9**	**ND**	**ND**
23	SDG&E Service Center Yard (Control)	8.1	16.6	**15.7**	**14.8**	**15.8**	**16.9**	**ND**	**ND**	**ND**	**ND**	66.4	**63.2**	**ND**	**ND**
31	Aurora Park - Mission Viejo (Control)	18.6	19.4	**19.9**	**17.5**	**20.4**	**21.7**	**ND**	**ND**	**ND**	**ND**	77.8	**79.4**	**ND**	**ND**
33	Camp Talega – MCB (Control)	5.9	19.9	**18.5**	**18.5**	**19.2**	**20.8**	**ND**	**ND**	**ND**	**ND**	79.5	**77.1**	**ND**	**ND**
34	San Onofre School – MCB	1.9	17.0	**17.4**	**16.0**	**16.3**	**18.4**	**ND**	**ND**	**ND**	**ND**	68.1	**68.1**	**ND**	**ND**
35	Range 312 – MCB	4.8	17.8	**16.1**	**15.4**	**15.3**	**16.9**	**ND**	**ND**	**ND**	**ND**	71.1	**63.7**	**ND**	**ND**
36	Range 208C – MCB	4.1	20.5	**18.9**	**19.4**	**20.0**	**21.2**	**ND**	**ND**	**ND**	**ND**	82.0	**79.6**	**ND**	**ND**
38	San Onofre State Beach Park	3.4	15.0	**11.6**	**9.6**	**9.4**	**11.6**	**ND**	**ND**	**ND**	**ND**	60.1	**42.1**	**ND**	**ND**
40	SCE Training Center – Mesa	0.7	18.0	**17.1**	**17.3**	**17.3**	**18.9**	**ND**	**ND**	**ND**	**ND**	71.9	**70.6**	**ND**	**ND**
44	Fallbrook Fire Station (Control)	17.7	14.7	**15.4**	**14.5**	**14.8**	**16.6**	**ND**	**ND**	**ND**	**ND**	58.9	**61.4**	**ND**	**ND**
46[b]	San Onofre State Beach Park	1.0	12.8	**14.5**	**-**	**11.9**	**14.9**	**ND**	**N/A**	**ND**	**ND**	51.3	**55.0**	**ND**	**ND**
47	Camp Las Flores – MCB (Control)	8.6	14.0	**16.7**	**15.0**	**14.9**	**17.5**	**ND**	**ND**	**ND**	**ND**	55.9	**64.1**	**ND**	**ND**
49	Camp Chappo – MCB (Control)	12.9	14.9	**16.0**	**14.4**	**14.5**	**16.2**	**ND**	**ND**	**ND**	**ND**	59.7	**61.1**	**ND**	**ND**
50	Oceanside Fire Station (Control)	15.6	17.4	**17.8**	**17.0**	**17.0**	**18.9**	**ND**	**ND**	**ND**	**ND**	69.8	**70.7**	**ND**	**ND**
53	San Diego County Operations Center (Control)	44.2	19.1	**20.3**	**18.5**	**18.7**	**20.9**	**ND**	**ND**	**ND**	**ND**	76.5	**78.5**	**ND**	**ND**
54	Escondido Fire Station (Control)	31.8	16.9	**19.1**	**17.3**	**18.1**	**20.5**	**ND**	**ND**	**ND**	**ND**	67.7	**74.9**	**ND**	**ND**
61	Mesa - East Boundary	0.7	16.2	**15.6**	**15.0**	**15.4**	**16.6**	**ND**	**ND**	**ND**	**ND**	64.8	**62.6**	**ND**	**ND**
62	Camp Pendleton	0.7	13.9	**13.3**	**12.5**	**12.7**	**14.1**	**ND**	**ND**	**ND**	**ND**	55.5	**52.6**	**ND**	**ND**
63	Camp Pendleton	0.6	14.6	**14.0**	**13.7**	**14.2**	**14.9**	**ND**	**ND**	**ND**	**ND**	58.4	**56.9**	**ND**	**ND**
64	Camp Pendleton	0.6	15.8	**15.8**	**14.9**	**15.5**	**16.4**	**ND**	**ND**	**ND**	**ND**	63.1	**62.7**	**ND**	**ND**
65	Camp Pendleton	0.7	14.1	**14.0**	**13.0**	**12.8**	**14.2**	**ND**	**ND**	**ND**	**ND**	56.3	**54.0**	**ND**	**ND**
66	San Onofre State Beach	0.6	14.7	**14.1**	**13.9**	**13.9**	**14.7**	**ND**	**ND**	**ND**	**ND**	58.9	**56.6**	**ND**	**ND**

TLD (SCE-##)	Location	Distance (miles)	Qtr. Baseline (mrem)	2021 Quarterly Results (mrem)				Baseline Adjusted Quarterly Results (mrem)				Ann. Baseline (mrem)	Annual Total (mrem)	Annual Facility Dose (mrem)	Annual Public[e] Dose (mrem)
				1	2	3	4	1	2	3	4				
67	Former SONGS Evaporation Pond	0.6	17.8	**17.9**	**17.5**	**17.4**	**18.2**	**ND**	**ND**	**ND**	**ND**	71.1	**71.0**	**ND**	**ND**
68	Range 210C – MCB	4.4	15.8	**16.5**	**16.1**	**16.6**	**17.6**	**ND**	**ND**	**ND**	**ND**	63.1	**66.8**	**ND**	**ND**
74	Oceanside City Hall (Backup Control)	15.6	14.0	**14.1**	**13.7**	**12.9**	**14.7**	**ND**	**ND**	**ND**	**ND**	55.9	**55.4**	**ND**	**ND**
75	Gate 25 MCB	4.6	16.7	**16.1**	**15.3**	**14.9**	**17.1**	**ND**	**ND**	**ND**	**ND**	66.9	**63.4**	**ND**	**ND**
76	El Camino Real Mobil Station	4.6	18.2	**18.2**	**17.8**	**18.0**	**19.6**	**ND**	**ND**	**ND**	**ND**	72.7	**73.6**	**ND**	**ND**
77	Area 62 Heavy Lift Pad	4.2	20.2	**19.0**	**19.1**	**19.9**	**20.5**	**ND**	**ND**	**ND**	**ND**	80.7	**78.6**	**ND**	**ND**
78[b]	Horno Canyon	4.4	11.7	**-**	**12.3**	**12.6**	**12.9**	**N/A**	**ND**	**ND**	**ND**	46.7	**50.4**	**ND**	**ND**
11	Former Visitors' Center	0.4*	15.8	**15.9**	**16.0**	**16.4**	**17.7**	**ND**	**ND**	**ND**	**ND**	63.1	**66.1**	**ND**	**ND**
12[a]	South Edge of Switchyard	0.2*	15.8	**18.1**	**16.2**	**17.4**	**19.7**	**ND**	**ND**	**ND**	**ND**	63.1	**71.5**	**ND**	**ND**
13[e]	Southeast Site Boundary (Bluff)[a]	0.4*	15.8	**18.0**	**17.2**	**16.0**	**19.3**	**ND**	**ND**	**ND**	**ND**	63.1	**70.5**	**ND**	**ND**
15[a]	Southeast Site Boundary (Office Bldg)[a]	0.1*	15.8	**16.9**	**16.4**	**17.1**	**19.4**	**ND**	**ND**	**ND**	**ND**	63.1	**69.7**	**ND**	**ND**
16[c]	East Southeast Site Boundary[a]	0.4*	15.8	**17.6**	**14.9**	**15.9**	**17.7**	**ND**	**ND**	**ND**	**ND**	63.1	**66.1**	**ND**	**ND**
41[c]	Old Route 101 – East	0.3*	15.8	**16.1**	**15.3**	**15.7**	**17.8**	**ND**	**ND**	**ND**	**ND**	63.1	**64.8**	**ND**	**ND**
55[a, b, d]	San Onofre State Beach (U1 West)	0.2*	15.8	**-**	**19.9**	**21.4**	**22.6**	**N/A**	**ND**	**5.6**	**6.8**	63.1	**85.2**	**22.1**	**ND**
56[a]	San Onofre State Beach (U1 West)	0.2*	15.8	**18.7**	**18.2**	**18.1**	**19.5**	**ND**	**ND**	**ND**	**ND**	63.1	**74.4**	**11.3**	**ND**
57[a]	San Onofre State Beach (Unit 2)	0.1*	15.8	**17.5**	**16.6**	**16.7**	**18.1**	**ND**	**ND**	**ND**	**ND**	63.1	**68.9**	**ND**	**ND**
58[a]	San Onofre State Beach (Unit 3)	0.1*	15.8	**17.6**	**17.1**	**17.1**	**19.1**	**ND**	**ND**	**ND**	**ND**	63.1	**70.8**	**ND**	**ND**
59[c]	SONGS Meteorological Tower	0.3*	15.8	**20.3**	**19.1**	**19.6**	**18.9**	**ND**	**ND**	**ND**	**ND**	63.1	**77.8**	**14.7**	**ND**
73[c]	South Yard Facility	0.4*	15.8	**19.1**	**17.7**	**18.6**	**20.3**	**ND**	**ND**	**ND**	**ND**	63.1	**75.6**	**12.5**	**ND**

* Indicates that the station is within the EAB. The baseline has been estimated to be 15.8 mrem per standard 91-day quarter within the EAB.

a The dose to members of the public is based on a beach annual occupancy time of 300 hours per year near the SONGS sea wall.

b TLD 55 was discovered missing for during the 1Q21 TLD exchange. TLD 78 was not available from 2Q20 through 1Q21 due to construction activities. TLD 46 was discovered missing during the 2Q21 TLD exchange. The annual dose was estimated based on the remaining three quarter's data.

c This location is not accessible to members of the general public

d A neutron dosimeter was collocated with REMP TLD 55 and selected ISFSI TLDs. The estimated neutron dose was added to the gamma dose.

e Adjusted for occupancy in accordance with Radiation Monitoring and Exposure Controls procedure. Where adjusted dose is < 1 mrem, Public Dose is reported as ND per ANSI/HPS N13.37-2014.

f TLD 6 was moved to a shielded storage vault from 4/26/21-6/16/21 due to planned removal and replacement of the power pole it is located on. TLD 6 was deployed on a nearby pole (~50 feet SW) from 6/16/21-9/13/21 when it was returned to the newly installed pole in the original location. The annual dose was estimated based on the remaining three quarter's data.

Quality Control Duplicate Direct Radiation Samples

Duplicate Quality Control (QC) TLD was installed adjacent to TLD 66 and TLD 67. The duplicate TLDs agreed closely with the indicator TLDs, see Appendix C for results. These TLDs were not required by the ODCM and are not included in the Statistical Summary of REMP Data.

ISFSI Direct Radiation Samples

ISFSI TLDs were placed in the vicinity of the ISFSI. Though data from these TLDs are not included in the statistical summary of REMP data because they are not part of the ODCM, the ISFSI data are listed and discussed in Appendix I.

Airborne Particulate and Composite Isotopic Analyses

Air particulate samples were collected on a weekly basis from seven locations including four required indicator locations, two optional indicator locations, and one control location. The samples were analyzed for gross beta activity and composited quarterly for gamma isotopic analysis. Sample locations were selected according to the requirements of the ODCM. Samples were collected from air sample location #11 (AS-11) through May 14, 2021, when the sampler was permanently removed from service due to electrical isolation. AS-11 was not required by the ODCM.

Gross beta analysis is a measure of total radioactivity of beta-emitting radionuclides in a sample. Beta radiation is emitted by many radionuclides and the gross beta measurements are used to identify samples with elevated levels of beta activity that would warrant further analysis. All of the weekly gross beta activity analysis results were above the MDC. The indicator data trends closely with the control data. Seasonal variability observed in the data is attributable to a factor external to SONGS. The 2021 gross beta data is similar to the gross beta data from recent years.

The gross beta analysis does not identify specific radionuclides. To identify specific radionuclides, the weekly particulate media is composited quarterly and is analyzed for gamma emitters. During 2021, only naturally occurring radionuclides were identified and no SONGS-related radionuclides were detected. Beryllium-7 (a naturally occurring radionuclide) was present in all of the quarterly composites.

Ocean Water

Monthly ocean water samples were collected from three indicator locations near each station discharge and from the control location at Newport Beach. The samples were analyzed for naturally occurring and SONGS-related gamma-emitting radionuclides, including tritium. Quarterly composite ocean water samples were analyzed for tritium according to ODCM requirements.

Throughout 2021, only naturally occurring radionuclides were detected in the monthly gamma spectral analyses of ocean water. Monthly ocean water samples were also analyzed for tritium, consistent with the CDPH split sample program. During 2021, all SONGS REMP and duplicate CPDH tritium ocean water sample results were less than detectable.

The data indicate that SONGS had no measurable impact on the environment as measured in ocean water.

Shoreline Sediment (Beach Sand)

Beach sand was collected semiannually in 2021 from three indicator locations and from a control location situated in Newport Beach. After collection, the samples were analyzed for plant-related and naturally occurring radionuclides. Only naturally occurring radionuclides were detected in all samples. No plant-related radionuclides were reported above the MDC. SONGS had no impact on the environment as measured in beach sand.

Ocean Bottom Sediments

Ocean bottom sediments were collected from four indicator locations and the Laguna Beach control location. The samples were analyzed by gamma spectral analysis for naturally occurring and station-related radionuclides. Only naturally occurring radionuclides were detected in ocean bottom sediment samples collected during 2021. The Ocean Bottom Sediments analyzed in 2021 did not yield any radionuclides attributable to SONGS.

Marine Species (Flesh)

Species of adult fish, crustacean and mollusks were collected on a semi-annual basis at the SONGS Unit 1 outfall, the SONGS Units 2/3 outfall, and from the Laguna Beach control location. The edible portion of each sample type was analyzed for gamma-emitting station-related and naturally occurring radionuclides. The results were subsequently reported to SONGS in terms of wet sample weights. Because results based on a wet sample weight are most useful for calculating doses, the results of sample analyses are summarized in terms of "as received" wet weights.

Cs-137 was detected in two indicator (fish) samples above the MDC and below the required LLD. The concentrations identified are consistent with results from previous years at both control and indicator locations. This is consistent with the conclusion that the Cs-137 is attributable to sources external to SONGS. The Cs-137 result (greater than the MDC but less than the LLD) is consistent with results from marine species samples collected at other West Coast locations. Publicly available research from scientific organizations indicates that the presence of Cs-137 in Pacific Ocean sea creatures is attributable to the legacy radioactive contamination from global weapons testing, Chernobyl, and Fukushima (Woods Hole Oceanographic Institution website 3-30-2021). Naturally occurring radionuclides, such as K-40, were also detected in marine species samples collected during 2021. Some samples were split with the CDPH; refer to Table 25 and Table 26 for comparison results. SONGS had no measurable impact on the environment as measured by this sample medium.

Local Crops

Fleshy and leafy crops were collected semiannually in 2021 from the SONGS garden and from the control location 21 miles SE from SONGS Units 2/3 midpoint. Only naturally occurring radionuclides were identified and no plant-related radioactivity was detected during 2021. SONGS had no measurable impact on local crops.

Soil

To determine if there is evidence of a build-up of radionuclides in the land near SONGS, indicator soil samples were collected from Camp San Onofre, Old Route 101, Basilone Road and the East Site Boundary (Former Visitors Center). A control sample was obtained from Prince of Peace Abbey in Oceanside. Surface soil was collected from all indicator and control locations at the depth of three inches. The sampling protocol is consistent with the procedure described in HASL-300. Soil sampling is not required by the ODCM.

Soil samples were analyzed for naturally occurring and SONGS-related gamma-emitting radionuclides using gamma spectral analysis. The 2021 soil samples showed measurable levels of naturally occurring radionuclides and measurable Cs-137, which is consistent with the decay of legacy Cs-137 in soil attributable to factors external to SONGS (e.g., residual nuclear weapons testing fallout and the Chernobyl accident).

Cs-137 and strontium-90 (Sr-90) were detected in soil profile analyses conducted in previous years. These radionuclides are attributable to nuclear weapon testing fallout depositing on soil; Cs-137 and Sr-90 are retained in the soil for extended periods due to their long half-lives and biogeochemical characteristics. The presence of Cs-137 in indicator and in control samples at similar levels supports the conclusion that the source of this radionuclide is due to a factor external to SONGS (fallout deposition). During 2021, SONGS did not have a detectable effect on the environment as measured by soil samples.

Kelp

Three Kelp samples (two indicator and one control) were available during the April 2021 sample event. Only the Control sample was available during the October 2021 sampling event. Kelp sampling is not required by the ODCM.

Cs-137 was detected in one indicator sample from San Mateo Kelp Bed; the detected activity was confirmed by re-counting the sample. The low concentration is consistent with low levels of Cs-137 observed in marine samples over time. SONGS had no impact on the environment as measured by this exposure pathway in 2021.

Correlation of Effluent Concentration to Concentrations in the Environment

In accordance with 10 CFR 50 Appendix I, Section IV, B.2, data on measurable levels of radiation and radioactive materials in the environment have been evaluated to determine the relationship between quantities of radioactive material released in effluents and resultant radiation doses to individuals from principal pathways of exposure.

REMP samples, both terrestrial and marine, indicated no accumulation of plant-related radioactivity in the environs. Samples with detectable activity were not statistically different from control samples. Non-natural radionuclides detected during 2021 were attributed to sources external to SONGS (past nuclear weapons fallout, Chernobyl, and Fukushima). The regulatory requirement to evaluate the relationship between quantities of radioactive materials released in effluents and the resultant radiation doses to individuals may be summarized by the following conclusion:

Effluent program releases are evaluated annually to determine the receptor(s) with the highest hypothetical dose. The 2021 REMP sample data indicated no detectible accumulation of plant-related radionuclides in the environment attributable to SONGS, confirming the adequacy of the in-plant effluent controls program and dose assessments. Furthermore, the SONGS REMP data are consistent with the conclusion that SONGS has had no significant radiological impact on the environment in 2021.

Statistical Summary of REMP Data for 2021

For Table 13 through Table 22 below, the numbers in parentheses next to the mean value indicate the number of samples with positive results compared to the total number of samples. The smaller font numbers in parentheses indicate the range of results.

Table 13 – Weekly Airborne Particulates Gross Beta

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Air Filter Inhalation (pCi/m^3)	Gross Beta	332	0.01	0.033 (280/280) (0.013 – 0.133)	San Luis Rey Substation 16.7 mi. SE	0.039 (52/52) (0.013 – 0.117)	0.039 (52/52) (0.013 – 0.117)	0

NOTES:

a. Air Sampler # 11 (not required by the ODCM) was permanently discontinued in May 2021 due to the permanent isolation of power to the sample site.

Table 14 – Quarterly Composite Airborne Particulate Gamma Activity

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Air Filter Inhalation (pCi/m^3)	Cs-134	26	0.05	< MDC (0/22)	< MDC	< MDC	< MDC (0/4)	0
	Cs-137	26	0.06	< MDC (0/22)	< MDC	< MDC	< MDC (0/4)	0

NOTES:

[a] Naturally occurring Be-7 was detected in all quarterly composite air particulate samples. Other naturally occurring radionuclides (such as K-40) were observed in some 2021 quarterly composite air samples.

[b] Air sampler # 11 (Mesa EOF) was permanently removed from service in May 2021 due to the permanent isolation of power to the sample site.

Table 15 - Monthly Ocean Water Activity

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Ocean Water (pCi/L)	H-3	48	3000	< MDC(0/36)	< MDC	< MDC	< MDC (0/12)	0
	Mn-54	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Co-58	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Co-60	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Zn-65	48	30	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Cs-134	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Cs-137	48	18	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0

NOTES:
a Naturally occurring K-40 was observed in all 2021 ocean water samples.

Table 16 - Quarterly Ocean Water Tritium

Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Ocean Water (pCi/L)	H-3	16	3000	< MDC (0/12)	< MDC	< MDC	< MDC (0/4)	0

Table 17 - Semi-annual Shoreline Sediment Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Beach Sand Direct Exposure (pCi/g)	Cs-134	8	0.150	< MDC (0/6)	< MDC	< MDC	< MDC (0/2)	0
	Cs-137	8	0.180	< MDC (0/6)	< MDC	< MDC	< MDC (0/2)	0

NOTES:
a Naturally occurring K-40 was detected in all 2021 shoreline sediment samples.

Table 18 - Semi-annual Ocean Bottom Sediment Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Waterborne Ocean Bottom Sediment (pCi/g)	Cs-134	10	0.150	< MDC (0/8)	< MDC	< MDC	< MDC (0/2)	0
	Cs-137	10	0.180	< MDC (0/8)	< MDC	< MDC	< MDC (0/2)	0

NOTES:

a Naturally occurring radionuclides (K-40 and others) were detected in the 2021 ocean bottom sediment samples.

Table 19 - Semi-annual Marine Animal Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Non-Migratory Marine Animals (pCi/g)	Mn-54	24	0.130	< MDC (0/16)	< MDC	< MDC	< MDC (0/8)	0
	Co-58	24	0.130	< MDC (0/16)	< MDC	< MDC	< MDC (0/8)	0
	Co-60	24	0.130	< MDC (0/16)	< MDC	< MDC	< MDC (0/8)	0
	Zn-65	24	0.260	< MDC (0/16)	< MDC	< MDC	< MDC (0/8)	0
	Cs-134	24	0.130	< MDC (0/16)	< MDC	< MDC	< MDC (0/8)	0
	Cs-137	24	0.150	0.0097 (2/16) (0.0097 – 0.0097)	Unit 1 Outfall 0.9 mi. WSW	0.0097 (2/16) (0.0097 – 0.0097)	<MDC (0/8)	0 [b]

NOTES:

a Naturally occurring radionuclides (K-40 and others) were detected in the 2021 non-migratory marine animal samples.

b Cs-137 has been routinely identified in Non-Migratory Marine Animal samples taken for SONGS REMP. The levels of Cs-137 identified have been consistent between Control and Indicator samples and these low levels of activity are expected based on environmental Cs-137 levels attributable to fallout and accidents such as Fukushima Daiichi.

Table 20 - Semi-annual Local Crops Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Local Crops ingestion (pCi/g)	Cs-134	8	0.06	< MDC (0/4)	< MDC	< MDC	< MDC (0/4)	0
	Cs-137	8	0.08	< MDC (0/4)	< MDC	< MDC	< MDC (0/4)	0

NOTES:

a Naturally occurring radionuclides (K-40 and others) were observed in the 2021 local crop samples.

Table 21 - Annual Soil Gamma Activity, 3" Depth (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Soil Direct Exposure (pCi/g)	Cs-134	5	0.150	< MDC (0/4)	< MDC	< MDC	< MDC (0/1)	0
	Cs-137 [b]	5	0.180	0.0628 (2/4) (0.0416 – 0.0841)	Prince of Peace Abby (Control) 15 mi. SE	0.138 (1/1) (0.138 – 0.138)	0.138 (1/1) (0.138 – 0.138)	0

NOTES:

a K-40 and other naturally occurring radionuclides were detected in the 2021 REMP soil samples.

b The Cs-137 detected in the control and in two indicator samples similar concentrations (approximately 0.1 pCi/g). This has been observed in previous AREORs and is due to factors external to SONGS (legacy fallout from nuclear weapons testing and Chernobyl) and are not attributable to SONGS.

Table 22 - Semi-Annual Kelp Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a, b]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Kelp Ingestion (pCi/g)	Cs-137 [c]	4	0.08	0.0203 (1/2) (0.0203 – 0.0203)	San Mateo Kelp Bed 3.8 mi. WNW	0.0203 (1/2) (0.0203 – 0.0203)	< MDC (0/2)	0

NOTES:

a Kelp sampling is not required by the ODCM.

b Kelp samples were available at the Control location twice in 2021. Samples were available at two Indicator locations during the April sample event and no Indicator locations during the October sample event. K-40 and other naturally occurring radionuclides were detected in the 2021 kelp samples

c Cs-137 was identified in one indicator sample during 2021 and was confirmed by re-count. The result from the original count is reported.

APPENDIX C. SUMMARY OF QUALITY CONTROL PROGRAMS

Summary

All REMP samples are collected, shipped, and analyzed in accordance with Regulatory Guide 4.15. Marine radiological environmental samples are collected by a vendor, MBC Aquatic Sciences, per the vendor's Quality Assurance manual.

REMP sample analysis is performed by GEL in accordance with GEL's Laboratory Quality Assurance Plan. GEL participates in three independent cross check programs. GEL's QA programs consists of these testing vendors: Eckert & Ziegler Analytics, U.S. DOE MAPEP, ERA's MRaD-Multimedia Radiochemistry Proficiency test program and ERA's InterLaB RadCheM Proficiency Testing Program. Non-agreement results were resolved in accordance with GEL's corrective action program.

The CEAL for REMP TLDs was Stanford Dosimetry. The raw data for TLDs was reported as milli-Roentgen/standard quarter and converted to millirem per standard quarter using conversion factors in ANSI N13.37. In 2021, routine quality control (QC) testing was performed for the types of environmental TLDs issued by the Environmental Dosimetry Company (EDC). During 2021, 100% (72/72) of individual dosimeters evaluated against the EDC internal performance acceptance criteria (high-energy photons only) met the criterion for accuracy and 100% (72/72) met the criterion for precision. Independent testing was also performed and 100% (6/6 data sets) passed the performance criteria.

The GEL and Stanford Dosimetry performance meets the criteria described in Reg. Guide 4.15 and ANSI/HPS N13.37-2014.

Quarterly Duplicate TLDs

SONGS deployed a duplicate TLD package, TLD 200, in the same canister as TLD 66. The quarterly dose measured by the duplicate TLD package was statistically equivalent.

Table 23 - 2021 Quarterly Duplicate TLD Data Comparison

TLD #	1ST QUARTER (mR) +/- 1 sigma	2ND QUARTER (mR) +/- 1 sigma	3RD QUARTER (mR) +/- 1 sigma	4TH QUARTER (mR) +/- 1 sigma
TLD 66	13.39 ± 0.65[a]	13.24 ± 0.50	13.23 ± 0.72	14.02 ± 0.66
TLD 200	13.28 ± 0.73	13.36 ± 0.86	13.56 ± 0.88	14.15 ± 0.63

NOTES:
a Data is reported as mR per standard quarter ± 1 sigma

Annual Duplicate TLDs

SONGS deployed an annual duplicate TLD package, TLD 201, in the same location and canister as REMP TLD 67. The average of the four quarterly TLD 67 exposure results is statistically equal to the annual TLD 201 results for 2021 expressed as mR/91 days.

Table 24 - 2021 Annual Duplicate TLD Data Comparison

TLD #	January 2021 to December 2021 Average of the quarterly values (mR/91 days +/- 1 sigma)
TLD 67	16.89 ± 0.79
TLD 201	17.44 ± 0.85

Calibration of Air Sampler Volume Meters

All REMP air sampler flow meters are calibrated annually using standards referenced to National Institute of Standard and Technology. Calibration of all REMP air samplers is verified quarterly to ensure the flow meters remain within limits. Meters are removed from service if they fail the quarterly test. Additionally, a review of the air particulate beta results over the course of the year did not indicate bias for any particular sampler. The trends in the beta results over the course of the year were consistent, within the limitations of the gross beta method of analysis and natural variation between sample locations.

Interlaboratory Cross-Check Program

As discussed in the Appendix C Summary section above, the laboratories providing analysis results for SONGS have robust QA programs that include interlaboratory cross-checks. Both labs performed acceptably.

Additionally, the CDPH participates in a comprehensive radiological environmental split sampling program in conjunction with SONGS. In 2021, the CDPH acquired split samples, collected by an independent third party, from the following SONGS media: non-migratory marine animals, kelp, ocean water gamma emitters, and ocean water tritium. The CDPH also conducts parallel atmospheric radioactivity and terrestrial direct radiation (TLD) measurement efforts at SONGS, (refer to Appendix H for a discussion of the CDPH TLD data).

CDPH Atmospheric Radioactivity Gross Beta and quarterly gamma analysis results were similar to the SONGS results for the same media. As expected, both the CDPH Drinking Water and Radiation Laboratory (DWRL) and the SONGS contracted GEL found a gross beta signal above the detection limit. Both labs detected naturally occurring Be-7 in the quarterly composite gamma particulate media samples. Both labs did not detect anthropogenic radionuclides in the split samples with the exception of non-migratory marine animals and one positive result for Cs-137 in kelp identified by the SONGS contracted laboratory.

Since ocean water tritium and non-migratory marine animals have the potential for human consumption, their raw data are tabulated below. Fourteen split sample analyses for marine species were conducted. Analysis methodologies are different in that the SONGS contracted laboratory reported a wet weight result, where the CDPH lab reported a dry weight result. Low level Cs-137 was detected above MDC in some samples. The variability in the detection of positive results is due to the low activity of the samples, the differences in sample processing, the uncertainty of isotope detection and detection limits at low concentrations. (For a discussion on the presence of Cs-137 in fish, refer to Appendix B.)

Table 25 - Non-migratory marine animals analysis results – Potassium-40

SPLIT SAMPLE LOCATION		Sample Date	Sample Type	Dry/Wet Weight Ratio (g_{dry}/g_{wet})	Nuclide	SONGS data (wet weight)		CDPH data (dry weight)	
						Gamma result +/- 2 sigma (pCi/g)	MDC (pCi/g)	Gamma result +/- uncertainty (pCi/g)	MDC (pCi/g)
A	Outfall – Unit 1	4/14/2021	Crustacean	0.269	Potassium-40	3.36 ± 0.28	0.07	15.60 ± 0.71	0.43
		4/14/2021	Mollusk	0.223	Potassium-40	2.20 ± 0.24	0.08	11.10 ± 0.65	0.53
		4/28/2021	Fish	0.242	Potassium-40	3.93 ± 0.31	0.09	16.70 ± 0.82	0.32
		10/20/2021	Crustacean	0.266	Potassium-40	3.50 ± 0.34	0.07	15.40 ± 0.81	0.50
		10/20/2021	Mollusk	0.214	Potassium-40	1.90 ± 0.24	0.08	9.63 ± 0.60	0.61
B	Outfall – Units 2 & 3	4/14/2021	Fish	0.240	Potassium-40	4.28 ± 0.28	0.07	17.80 ± 0.95	0.68
		10/20/2021	Fish	0.244	Potassium-40	4.17 ± 0.31	0.05	16.00 ± 0.84	0.49
		10/20/2021	Fish	0.259	Potassium-40	3.32 ± 0.28	0.08	16.40 ± 0.77	0.51
C	Laguna Beach – Control	4/5/2021	Fish	0.236	Potassium-40	3.42 ± 0.27	0.07	18.20 ± 0.99	0.29
		4/5/2021	Crustacean	0.255	Potassium-40	2.78 ± 0.35	0.08	15.50 ± 0.93	0.94
		4/5/2021	Mollusk	0.197	Potassium-40	2.69 ± 0.43	0.19	11.20 ± 0.67	0.60
		10/28/2021	Fish	0.243	Potassium-40	3.71 ± 0.32	0.09	16.90 ± 0.98	0.94
		10/28/2021	Crustacean	0.262	Potassium-40	3.73 ± 0.32	0.05	14.50 ± 0.83	0.74
		10/28/2021	Mollusk	0.171	Potassium-40	1.92 ± 0.21	0.05	10.70 ± 0.70	0.73

Table 26 - Non-migratory marine animals analysis results – Cesium-137

SPLIT SAMPLE LOCATION		Sample Date	Sample Type	Dry/Wet Weight Ratio (g_{dry}/g_{wet})	Nuclide	SONGS data (wet weight)		CDPH data (dry weight)	
						Gamma result +/- 2 sigma (pCi/g)	MDC (pCi/g)	Gamma result +/- uncertainty (pCi/g)	MDC (pCi/g)
A	Outfall – Unit 1	4/14/2021	Crustacean	0.269	Cesium-137	1.25E-2 ± 8.52E-3 (UI)	5.99E-3	1.98E-2 ± 8.14E-3	1.79E-2
		4/14/2021	Mollusk	0.223	Cesium-137	6.69E-3 ± 6.98E-3	7.31E-3	6.55E-4 ± 7.15E-3	1.64E-2
		4/28/2021	Fish	0.242	Cesium-137	9.75E-3 ± 6.10E-3	6.93E-3	2.73E-2 ± 8.27E-2	1.78E-2
		10/20/2021	Crustacean	0.266	Cesium-137	1.15E-2 ± 1.07E-2 (UI)	9.75E-3	1.05E-2 ± 6.40E-3	1.57E-2
		10/20/2021	Mollusk	0.214	Cesium-137	1.05E-2 ± 6.93E-3 (UI)	7.97E-3	1.24E-3 ± 7.53E-3	1.73E-2
B	Outfall – Units 2 & 3	4/14/2021	Fish	0.240	Cesium-137	6.50E-3 ± 4.66E-3	9.09E-3	2.36E-2 ± 1.17E-2	2.61E-2
		10/20/2021	Fish	0.244	Cesium-137	8.93E-3 ± 9.03E-3 (UI)	7.54E-3	2.58E-2 ± 9.91E-3	2.15E-2
		10/20/2021	Fish	0.259	Cesium-137	5.77E-3 ± 5.81E-3	1.06E-2	1.75E-2 ± 7.29E-3	1.82E-2
C	Laguna Beach - Control	4/5/2021	Fish	0.236	Cesium-137	9.57E-4 ± 3.96E-3	6.68E-3	2.54E-2 ± 6.44E-3	1.30E-2
		4/5/2021	Crustacean	0.255	Cesium-137	5.22E-3 ± 9.63E-3	1.03E-2	1.25E-2 ± 9.68E-3	2.33E-2
		4/5/2021	Mollusk	0.197	Cesium-137	-5.77E-3 ± 1.12E-2	1.62E-2	1.20E-4 ± 7.81E-3	1.78E-2
		10/28/2021	Fish	0.243	Cesium-137	1.58E-3 ± 5.78E-3	9.71E-3	2.77E-2 ± 1.49E-2	3.34E-2
		10/28/2021	Crustacean	0.262	Cesium-137	7.26E-3 ± 5.32E-3	1.04E-2	1.16E-2 ± 7.86E-3	1.90E-2
		10/28/2021	Mollusk	0.171	Cesium-137	2.77E-3 ± 4.78E-3	8.55E-3	4.65E-3 ± 9.05E-3	2.13E-2

UI – Uncertain identification for gamma spectroscopy result.

Table 27 below shows the results from ocean water tritium samples. All the SONGS and the available CDPH results for 2021 tritium in ocean water were less than detectable. The November and December 2021 CDPH data was not available at the time of reporting.

NOTE: When sample results are analyzed to be lower in activity than the laboratory background result, the result is depicted as a negative value.

Table 27 - CDPH and SONGS split sample tritium in ocean water

SPLIT SAMPLE LOCATION		Sample Date	SONGS tritium data		CDPH tritium data	
			H-3 result ± 2 sigma (pCi/L)	MDC	H-3 result ± uncertainty (pCi/L)	MDC
A	Station Discharge Outfall - Unit 1	1/15/2021	-36.5 ± 358	609	-124 ± 140	247
		2/19/2021	63.6 ± 346	570	-92.3 ± 134	235
		3/17/2021	173 ± 425	678	-94.2 ± 134	235
		4/19/2021	304 ± 326	499	-64.2 ± 138	240
		5/17/2021	-54.0 ± 329	560	-31.1 ± 139	240
		6/15/2021	38.8 ± 369	614	-61.6 ± 129	224
		7/19/2021	306 ± 442	681	9.3 ± 131	224
		8/16/2021	141 ± 321	517	107 ± 132	222
		9/21/2021	-300 ± 356	645	11.3 ± 129	222
		10/18/2021	-142 ± 293	513	-13.8 ± 136	235
		11/15/2021	-274 ± 468	836		
		12/16/2021	-74.8 ± 257	437		

SPLIT SAMPLE LOCATION		Sample Date	SONGS tritium data		CDPH tritium data	
			H-3 result ± 2 sigma (pCi/L)	MDC	H-3 result ± uncertainty (pCi/L)	MDC
B	Outfall - Unit 2	1/15/2021	344 ± 409	619	-164 ± 139	247
		2/19/2021	-12.6 ± 349	588	26.9 ± 138	235
		3/17/2021	165 ± 431	689	5.8 ± 137	235
		4/19/2021	54.0 ± 291	480	-83.6 ± 137	240
		5/17/2021	-51.1 ± 349	594	-89.5 ± 137	240
		6/15/2021	54.5 ± 368	610	63.5 ± 132	224
		7/19/2021	69.0 ± 417	687	-89.6 ± 128	224
		8/16/2021	185 ± 328	522	20.7 ± 129	222
		9/21/2021	-408 ± 337	632	75.2 ± 131	222
		10/18/2021	98.5 ± 320	523	-49.2 ± 135	235
		11/15/2021	-287 ± 454	815		
		12/16/2021	-219 ± 260	450		
C	Outfall - Unit 3	1/15/2021	-86.7 ± 355	615	-153 ± 140	247
		2/19/2021	-56.0 ± 311	531	-55.7 ± 135	235
		3/17/2021	-51.0 ± 394	672	-34.6 ± 136	235
		4/19/2021	-9.2 ± 316	532	-52.5 ± 138	240
		5/17/2021	18.9 ± 351	585	-33.1 ± 139	240
		6/15/2021	123 ± 379	618	24.3 ± 131	224
		7/19/2021	251 ± 466	732	-106 ± 127	224
		8/16/2021	348 ± 339	518	20.7 ± 129	222
		9/21/2021	-126 ± 358	620	-88.3 ± 126	222
		10/18/2021	215 ± 330	522	-35.4 ± 136	235
		11/15/2021	-494 ± 555	1020		
		12/16/2021	39.3 ± 269	449		

SPLIT SAMPLE LOCATION		Sample Date	SONGS tritium data		CDPH tritium data	
			H-3 result ± 2 sigma (pCi/L)	MDC	H-3 result ± uncertainty (pCi/L)	MDC
D	Newport Beach (Control)	1/15/2021	-49.8 ± 358	612	-73.0 ± 142	247
		2/19/2021	78.6 ± 350	575	-73.0 ± 135	235
		3/17/2021	-32.8 ± 393	667	-67.3 ± 135	235
		4/19/2021	96.9 ± 316	514	-9.7 ± 139	240
		5/17/2021	-210 ± 315	561	-25.3 ± 139	240
		6/15/2021	38.3 ± 368	613	-76.6 ± 128	224
		7/19/2021	-214 ± 402	720	-50.4 ± 129	224
		8/16/2021	63.4 ± 324	533	37.6 ± 130	222
		9/21/2021	-335 ± 346	634	-50.7 ± 127	222
		10/18/2021	-17.8 ± 293	495	-92.4 ± 134	235
		11/15/2021	-197 ± 485	850		
		12/16/2021	60.1 ± 268	446		

Note that the EPA drinking water maximum permissible tritium activity is 20,000 pCi / liter. Both labs only detected naturally occurring radionuclides in ocean bottom sediments and ocean water. No plants related radionuclides were reported above the MDC.

Notes:

(a) The CDPH data for November and December 2021 was not available at the time of report generation.

APPENDIX D. COMPARISON OF 2021 REMP DATA TO HISTORICAL DATA

Comparison of 2021 REMP data to Historical Data and Analysis of Trends

Unit 1 achieved criticality on June 14, 1967 and was permanently retired from service on November 30, 1992. Unit 2 attained initial criticality on July 26, 1982 and Unit 3 on August 29, 1983.

A variety of environmental samples were analyzed and the analytical results (January 1, 1979 to July 31, 1982) were compared with the 2021 REMP data obtained for SONGS Units 2/3.

The following media were evaluated and compared with the operational data of SONGS Units 1, 2 & 3:

- External Radiation
- Air Particulates
- Ocean Water
- Shoreline Sediment (Sand)
- Ocean Bottom Sediments
- Marine Species
- Local Crops
- Soil
- Kelp

The measurements obtained from the SONGS Unit 1 operational Radiological Environmental Monitoring Program (REMP) during the period from January 1979 to July 1982 are used as the pre-operational baseline for SONGS Units 2/3. This is in accordance with San Onofre Units 2/3, Environmental Report, Operating License Stage, Appendix 6A, Pre-operational Radiological Environmental Monitoring, May 31, 1978. Comparisons of pre-operational data to 2021 REMP data are possible for each of the following exposure pathways: (1) direct radiation, (2) air particulates (inhalation), and (3) ocean water (marine pathway for ingestion). Comparisons can also be made between pre-operational and 2021 REMP data for ocean bottom sediment data to ascertain if there has been any significant increase in radioactivity in ocean bottom sediments near the SONGS Units 2/3 outfalls.

Currently, the pre-operational data are higher than the 2021 REMP data. The decrease in radioactivity is due primarily to the cessation of atmospheric nuclear weapons testing, decreased liquid discharge activity, and the decay of fallout radionuclides. There is a close correlation between indicator and control data over several decades. There are no indications of adverse effects from SONGS on the environment.

Direct Radiation

The direct radiation measurements for the SONGS REMP were made by TLDs on a quarterly collection cycle at 49 locations in 2021. (See Appendix I for ISFSI TLD data). The TLDs were located at inner ring, outer ring, special interest, and control locations as specified by the ODCM. During the pre-operational period from January 1979 to July 31, 1982, the indicator stations ranged from 16.1 to 46.6 mrem per quarter. The preoperational indicator average was 25.3 mrem per quarter. The pre-operational control range was 19.3 to 30.1 mrem per quarter and the control mean was 23.1 mrem per quarter.

During the 2021 REMP year for Units 2/3, the SONGS REMP TLD data was processed in accordance with ANSI/HPS N13.37-2014. Accordingly, the data from individual REMP TLD locations are evaluated against the baseline for each location. The individual REMP TLD locations are not compared with distant control locations for evaluation per the current regulatory guidance, Reg. Guide 4.13 Revision 2, 2019 (Environmental Dosimetry – Performance Specifications, Testing, and Data Analysis). Refer to Appendix B for a detailed discussion of the REMP TLD data evaluation process.

Factors such as meteorology, local geology, the fallout from atmospheric nuclear weapons testing, and seasonal fluctuations account for the variability in the data as observed during the preoperational period for each location. The decrease in radiation levels at all TLD sample locations is attributable to the curtailment of the atmospheric nuclear weapons testing, and the continued decay of the manmade background from fallout from past nuclear weapons tests.

Simultaneous variation in the radiation levels at both the control and indicator locations shows that the variations are due to factors external to SONGS. Outside the EAB there were no measurable levels of increased direct radiation associated with SONGS as measured by TLDs.

Airborne Particulates

From January 1979 through December 1982 (considered to be the pre-operational period for SONGS Units 2/3), there was a noticeably higher gross beta activity in air at all sample locations. This period extends from the fourth quarter of 1980 through the fourth quarter of 1981. These higher activity levels were attributable to the Chinese atmospheric nuclear weapons test conducted on October 15, 1980.

A chart showing the monthly-average gross beta results for SONGS indicator and control locations from January 1976 – December 2021 is presented in Figure 9. Several notable features of the chart support the sensitivity of air monitoring around SONGS and the lack of a detectible impact due to plant activities. Increased monthly average gross beta results can be seen following atmospheric nuclear weapon testing (1970's and 1980s), the Chernobyl accident (1986), and the Fukushima Daiichi accident (2011). Annual variations gross beta are due to seasonal mixing of the upper and lower atmosphere and long-term variations related to solar cycles are visible. The trends clearly show that Indicator and Control results are statistically equivalent.

For 2021, the maximum annual average airborne particulate gross beta result was 0.039 pCi/m^3 at the San Luis Rey Substation CONTROL location. This result is consistent with recent trends and is consistent with the conclusion that SONGS decommissioning work had no detectible impact on REMP air sample results during 2021.

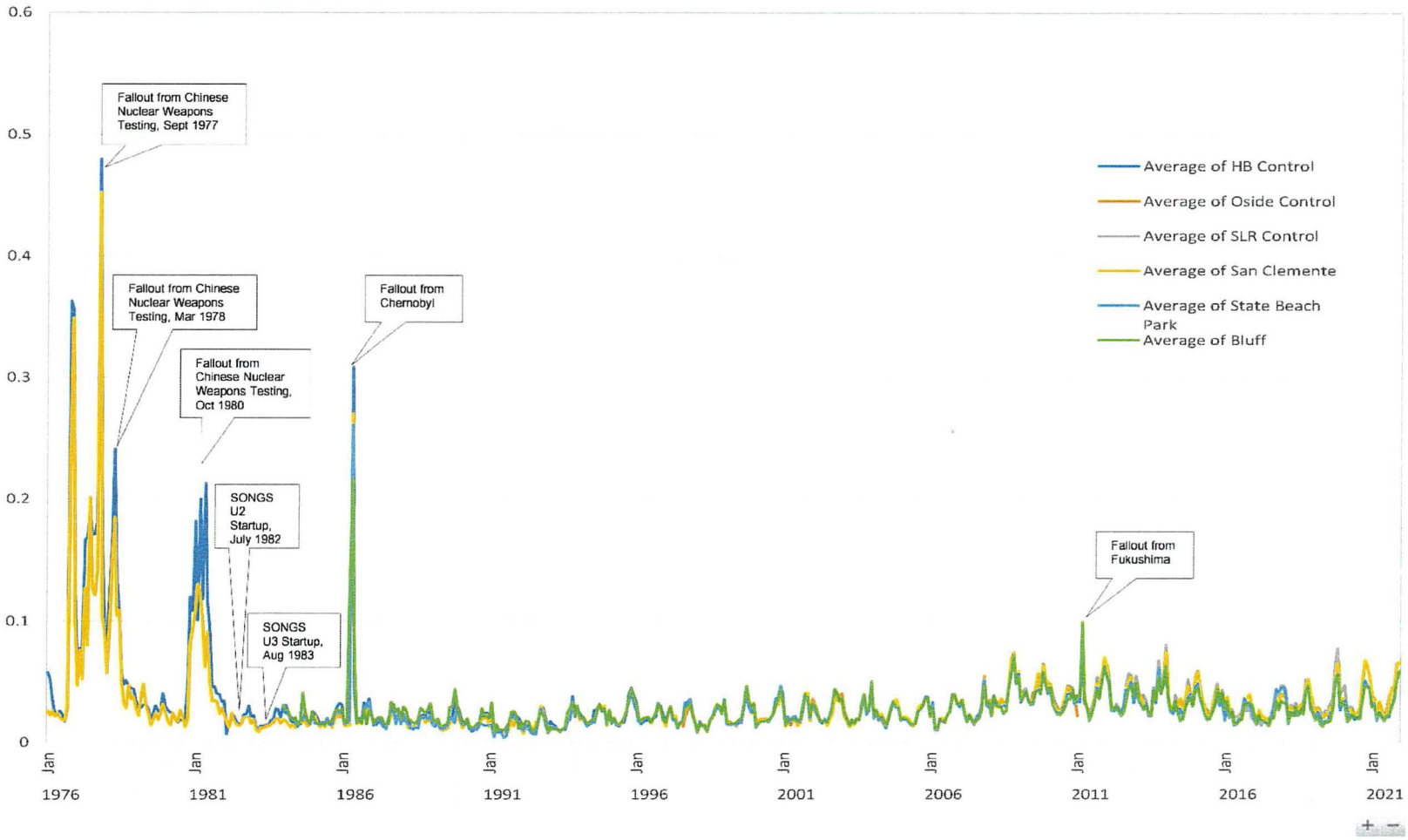

Figure 9 - Monthly Average Airborne Particulate Gross Beta (1976 – 2021)

Ocean Water

Monthly ocean water samples were collected near each of the Station discharge outfalls, and from the Newport Beach control location. The ocean water samples are analyzed for naturally occurring and station-related gamma-emitting radionuclides. Samples were composited quarterly and analyzed for tritium.

During the pre-operational period, naturally occurring potassium-40 was detected in each of the samples collected from both indicator and control locations. Other gamma-emitting radionuclides were detected in only one ocean water sample. In May 1980, Co-58, Co-60, Cs-134, and Cs-137 were detected in an ocean water sample collected from the SONGS Unit 1 outfall. Concentrations of the radionuclides in this sample were 11, 6, 380, and 430 pCi/l, respectively. Tritium was also detected in two of the ocean water samples collected in May 1980 from the SONGS Unit 2 outfall and in and from the Newport Beach control location.

No plant-related radionuclides were detected in ocean water during 2021. SONGS had no impact on the environment as measured by this exposure pathway in 2021.

Shoreline Sediments (Sand)

Beach sand is collected semiannually from three indicator locations and from a control location situated at Newport Beach. The samples are analyzed for naturally occurring and plant-related radionuclides.

To assess the impact of SONGS operations on this environmental medium, pre-operational data were compared to the 2021 REMP data (refer to Table 28). The radionuclide detected in shoreline sediment in the preoperational time frame was Cs-137 with a range of 0.012 to 0.022 pCi/g, averaging 0.019 in five sediment samples. One control sample with a Cs-137 activity of 0.032 pCi/g was observed in July 1979. The presence of Cs-137 in both control and indicator locations during the preoperational period leads to the conclusion that the activity is external to SONGS and is most likely attributable to atmospheric nuclear weapons testing. No SONGS-related radionuclides were detected in shoreline sediment during 2021. SONGS had no impact on the environment as measured by this exposure pathway in 2021.

Table 28 - Shoreline Sediment Concentration

		INDICATOR		CONTROL	
Radionuclide	**Period [a]**	**Range [b] (pCi/g, wet)**	**Average (pCi/g, wet)**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**
Cs-137	PreOp 2021 [c]	0.012 - 0.022 < LLD	0.019 < LLD	< LLD - 0.032 < LLD	< LLD < LLD
All other SONGS radionuclides	PreOp 2021 [c]	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

NOTES:
- a Preoperational period is January 1979 – July 1982.
- b LLD for operational data are listed in Appendix B
- c During 2021, all station related radionuclides from all sample locations were < LLD

Ocean Bottom Sediments

In 2021 and during the pre-operational periods, representative samples of ocean bottom sediments were collected semiannually from each of the Station discharge outfalls and from a control station in Laguna Beach. The samples were analyzed for naturally occurring and SONGS-related radionuclides.

Table 29 compares historical information versus 2021 sample results. During the pre-operational period, manganese-54 (Mn-54) was detected in 5 of the 28 samples. Cobalt-58 (Co-58) was detected in nine samples. Cobalt-60 (Co-60) was measured in 15 of the 28 samples. Cs-137 was detected in 16 of the 28 samples. The concentrations of Cs-137 in the samples ranged from 0.014 to 0.090 pCi/g, averaging 0.039 pCi/g. Cerium-144 (Ce-144) was found in two samples.

No SONGS-related radionuclides were detected in ocean bottom sediment samples during 2021. SONGS had no impact on the environment as measured by this exposure pathway in 2021.

Table 29 - Ocean Bottom Sediment Concentration

		INDICATOR		CONTROL	
Radionuclide	**Period [a]**	**Range[b] (pCi/g, wet)**	**Average[b] (pCi/g, wet)**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**
Mn-54	PreOp 2021	0.015 - 0.49 < LLD	0.129 < LLD	< LLD < LLD	< LLD < LLD
Co-58	PreOp 2021	0.013 - 1.160 < LLD	0.199 < LLD	< LLD < LLD	< LLD < LLD
Co-60	PreOp 2021	0.014 - 8.100 < LLD	0.788 < LLD	< LLD < LLD	< LLD < LLD
Ag-110m	PreOp 2021	< LLD - 0.020 < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
Cs-137	PreOp 2021	0.014 - 0.090 < LLD	0.039 < LLD	< LLD < LLD	< LLD < LLD
Ce-144	PreOp 2021	0.060 - 0.260 < LLD	0.160 < LLD	< LLD < LLD	< LLD < LLD
All other SONGS radionuclides	PreOp 2021	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

NOTES:

a Preoperational period is January 1979 – July 1982.

b LLD for operational data are listed in Appendix B

Marine Species (Flesh)

Non-migratory marine species are collected semi-annually near SONGS. Non-migratory marine animals are collected near the SONGS outfalls and from Laguna Beach and analyzed for gamma-emitting radionuclides as specified in the ODCM. The results are subsequently reported as pCi/g, wet weight.

Results for several marine species for both 2021 and for the pre-operational period for Units 2/3 are summarized in Table 30. The marine species used for purposes of comparison include: two species of fish, Bay Mussel (a mollusk), and Spiny Lobster (a crustacean). Radionuclides analyzed, but not included in Table 30, were below the lower limits of detection for both the pre-operational and operational periods.

During 2021, two samples had low level Cs-137 activity > MDC and < LLD, as reported in Table 19. The results are consistent with Pacific Ocean marine organism samples at other locations and consistent with the levels of Cs-137 in marine samples that may be attributable to the ocean water discharges from Fukushima. The data indicate no accumulation trends attributable to SONGS. SONGS had no significant impact on the environment as measured by this exposure pathway in 2021.

Table 30 - Marine Species Concentration

		INDICATOR		CONTROL	
Radionuclide	**Period [a]**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**
Fish Sample 1 Flesh[d]					
Co-58	PreOp 2021 [b]	0.016 - 0.030 < LLD	0.023 < LLD	< LLD < LLD	< LLD < LLD
Co-60	PreOp 2021	0.005 - 0.044 < LLD	0.017 < LLD	< LLD < LLD	< LLD < LLD
Ag-110m	PreOp 2021	< LLD - 0.004 < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
Cs-137	PreOp 2021	0.004 - 0.018 < LLD	0.007 < LLD	0.005 - 0.012 <LLD	0.007 < LLD
All other SONGS radionuclides	PreOp 2021	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
Fish Sample 2 Flesh[d]					
Co-58	PreOp 2021	0.009-0.011 < LLD	0.010 < LLD	< LLD < LLD	< LLD < LLD
Co-60	PreOp 2021	0.004-0.045 < LLD	0.017 < LLD	< LLD < LLD	< LLD < LLD
Ag-110m	PreOp 2021	0.002-0.009 < LLD	0.006 < LLD	< LLD < LLD	< LLD < LLD
Cs-137	PreOp 2021	0.003-0.015 < LLD	0.008 <LLD	0.004-0.014 < LLD	0.009 < LLD
All other SONGS radionuclides	PreOp 2021	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

		INDICATOR		CONTROL	
Radionuclide	**Period [a]**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**
Mussel Flesh (Bay or California)[d]					
Mn-54	PreOp 2021	0.009 - 0.025 < LLD	0.017 < LLD	< LLD < LLD	< LLD < LLD
Co-58	PreOp 2021	0.008 - 0.080 < LLD	0.028 < LLD	-- < LLD	-- < LLD
Co-60	PreOp 2021	0.005 - 0.400 < LLD	0.077 < LLD	< LLD < LLD	< LLD < LLD
Cs-137	PreOp 2021	0.003 - 0.006 < LLD	0.004 < LLD	< LLD < LLD	< LLD < LLD
Ru-103	PreOp 2021	< LLD - 0.045 < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
All other SONGS Radionuclides	PreOp 2021[c]	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
Spiny Lobster Flesh (Bay or California)[d]					
Co-58	PreOp 2021	0.007 - 0.270 < LLD	0.086 < LLD	< LLD < LLD	< LLD < LLD
Co-60	PreOp 2021	0.014 - 0.210 < LLD	0.060 < LLD	< LLD < LLD	< LLD < LLD
Cs-137	PreOp 2021	0.005 - 0.011 < LLD	0.008 < LLD	0.004 - 0.015 < LLD	0.008 < LLD
All other SONGS radionuclides	PreOp 2021[c]	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

NOTES:

a Preoperational period is January 1979 – July 1982.

b LLD for the 2021 data are listed in Appendix B

c During 2021, all station-related radionuclides from all sample locations were < LLD

d Samples collected in 2021 include crustacea, mollusks, and two adult species of fish at each location and collection evolution.

Local Crops

In the preoperational period of January 1979 through July 1982, Sr-90 was detected in the control samples of kale, parsley, and squash. Naturally occurring K-40 was detected in cucumber, kale, and tomato samples from the indicator and control locations. Ce-144 and Zr-95 were detected in one sample of parsley at the control location at concentrations of 0.12 and 0.09 pCi/g, wet weight respectively.

During 2021, only natural radionuclides were identified in local crops at both the indicator and control locations. SONGS had no impact on the environment as measured by this exposure pathway in 2021.

Soil

A comparison of operational and preoperational data does not reveal any accumulation pattern of SONGS-related isotopes in soil (refer to Table 31). The intermittent detection of Cs-137 in both indicator and control locations is due to residual fallout from atmospheric nuclear weapons testing. SONGS had no impact on the environment as measured by this exposure pathway in 2021.

Table 31 - Soil Concentration

Radionuclide	Period	Indicator		Control	
		Range (pCi/g)	Average (pCi/g)	Range (pCi/g)	Average (pCi/g)
Sr-90	PreOp 2021	0.02 - 0.08 N/A	0.044 N/A	< LLD - 0.03 N/A	< LLD N/A
Cs-137	PreOp 2021	0.02 - 0.20 <LLD	0.096 <LLD	< LLD - 0.06 <LLD	< 0.10 <LLD
All other SONGS radionuclides	PreOp 2021	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

Kelp

Kelp is normally collected semiannually from three indicator locations and from a control location situated at Salt Creek when kelp canopy is available. Kelp sampling is not required by the ODCM. The samples are analyzed by gamma-spectral analysis for naturally occurring and SONGS-related radionuclides.

To assess the impact of SONGS on kelp, pre-operational data were compared to 2021 REMP data in Table 32. Radionuclides detected during the pre-operational period for SONGS included Mn-54, Co-60, Zr-95, I-131, and Cs-137.

Although I-131 activity has been detected in kelp since 1977, there is no evidence that the concentrations of I-131 are a result of operations at SONGS. The presence of I-131 in kelp is due to the sewer release of medical administrations of radioisotopes, since it has been detected consistently in control as well as indicator locations. Since 1988, the concentration of I-131, when detected, has typically been highest at the control locations. There is correlation between indicator and control sample locations over an extended period of time.

During 2021, kelp was collected at two indicator locations and the control location in April and only the control location in October. The kelp canopy was missing from all other locations in 2021. Cs-137 was detected in one indicator sample from San Mateo Kelp Bed, as reported in Table 22; the detected activity was confirmed by re-counting the sample. The low concentration is consistent with low levels of Cs-137 observed in marine samples over time; these low levels of Cs-137 are attributable to sources external to SONGS such as atmospheric nuclear weapons testing and the Fukushima Daiichi accident. I-131 was not detected in kelp samples during 2021. SONGS had no impact on the environment as measured by this exposure pathway in 2021.

Table 32 - Kelp Concentration

Radionuclide	Period	Indicator		Control	
		Range (pCi/g)	Average (pCi/g)	Range (pCi/g)	Average (pCi/g)
Mn-54	PreOp 2021	< LLD - 0.005 < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
Co-60	PreOp 2021	0.006 - 0.009 < LLD	0.008 < LLD	< LLD < LLD	< LLD < LLD
Zr(Nb)-95	PreOp 2021	0.014 - 0.090 < LLD	0.046 < LLD	0.018 - 0.053 < LLD	0.036 < LLD
I-131	PreOp 2021	0.006 - 0.024 < LLD	0.013 < LLD	0.008 - 0.030 < LLD	0.014 < LLD
Cs-137	PreOp 2021	0.004 - 0.071 < LLD	0.027 < LLD	< LLD < LLD	< LLD < LLD
All other SONGS radionuclides	PreOp 2021	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

APPENDIX E. DEVIATIONS FROM ODCM SAMPLING REQUIREMENTS IN 2021

DEVIATIONS FROM ODCM SAMPLING REQUIREMENTS

Deviations from the ODCM sampling requirements are identified below in accordance with section 5.0 of the ODCM. During 2021, the ODCM specified *a priori* LLD was achieved for all REMP samples. Deviations from the ODCM were associated with external factors not within the control of REMP personnel such as limited availability of marine samples at the locations specified in the ODCM, external power outages, and other unavoidable deviations. The 2021 ODCM deviations had no meaningful impact on the REMP data and do not compromise the validity of the reported conclusions.

Direct Radiation

Thermoluminescent Dosimeters (TLDs)

1. TLD 38 was moved in January 2021 due to a safety concern with sample location. Quarterly results from 2021 indicate that the new location has a lower background dose rate than the previous location. The location change did not affect the direction, distance, or map location from the ODCM.
2. TLD 75 was moved in January 2021 due to safety and environmental concerns with the existing location. Data from 2021 trends well with recent years. The location change did not affect the direction, distance, or map location from the ODCM.
3. TLD 55 was discovered to be missing on 3/8/2021. The TLD location appeared to be vandalized. A new TLD box was installed using a metal strap to make the installation more secure.
4. TLD 78 remained unavailable from 2Q20-1Q21 due to construction activities that removed the power pole the TLD was installed on. TLD was placed back in service on April 2021 when a new post was installed to hold the TLD canister.
5. TLD 6 and collocated CDPH TLD were removed from sample location and placed in a shielded storage vault from 4/26/21-6/16/21 due to power pole construction activities. The TLD was deployed in a temporary location near the original location from 6/16/21-9/13/21 and returned to the original location for the remainder of 2021. The second quarter result for TLD 6 was reported as missing due to a notably lower result than other quarters; the average of the three remaining quarters was used to determine annual dose for this location.
6. TLD 46 was discovered to be missing during quarterly TLD exchange on 7/1/21. Loss was due to vandalism. TLD sample container closure was lubricated to ensure lock mechanism would be effective in the future.

Air Sampling

At SONGS, the ODCM requires a total of four Indicator stations and one Control station.

Downtime for each air sampler in 2021 was due to weekly sample collection, quarterly calibrator flow comparison checks, scheduled air sampler motor assembly / calibrator change-outs, and preventative air sampler motor assembly change-outs which was conducted if a motor assembly was observed to show signs of degraded performance (excessive bearing noise, vane erosion, flow decline, etc.). During 2021, there were no avoidable deviations from the ODCM-required air sample schedule.

Downtime events exceeding one hour for each ODCM-required air sample are addressed below:

1) Air Sampler #12 (Former SONGS Evaporation Pond) was out of service for approximately 4 hours during the collection period ending 2/23/2021. The sampler was running when the sample was collected and a temporary power outage is suspected.
2) Air Sampler #9 (State Beach Park) had a down time of approximately 8 hours during the collection period ending 8/3/2021 due to an external power outage.
3) Air Sampler #12 (Former SONGS Evaporation Pond) had a down time of approximately 8 hours during the collection period ending 8/3/2021 due to an external power outage.

Note: There were also downtime events associated with Air Samplers #10 and #11. These air samplers are not required by the ODCM and the associated downtimes are not reported.

Ocean Water Sampling

No deviations were observed.

Shoreline Sediments

No deviations were observed.

Ocean Bottom Sediments

No deviations were observed.

Marine Species (Flesh)

No deviations were observed.

Local Crops

No deviations were observed.

Soil

No deviations were observed.

Kelp

Kelp samples are not required by Section 5.1 of the ODCM. Normally, four kelp beds are collected twice a year for a total of eight kelp samples. Only three samples were available during April 2021 (two indicator and one control) and one sample (control) was available during October 2021. The Kelp canopy was absent at the remaining locations during the sample events. Kelp sampling is not required and this did not constitute a deviation from the ODCM.

APPENDIX F. ERRATA TO PREVIOUS AREORs

No corrections to previous AREORs were identified in 2021.

APPENDIX G. CDPH CO-LOCATED TLDs

DATA FROM THE CDPH TLDs CO-LOCATED WITH SONGS REMP TLDs DURING 2021

CDPH maintains a TLD program in the environs of SONGS. Per CDPH request, the 2021 exposure results from the CDPH dosimeters are reported in Table 33 below. The Location Numbers refer to the current SONGS Decommissioning*Solutions* (SDS) alphanumeric location identifier and the current CDPH location number.

Table 33 - 2021 State of California Data from the CDPH TLD program (mR)

Location Numbers	Location Name	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
SDS-1, CDPH #2	City of San Clemente	25	27	24	8
SDS-22, CDPH #4	Former US Coast Guard Station – San Mateo Point	23	26	25	16
SDS-34, CDPH #5	San Onofre Elementary School	23	25	25	M
SDS-10, CDPH #6	Bluff (Adjacent to PIC #1) (San Onofre Surfing Beach)	23	24	28	14
SDS-16, CDPH #7	East Southeast Site Boundary	19	23	22	13
SDS-2, CDPH #8	Camp San Mateo	26	28	30	M
SDS-3, CDPH #9	Camp San Onofre	24	23	26	14
SDS-6, CDPH #10	Old El Camino Real (Old Highway 101) (ESE)	18	M	M	11
SDS-50, CDPH #13	Oceanside Fire Station	22	25	25	14

M=CDPH data is not available for the following locations and sample periods:

- CDPH #10: 2Q21 & 3Q21
- CDPH #5: 4Q21
- CDPH #8: 4Q21

The CDPH TLD program does not conform to the same environmental dosimeter standard Reg. Guide 4.13 (ANSI N13.37-2014) used to generate direct radiation data for the SONGS REMP TLD program. The CDPH reports results in different units of measurement and is therefore not technically equivalent to the SONGS TLD data set. The different methodologies and the different units of measurement make it unsuitable to directly compare individual REMP data to the corresponding individual CDPH TLD data. However, the CDPH results are consistent with conclusion that beyond the EAB there is no detectable direct radiation that is attributable to SONGS.

It was noted during report generation that the fourth quarter CDPH TLD results appear to be significantly lower than the trend of the first three quarters. CDPH is reviewing the anomaly.

APPENDIX H. ISFSI TLD DATA

Summary

Per 10 CFR 72.126, SONGS implemented an area monitoring TLD program in the vicinity of the ISFSI.

An evaluation of the entire REMP TLD database yielded an estimated background exposure rate of approximately 15.8 mrem/std. quarter (91 days). However, some local variability within the SONGS EAB is known to exist and cannot be precisely known at every location within SONGS. This value would need to have been measured before SONGS was constructed and TLD technology did not exist at that time. Therefore, a comparison of pre-operational data to the 2021 data needs to be considered in conjunction with a comparison of ISFSI TLD data and the estimated baseline background exposure rate within the EAB.

Environmental exposure rates are variable and small changes in TLD location can measurably change the data. SONGS REMP TLD data show an environmental seasonal variability that is not related to any activities at SONGS. The ISFSI TLD data gathered to date follow a similar seasonal variability.

The measured exposure rates for the ISFSI TLDs close to the ISFSI are consistent with the exposure rates expected from known radiological work activities and storage of spent fuel and radioactive material in the ISFSI.

Publicly accessible REMP TLDs include SCE-55, SCE-56 and SCE-57. In 2021, ISFSI TLDs SCE-55 (San Onofre State Beach, U1 West), SCE-56 (located next to SCE-55), and SCE-59 (SONGS Meteorological Tower), recorded measurable annual facility doses. TLD 55 was missing in 1Q21 and the average of the remaining three quarters were used to estimate the annual dose. The occupancy-adjusted doses to a member of the general public are less than one (1) mrem per year and are reported as ND per ANSI/HPS N13.37-2014. This result was reported in the 2021 Annual Radioactive Effluent Release Report.

The 2021 neutron TLDs identified low levels of neutron radiation from the ISFSI. Neutron TLDs were added to several locations around the ISFSI prior to the off load of spent fuel from Units 2 & 3 to obtain neutron dose information. Currently, neutron dosimeters are collocated with ISFSI TLDs 311, 326, 339-344, and REMP TLD 55.

A dose equivalent conversion factor for the TLD neutron signal based on a similar ISFSI facility at another site was adopted to estimate the neutron dose rate at SONGS. This conversion factor is being applied to the SONGS TLD results to provide an estimate of the neutron dose equivalent being measured. The neutron dose has been included in the quarterly results for these locations in Table 34. The results from all locations at the fence around the ISFSI pad show that the dose to a member of the public, when adjusted for occupancy, would be less than one (1) mrem per year.

Table 34 - 2021 ISFSI TLD Data

TLD (SCE-##)	Location [a]	Qtr. Baseline (mrem)	2021 Quarterly Results (mrem)[f]				Baseline Adjusted Quarterly Results (mrem)				Annual Dose (mrem)	Annual Facility Dose (mrem)	Annual Public Dose[b] (mrem)
			1	*2*	*3*	*4*	*1*	*2*	*3*	*4*			
301		15.8	19.2	17.1	17.2	19.2	ND	ND	ND	ND	72.8	ND	-
302		15.8	23.3	20.8	21.7	23.4	7.6	5.1	6.0	7.6	89.3	26.2	-
303		15.8	22.2	20.4	20.6	22.8	6.4	ND	ND	7.0	86.0	22.9	-
304		15.8	21.3	19.2	20.2	22.1	5.5	ND	ND	6.3	82.7	19.7	-
307		15.8	19.5	17.3	18.3	20.2	ND	ND	ND	ND	75.2	12.2	-
308		15.8	18.5	17.2	17.5	19.4	ND	ND	ND	ND	72.6	ND	-
309		15.8	19.5	18.6	19.2	20.4	ND	ND	ND	ND	77.6	14.5	-
310		15.8	21.0	19.5	19.4	21.6	5.3	ND	ND	5.8	81.6	18.5	-
311	ISFSI-01[c]	15.8	20.1	18.6	18.8	20.9	ND	ND	ND	5.2	78.5	15.5	-
312		15.8	15.5	14.5	15.2	16.3	ND	ND	ND	ND	61.5	ND	-
314		15.8	20.9	18.5	18.9	20.1	5.2	ND	ND	ND	78.4	15.3	-
315		15.8	19.1	18.0	18.2	19.2	ND	ND	ND	ND	74.5	11.4	-
316		15.8	16.7	15.1	15.2	17.0	ND	ND	ND	ND	64.0	ND	-
317		15.8	17.5	18.1	15.9	17.8	ND	ND	ND	ND	69.2	ND	-
318[e]		15.8	19.1	17.3	18.0	20.3	ND	ND	ND	ND	74.7	11.6	-
319[e]		15.8	18.8	17.8	18.6	20.5	ND	ND	ND	ND	75.7	12.6	-
320[e]		15.8	18.7	17.7	18.2	20.4	ND	ND	ND	ND	75.0	11.9	-
321[e]		15.8	19.3	18.2	18.4	20.7	ND	ND	ND	ND	76.7	13.6	-
326	ISFSI-02[c]	15.8	20.0	20.1	20.5	26.9	ND	ND	ND	11.1	87.5	24.4	-
339	ISFSI-08[c]	15.8	24.9	22.3	23.3	25.4	9.2	6.5	7.5	9.6	95.9	32.8	-
340	ISFSI-09[c]	15.8	22.0	21.1	21.2	22.2	6.2	5.3	5.5	6.4	86.5	23.4	-
341	ISFSI-10[c]	15.8	22.5	22.3	23.7	22.4	6.7	6.6	7.9	6.6	90.9	27.8	-
342	ISFSI-11[c]	15.8	25.9	24.3	25.3	24.7	10.2	8.6	9.5	8.9	100.2	37.2	-
343	ISFSI-12[c]	15.8	23.8	21.4	22.7	22.6	8.0	5.6	6.9	6.9	90.4	27.3	-
344		15.8	22.3	19.2	19.3	20.7	6.5	ND	ND	ND	81.5	18.4	-

TLD (SCE-##)	Location [a]	Qtr. Baseline (mrem)	2021 Quarterly Results (mrem)[f]				Baseline Adjusted Quarterly Results (mrem)				Annual Dose (mrem)	Annual Facility Dose (mrem)	Annual Public Dose[b] (mrem)
			1	*2*	*3*	*4*	*1*	*2*	*3*	*4*			
55 [d, e]	San Onofre State Beach (U1 West) ISFSI-07[c]	15.8	--	19.9	21.4	22.6	--	ND	5.6	6.8	85.2	22.1	ND
56 [d]	San Onofre State Beach (U1 West)	15.8	18.7	18.2	18.1	19.5	ND	ND	ND	ND	74.4	11.3	ND
57 [d]	San Onofre State Beach (Unit 2)	15.8	17.5	16.6	16.7	18.1	ND	ND	ND	ND	68.9	ND	ND
59	SONGS Meteorological Tower	15.8	20.3	19.1	19.6	18.9	ND	ND	ND	ND	77.8	14.7	-

Notes:

a ISFSI TLDs (SCE-301 through SCE-344) are placed around the ISFSI pad, and not in locations accessible to the general public. TLD 59 is also in an area that is not accessible to the general public.

b Public dose is not applicable for those TLDs that are not accessible to the general public.

c Station has a collocated neutron dosimeter package. The neutron dose is estimated using a neutron signal conversion factor measured at a similar ISFSI installation.

d These TLDs are publicly accessible. The public dose is based on an estimated occupancy of 300 hours per year.

e For TLD 55, the estimated neutron dose contributed to the total measured dose in 2021.

f For locations with a collocated neutron dosimetry package the estimated neutron dose (if any) is included in the reported dose.

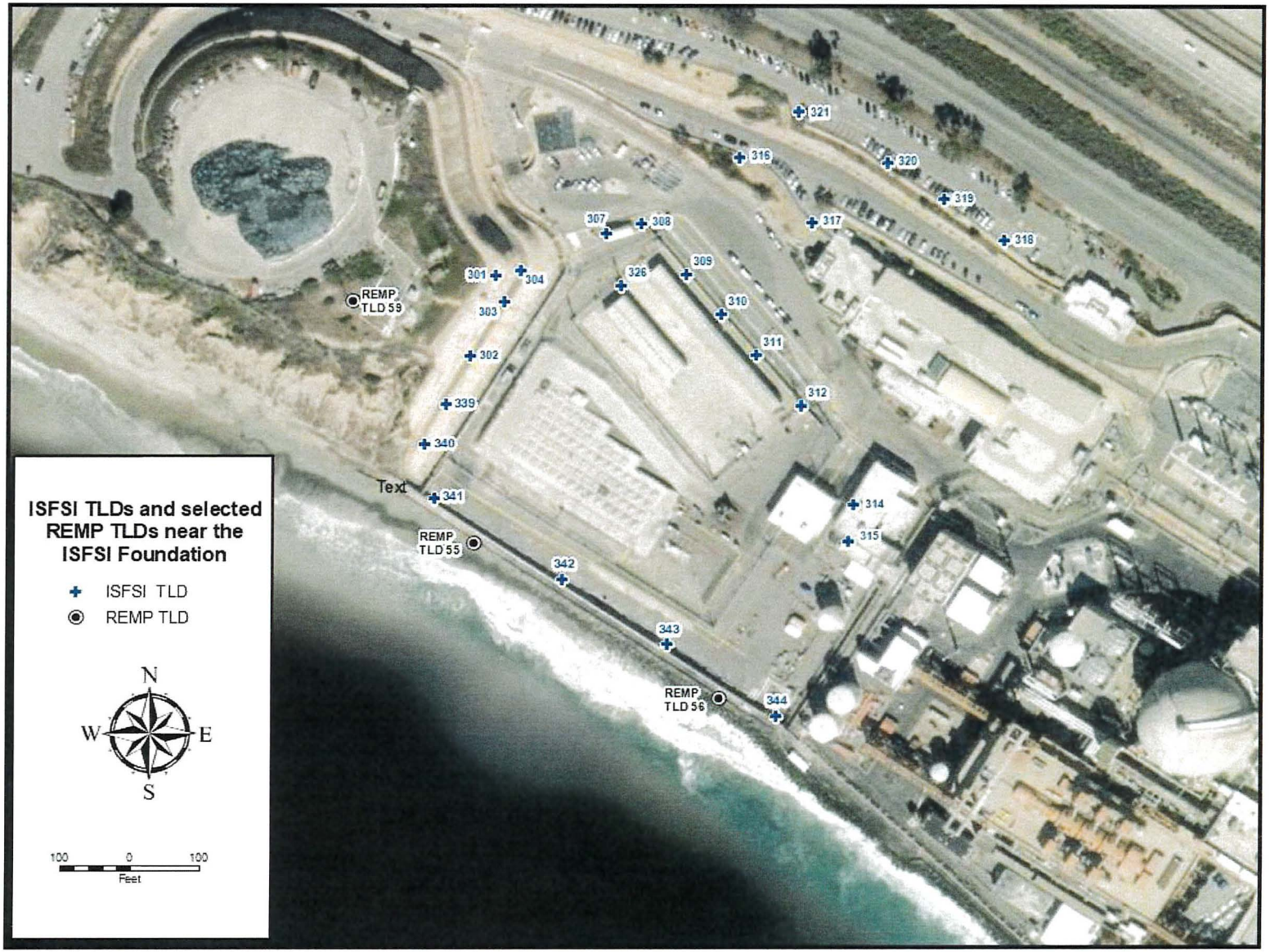

Figure 10 - SONGS ISFSI and Selected REMP TLD Locations

Glossary

a posteriori After the fact

a priori Before the fact

ALARA As Low As is Reasonably Achievable means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Cosmogenic nuclides Radionuclides (or isotopes) created when a high-energy cosmic ray interacts with the nucleus of an atom. These isotopes are produced within Earth materials such as rocks or soil, in Earth's atmosphere, and in extraterrestrial items such as meteorites. Radioactive isotopes beryllium-7 and beryllium-10 fall into this series of three light elements (lithium, beryllium, boron) formed mostly by cosmic ray spallation nucleosynthesis, both of these nuclides have half-lives too short for them to have been formed before the formation of the Solar System, and thus they cannot be primordial nuclides. Since the cosmic ray spallation route is the only possible source of beryllium-7 and beryllium-10 occurrence naturally in the environment, they are therefore cosmogenic.

Below is a list of radioisotopes formed by the action of cosmic rays in the atmosphere; the list also contains the production mode of the isotope.

Isotope	Mode of formation	Isotope	Mode of formation
^{3}H (tritium)	^{14}N (n, $^{12}C)^{3}H$	^{32}P	Spallation (Ar)
^{7}Be	Spallation (N and O)	^{34m}Cl	Spallation (Ar)
^{10}Be	Spallation (N and O)	^{35}S	Spallation (Ar)
^{11}C	Spallation (N and O)	^{36}Cl	^{35}Cl (n, γ)^{36}Cl
^{14}C	^{14}N (n, p) ^{14}C	^{37}Ar	^{37}Cl (p, n)^{37}Ar
^{18}F	^{18}O (p, n)^{18}F and Spallation (Ar)	^{38}Cl	Spallation (Ar)
^{22}Na	Spallation (Ar)	^{39}Ar	^{38}Ar (n, γ)^{39}Ar
^{24}Na	Spallation (Ar)	^{39}Cl	^{40}Ar (n, np)^{39}Cl & spallation (Ar)
^{28}Mg	Spallation (Ar)	^{41}Ar	^{40}Ar (n, γ)^{41}Ar
^{31}Si	Spallation (Ar)	^{81}Kr	^{80}Kr (n, γ) ^{81}Kr
^{32}Si	Spallation (Ar)		

Decay Series	There are three naturally occurring decay series of heavy elements that transform into a series of various radioactive elements by releasing energy in the form of particles, (such as alpha or beta), and/or gamma rays to end in a stable form of non-radioactive Lead. All three decay series start with extremely long lived radioactive, heavy elements that can be measured in geologic time units. They are Uranium-238 with an approximate half-life of 4.5 billion years, Uranium-235 with a half-life of about 700 million years, and Thorium-232 with a half-life of 14 billion years. All three series contain some more well-known radioactive species, Radium and Radon.
Distinguishable from background	Detectable concentration of a radionuclide that is statistically different from the background concentration of that radionuclide at that location.
Dose	The amount of radiation that is absorbed by a person's body. In the radiation field the term dose is sometimes used interchangeably with dose equivalent.
Exclusion Area Boundary (EAB)	The boundary used for routine effluent calculations required by 10 CFR 20 at San Onofre Units 2 & 3; formed by two semi-circles with radii of 1967.5 ft. from the containment centers with a tangent connecting the landward and the seaward arcs.
Half-life	A measure of how fast half the mass of a radioactive element will transform itself into another element. Each radioactive element has its own unique rate of transformation. Consequently, if a radioactive element, such as Iodine-131 has a half-life of 8 days, then in 8 days half of the original amount of Iodine-131 will be gone; in another 8 days half of that half will be left and so on.
Gamma Spectroscopy	A scientific method used to analyze gamma rays emanating from radioactive elements. The analytical system determines the gamma ray energy which acts as a "fingerprint" for specific radioactive materials. For example, Potassium-40 (K-40) has a very, distinctive gamma energy at 1460 keV. This uniqueness allows the instrument to positively identify the K-40 1460 keV energy as its own unique fingerprint. A keV is an abbreviation for kilo electron volt, which is a measure of energy at the atomic level. A kilo is a scientific prefix for the multiplier 1,000.
Gross Beta	A screening technique employed to measure the total number of beta particles emanating from a radioactive sample, without isotopic identification. At SONGS samples with an elevated gross beta are analyzed by gamma spectroscopy to identify the specific radionuclides causing the elevated gross beta signal. A beta particle is a negatively charged particle a mass equal to that of an orbiting electron.
Liquid Scintillation	The analytical technique by which tritium activity is measured in water. A sample is placed in a glass vial containing scintillation cocktail. The mixture is sealed and homogenized. When the tritium decays it emits a very low energy beta particle. The beta interacts with the scintillating medium and produces a light pulse that is counted by the instrument.
millirem (mrem)	One thousandth (1/1000) of a rem.

milliRoentgen (mR)	One thousandth (1/1000) of a Roentgen
pCi/kg	An acronym for a pico-curie per kilogram, which is a concentration unit that defines how much radioactivity is present in a unit mass, such as a kilogram. A "pico" is a scientific prefix for an exponential term that is equivalent to one trillionth (1/1,000,000,000,000).
pCi/l	An acronym for a pico-curie per liter, which is a concentration unit that defines how much radioactivity is present in a unit volume, such as a liter.
Rem	An acronym for roentgen equivalent man. It is a conventional unit of dose equivalent that is based on how much of the radiation energy is absorbed by the body multiplied by a quality factor, which is a measure of the relative hazard of energy transfer by different particles, (alpha, beta, neutrons, protons, etc.), gamma rays or x-rays. In comparison the average natural background radiation dose equivalent to the United States population is estimated to be 292 millirems per year, or 0.8 millirem per day, with 68% of that dose coming from radon. A millirem is one thousandth, (1/1000), of a rem.
Roentgen	A special unit of exposure named after the discoverer of X-Rays, Wilhelm Roentgen. It is a measure of how much ionization is produced in the air when it is bombarded with X-Rays or Gamma Rays. Ionization is described as the removal of an orbital electron from an atom.
Skyshine	Radiation from a radioactive source that bounces off air molecules in the sky, much like a cue ball does off the banking of a billiard table, and is scattered/redirected back down to the earth.
Thermoluminescent Dosimeters (TLD)	Very small plastic-like phosphors or crystals that are placed in a small plastic cage and mounted on trees, posts, etc. to absorb any radiation that impinges on the material. Special readers are then used to heat the plastic to release the energy that was stored when the radiation was absorbed by the plastic. The energy released is in the form of light and that light is counted by the TLD reader. The intensity of the light emitted from the crystals is directly proportional to the amount of radiation that the TLD phosphor was exposed to.
Tritium (Hydrogen-3 or H-3)	H-3 is the naturally occurring radioactive form of Hydrogen. All radioactive elements are represented as a combination of their chemical symbol and their mass number. Therefore, Tritium, which is a heavy form of the Hydrogen molecule with one proton and two neutrons in the nucleus of its atom, is abbreviated and represented by its chemical symbol, H-3, for Hydrogen and 3 for the number of particles in its nucleus, or mass number. Similarly, other radioactive elements, such as Potassium-40, can be represented and abbreviated as K-40, and so on.