SCATTERGOOD GENERATING STATION

SUMMARY OF EXISTING PHYSICAL AND BIOLOGICAL INFORMATION AND IMPINGEMENT MORTALITY AND ENTRAINMENT CHARACTERIZATION STUDY SAMPLING PLAN

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Prepared for:

Los Angeles Department of Water and Power
Los Angeles, California

Prepared by:

Tenera Environmental
San Luis Obispo, California

MBC *Applied Environmental Sciences*
Costa Mesa, California

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1.0 INTRODUCTION

On 9 July 2004, the U.S. Environmental Protection Agency (EPA) published Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities. These §316(b) requirements went into effect in September 2004, and apply to existing generating stations with cooling water intake structures that withdraw at least 50 million gallons per day (mgd) from rivers, streams, lakes, reservoirs, oceans, estuaries, or other waters of the United States. The Scattergood Generating Station (SGS) has two oil/gas turbines (Units 1 & 2) rated at a capacity of 179 MW each, and one gas turbine (Unit 3) rated at a capacity of 460 MW for a total generating capacity of 818 MW. All three units draw cooling water from a common submerged offshore intake equipped with a velocity cap located approximately 1,600 ft (500 m) offshore. The cooling water systems for Units 1 and 2 withdraws a maximum of 112.3 mgd per unit, and the system for Unit 3 withdraws a maximum of 270.7 mgd. Phase II facilities as part of the Proposal for Information Collection (PIC) are required to provide:

- *A list and description of any historical studies characterizing impingement mortality and entrainment (IM&E), and/or the physical and biological conditions in the vicinity of the cooling water intake structures and their relevance to this proposed Study. If you propose to use existing data, you must demonstrate that the data are representative of current conditions and were collected using appropriate quality assurance/quality control procedures.*
- *A sampling plan for any new studies you plan to conduct in order to ensure that you have sufficient data to develop a scientifically valid estimate of IM&E at your site. The sampling plan must document all methods and quality assurance/quality control procedures for sampling and data analysis. The sampling and data analysis methods you propose must be appropriate for a quantitative survey and include consideration of the methods used in other studies performed in the source waterbody. The sampling plan must include a description of the study area (including the area of influence of the cooling water intake structure [CWIS]), and provide taxonomic identifications of the sampled or evaluated biological assemblages (including all life stages of fish and shellfish).*

This document provides this information. As part of the §316(b) Comprehensive Demonstration Study (CDS) required under the new regulations, a facility may be required to submit an Impingement Mortality and Entrainment Characterization Study depending on the chosen compliance pathway. The Impingement Mortality component is not required if a facility's through-screen intake velocity is less than or equal to 0.5 ft/s (15 cm/s). The Entrainment Characterization component is not required if a facility: (a) has a capacity utilization rate of less than 15 percent; (b) withdraws cooling water from a lake or reservoir, excluding the Great Lakes; or (c) withdraws less than five percent of the mean annual flow of a freshwater river or stream. Based on previously collected intake velocity measurements and plant operating characteristics, both the Impingement Mortality and Entrainment components of the Study apply at the SGS. According to the §316(b) Phase II Regulations, the Impingement Mortality and Entrainment Characterization Study must include the following (for all applicable components):

- Taxonomic identifications of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) that are in the vicinity of the cooling water intake structure(s) and are susceptible to impingement and entrainment;
- A characterization of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified in the taxonomic identification noted previously, including a description of the abundance and temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize the annual, seasonal, and diel variations in the impingement mortality and entrainment; and

- Documentation of current impingement mortality and entrainment of all life stages of fish, shellfish, and any protected species identified previously and an estimate of impingement mortality and entrainment to be used as the calculation baseline.

The Rule allows facilities to use four sources of information in developing the Impingement Mortality and Entrainment Characterization Baseline. These include:

- Use of historical studies
- Use of source waterbody biological information
- Use of data from other facilities
- Results of new studies

As discussed below, SGS plans to use a combination of these sources of information to prepare the Impingement Mortality and Entrainment Characterization Study Report. Under the new 316(b) regulations the impingement mortality component of the IM&E studies is not required if a facility's through-screen intake velocity is less than or equal to 0.5 ft/s (15 cm/s). The cooling water intake flow at the SGS exceeds this value so impingement mortality studies will be conducted. The entrainment characterization component is not required if a facility: (a) has a capacity utilization rate of less than 15 percent; (b) withdraws cooling water from a lake or reservoir, excluding the Great Lakes; or (c) withdraws less than five percent of the mean annual flow of a freshwater river or stream. None of these criteria apply to the SGS so the entrainment component of the study also will be conducted.

1.1 Environmental Setting

The SGS (33°54'59" N, 118°26'08" W) is located in the city of Los Angeles on the shore of Santa Monica Bay. Santa Monica Bay is an open embayment approximately 27 mi (43 km) across and delineated by Point Dume, which is located approximately 23 mi (37 km) to the northwest of the SGS and Palos Verdes Point, which is located approximately 9 mi (15 km) to the south (**Figure 1-1**). The surface area of the Bay is approximately 266 square miles (428 square km) (MBC 1988). The Bay is characterized by a gently sloping continental shelf which extends seaward to the shelf break at water depths of approximately 265 ft (80 m) (Terry et al. 1956). Natural rocky outcrops are confined to the northern and southern portions of the bay from Point Dume to the Malibu coast area to the north, and the Palos Verdes point area to the south, respectively.

The prevailing current direction in the shallow, nearshore areas of Santa Monica Bay is downcoast (equatorward) suggesting an eddy-type circulation pattern resulting from the upcoast (poleward) currents outside of the bay (Hendricks 1980). This description is supported by more extensive studies by Hickey (1992) that also showed downcoast currents on the shelf within the bay and prevailing upcoast (poleward) currents at the edge of the shelf at the outer boundary of Santa Monica Bay. The circulation pattern within the bay results from the presence of the Southern California Countercurrent in the outer coastal waters of the Southern California Bight.

Sediments in the areas directly offshore from the SGS are primarily composed of sand, with lesser amounts of silt and clay (Allen et al. 1998, MBC 2003). The infaunal community is typical for the sandy nearshore habitat, primarily composed of annelid worms, arthropods, small mollusks, and nemertean worms (MBC 2003). The nearshore demersal soft-bottom fish community, as sampled by otter trawl, is largely composed of flatfishes, including speckled sanddab (*Citharichthys stigmaeus*), English sole (*Parophrys vetulus*), hornyhead turbot (*Pleuronichthys verticalis*), and California halibut (*Paralichthys californicus*) (Allen et al. 1998, MBC 2003). Other species present further offshore include Pacific sanddab (*Citharichthys sordidus*), longfin sanddab (*C. xanthostigma*), yellowchin sculpin (*Icelinus quadriseriatus*), pink surfperch (*Zalembius rosaceous*), plainfin midshipman (*Porichthys notatus*), and California scorpionfish (*Scorpaena guttata*) (CLA-EMD 1999, 2001). Fish assemblages commonly associated with hard substrate in southern California are often comprised of both larger fishes, such as kelp bass (*Paralabrax clathratus*), black surfperch (*Embiotoca jacksoni*), garibaldi (*Hypsypops rubicundus*), California sheephead (*Semicossyphus pulcher*), etc. (Allen 1985, Stephens and Pondella 2002), as well as smaller fishes such as the reef finspot (*Paraclinus integrippinnis*), bluebanded goby (*Lythrypnus dalli*), and combtooth blennies (*Hypsoblennius* spp.) (Allen et al. 1992, Stephens and Pondella 2002).

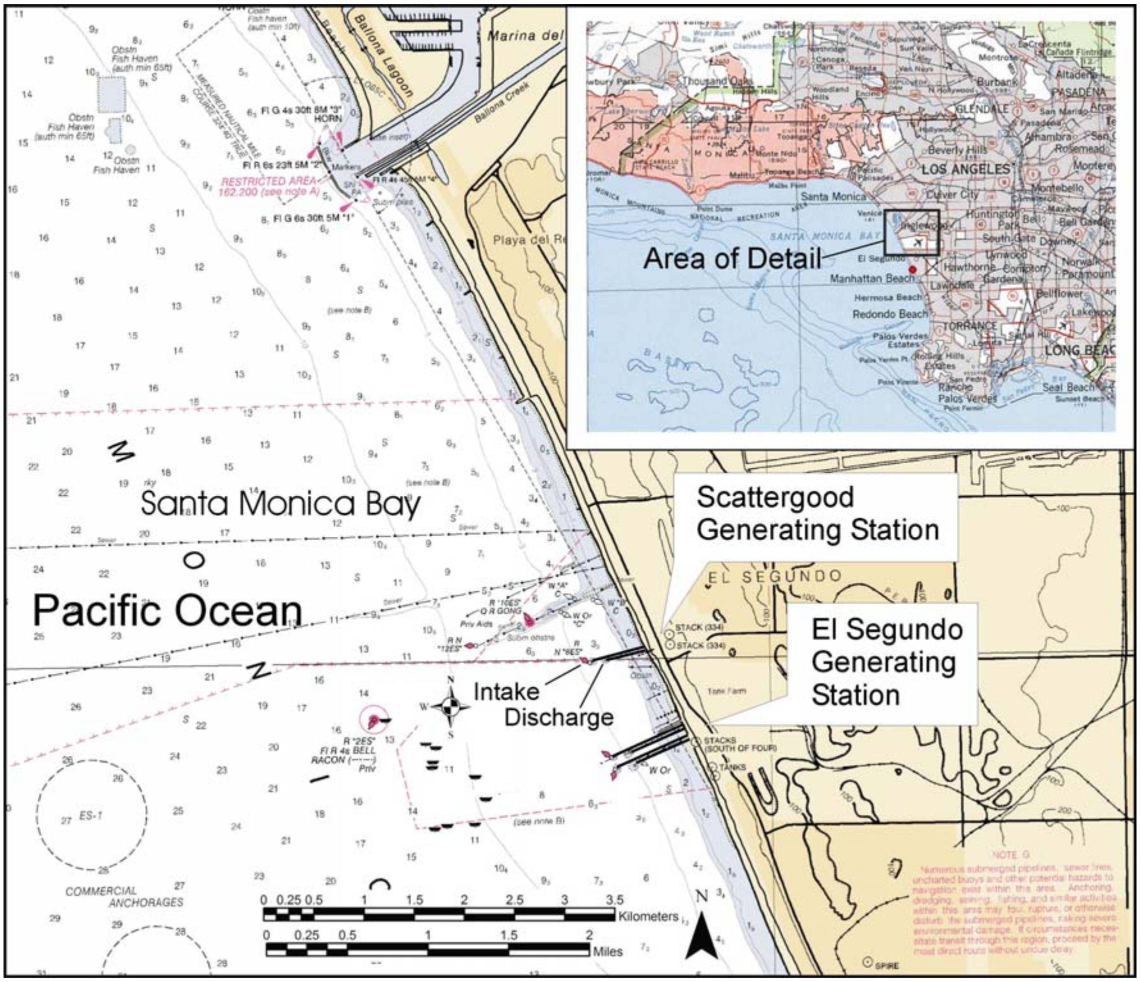

Figure 1-1. Location of the Scattergood Generating Station and intake and discharge structures in Santa Monica Bay. Location of the El Segundo Generating Station is also shown.

2.0 HISTORICAL PHYSICAL AND BIOLOGICAL STUDIES

The following identifies and summarizes previous physical and biological studies conducted at the SGS and relevant studies from Santa Monica Bay. Many studies were performed in cooperation with the El Segundo Generating Station (ESGS), which withdraws cooling water from two intake structures located approximately one kilometer down coast from the SGS. Unless otherwise specified, studies are summarized for information and context.

2.1 1978-1979 SGS 316(b) Demonstration

From October 1978 through November 1979, the LADWP performed impingement and entrainment (both in-plant and source water) studies at the SGS (IRC 1981). Entrainment sampling was performed biweekly for one year, and most sampling events consisted of both day and night sampling. Samples used to characterize entrainment and source water populations were collected at one station at the intake (near-field station) and at two stations in the source water located 3.8 km up coast and 2.4 km offshore the intake (far-field stations). Target species were selected for analysis prior to the initiation of the study, and included six larval fish taxa and five juvenile/adult fish species. The source water for the Scattergood plankton study was restricted to Santa Monica Bay and extended from shore out to the 90-ft depth contour. Impacts were assessed using a combination of approaches, including the Adult Equivalent Loss (*AEL*) model for fishes (Horst 1975, Goodyear 1978). The *AEL* estimates for target fishes are presented in (**Table 2-1**).

Table 2-1. Adult equivalent loss estimates from entrainment data collected at SGS from 1978-1979. AEL estimates were only calculated for these critical taxa identified from the entrainment data.

Critical Fish Taxa		**Adult Equivalent Loss Estimates** from fish eggs	from fish larvae
silversides	Atherinid species complex		84,600
anchovies	Engraulid species complex		9,880
northern anchovy	*Engraulis mordax*	13,300	
croakers	Scieaenid species complex	94,600	
white croaker	*Genyonemus lineatus*		23,200
queenfish	*Seriphus politus*		25,100
Total		**107,900**	**142,780**

IRC (1981) calculated were the source water volumes necessary to induce a 5% cropping rate on each taxa. It was determined that these volumes represented only a fraction of the volume of Santa Monica Bay, leaving ample room for immigration from elsewhere within the Bay. Loss estimates were considered conservative since compensatory factors were not taken into consideration. Consequently, it was concluded that entrainment losses were insignificant.

No routine impingement sampling was done during the 1978-1979 316(b) Demonstration Study. Impingement data presented in the 316(b) report included heat treatments and a 10-day special study under variable flow conditions conducted during the 1978-1979 period where queenfish (*Seriphus politus*), white croaker (*Genyonemus lineatus*), walleye surfperch (*Hyperprosopon argenteum*), and white seaperch (*Phanerodon furcatus*) were the most abundant fish. The report also presented data from the previous year's heat treatment surveys where the impingement of target species was estimated at 9,580 lbs (**Table 2-2**). For four juvenile/adult fish taxa analyzed (white croaker, queenfish, walleye surfperch, and northern anchovy), instantaneous mortality coefficients due to impingement at the SGS, recreational fishing, and commercial fishing were all extremely small relative to instantaneous total mortality. Impingement totals from the heat treatment sampling were compared to source population estimates. Source populations for queenfish, white croaker, and walleye surfperch were considered to reside in the Bay between Redondo Beach and Point Dume, and extending offshore to the 230 ft (70 m) isobath. Source population estimates were derived from nearshore trawl data. To compute these estimates, the fish collected in the trawl surveys were multiplied by the ratio of the source water volume to the volume of water sampled by the trawls. Trawl catch efficiencies were estimated to be 12% to 30%.

Table 2-2. Total numbers of critical fish taxa collected during seven heat treatment impingement surveys from November 1977 through November 1978.

		Total Annual Impingement	
Target Taxa		**Abundance**	**Biomass (lbs.)**
queenfish	*Seriphus politus*	89,230	5,507
white croaker	*Genyonemus lineatus*	19,437	2,340
walleye surfperch	*Hyperprosopon argenteum*	9,939	1,558
Northern anchovy	*Engraulis mordax*	Not available	175
Total			**9,580**

The source population for northern anchovy was considered to reside in the "Channel" area of the Southern California Bight, which extends between Dana Point and Santa Catalina Island to the south, and Santa Cruz Island and the city of Santa Barbara to the north. The effects of impingement mortality on these source populations during the study year ranged from 0.45% (queenfish; *Seriphus politus*) to 0.0004% (northern anchovy; *Engraulis mordax*). The study concluded that there were no adverse environmental impacts due to CWIS impingement and entrainment at SGS, and based on 316(b) assessment guidelines, no intake technology review was necessary (IRC 1981).

The sampling program was conducted with the approval of the Los Angeles Regional Water Quality Control Board (LARWQCB), and detailed procedures and methodologies, as well as Quality Assurance/Quality Control (QA/QC) methods, can be found in Appendices G (Biological Field Procedures), H (Laboratory Procedures), and I (Statistical and Analytical Procedures) of IRC (1981).

2.2 1997 SGS 316(b) Update

In 1997 MBC Applied Environmental Sciences synthesized available information to update the original 316(b) assessment for the SGS (MBC 1997). No additional recent data on through-plant effects on zooplankton, fish eggs, or ichthyoplankton were included in the 316(b) update. Studies conducted during the original 316(b) assessment were carried out with the plant operating at higher flow (24% higher than from 1982 through 1995) and higher capacity (35% higher than from 1981 through 1995) than in subsequent years. Cooling water flow at the SGS decreased substantially from the 1970's through the 1990's. Even though the cooling water flow was substantially reduced, the loss estimates from the original 316(b) studies calculated under full operation and flow were used to present the most conservative case.

In the 1997 316(b) update, data from heat treatment samples collected from 1989 through 1995 were used to determine effects of plant operations on adult fishes. Annual heat treatment loss estimates for the 10 most abundant fish species are presented in Table 2-3. Heat treatment data from SGS included fish species, abundance, biomass, and standard length. Critical fish taxa, chosen for the 316(b) update, included those most frequently entrained by the SGS, as well as those of high recreational or commercial value. Numbers of fishes impinged at the SGS were compared with numbers of fish reported caught in the Bay catch blocks between 1989 and 1994 and fish reported caught from sportfishing landings known to target the Bay. For most species, annual impingement totals were less than 2% of catch block totals from the Bay (from shore out to the 100-m isobath).

One exception was white croaker (*Genyonemus lineatus*), where 9,063 individuals were impinged during the seven-year period, but only 1,894 individuals were reported from the Bay catch blocks. Similarly, annual impingement totals were less than 1% of annual sportfishing landing reported from the Bay, with the exception of white croaker. Sportfishers in the Bay caught an annual average 148 white croaker, compared with 1,053 in annual impingement totals. The most abundant fish in impingement samples from 1989 to 1995 were jack mackerel (*Trachurus symmetricus*; 32%), queenfish (18%), topsmelt (*Atherinops affinis*; 11%), jacksmelt (*Atherinopsis californiensis*; 8%), and northern anchovy (7%).

Table 2-3. Average total annual impingement during heat treatment surveys conducted at SGS from 1989-1995. Note: the number of heat treatments varied among years.

		Average Total Annual Impingement	
Target Taxa		**Abundance**	**Biomass (lbs.)**
jack mackerel	*Trachurus symmetricus*	11,862	853
queenfish	*Seriphus politus*	6,596	536
topsmelt	*Atherinops affinis*	4,119	392
jacksmelt	*Atherinopsis californiensis*	2,883	688
northern anchovy	*Engraulis mordax*	2,496	40
Pacific sardine	*Sardinops sagax*	1,800	205
white croaker	*Genyonemus lineatus*	1,554	90
Salema	*Xenistius californiensis*	1,332	84
yellowfin croaker	*Umbrina roncador*	938	282
Walleye surfperch	*Hyperprosopon argenteum*	569	73
Total		**34,149**	**3,244**

As with the original 316(b) study, no alternative intake technologies were considered since entrainment and impingement losses were considered insignificant. Losses due to impingement represented less than 2% of fish taken locally by sportfishers, and less than 0.2% of standing stocks in the Bay where such calculations were possible. Similar to the original 316(b) Demonstration, source population estimates were derived from trawl surveys. Trawl data was available from just offshore the SGS (1986 and 1988) and the Hyperion Treatment Plant (1990-1992, 1994-1995). To compute source population estimates, the fishes collected in the trawl surveys were multiplied by the ratio of the source water area to the area sampled by the trawls. Trawl catch efficiencies were estimated to be 12% to 50%. Impingement abundance and biomass decreased substantially since the 1978-1979 316(b) demonstration (MBC 1997).

2.3 SGS Fish and Macroinvertebrate Impingement Monitoring

Heat treatment impingement surveys have been conducted at the SGS since the 1970s. Heat treatments are operational procedures designed to eliminate mussels, barnacles, and other fouling organisms growing in the cooling water conduit system. During a heat treatment, heated effluent water from the discharge is redirected to the intake conduit via cross-connecting tunnels until the water temperature rises to approximately 115°F (46°C) in the screenwell area. This water temperature is maintained for at least one hour, during which time all biofouling organisms, as well as fish and invertebrates living within the cooling water system, succumb to the heated water. During heat treatment surveys, all material impinged on the traveling screens was removed from the forebay. Fishes and macroinvertebrates (including shellfish) were separated from incidental debris, identified, and counted. Up to 200 individuals of each species were measured, examined for external parasites, anatomical abnormalities, and other abnormalities. Aggregate weights were taken by species.

Fish impingement monitoring results from the last six years are summarized in **Table 2-4**. Since 1999, annual impingement at the SGS averaged 106,237 fish weighing 6,542 lb. During this time period, an average of six heat treatment surveys were performed annually.

Since 1990, the fish species primarily affected by the operation of the SGS were nearshore schooling/aggregating species, such as topsmelt (*Atherinops affinis*; 27%), queenfish (24%), Pacific sardine (*Sardinops sagax*; 21%), jack mackerel (7%), jacksmelt (6%), white croaker (4%), and northern anchovy (3%). These seven species combined accounted for 92% of impingement abundance at the SGS. The remaining 94 taxa each contributed 2% or less to the 15-year impingement total (MBC 2004).

Table 2-4. Annual (October through September) numbers of fishes collected during heat treatments at SGS, 1999–2004.

	1999	2000	2001	2002	2003	2004	Average
Fish abundance	40,804	115,495	39,256	42,580	29,711	369,577	106,237
Fish biomass (lbs.)	5,111	11,736	4,681	2,680	3,334	11,710	6,542
Number of surveys	7	8	5	5	4	7	6

Impingement sampling was done in accordance with specifications set forth by the LARWQCB in the NPDES permit for the plant. Specimens of uncertain identity were crosschecked against taxonomic voucher collections maintained by MBC, as well as available taxonomic literature. Occasionally, outside experts were consulted to assist in the identification of species whose identification was difficult. Scales used to measure biomass (spring and electronic) were calibrated every three months.

The following measures were employed to ensure accuracy of all data entered into computer databases and spreadsheets:

- Upon returning from the field, all field data sheets were checked by the Project Manager for completeness and any obvious errors;
- Data were entered into pre-formatted spreadsheets;
- After data were entered, copies of the spreadsheets were checked against the field data sheets;
- Data were submitted annually to the LARWQCB, U.S. EPA Region IX, and the California Department of Fish and Game.

2.4 2004 SGS Larval Characterization Study

In preparation for potential §316(b) field studies, a preliminary larval fish and shellfish sampling program was conducted to document the composition and density of larval fishes and shellfish in the vicinity of the SGS cooling water intake structure (MBC 2005). Samples were collected during nine daytime/nighttime surveys from May through mid-July 2004. A total of five stations were sampled off the Scattergood and El Segundo Generating Stations (Figure 2-1). The wheeled bongo frame used for sampling had 2 ft (60 cm) diameter net rings with plankton nets constructed of 333-um Nitex® nylon mesh, similar to the nets used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). Each net was fitted with a Dacron sleeve and a plastic cod-end container to retain the organisms, as well as a calibrated General Oceanics flowmeter, allowing the calculation of the amount of water filtered. All fish larvae were sorted from the samples and identified to the lowest practical taxon. Target larval shellfish were also removed from the samples and quantified.

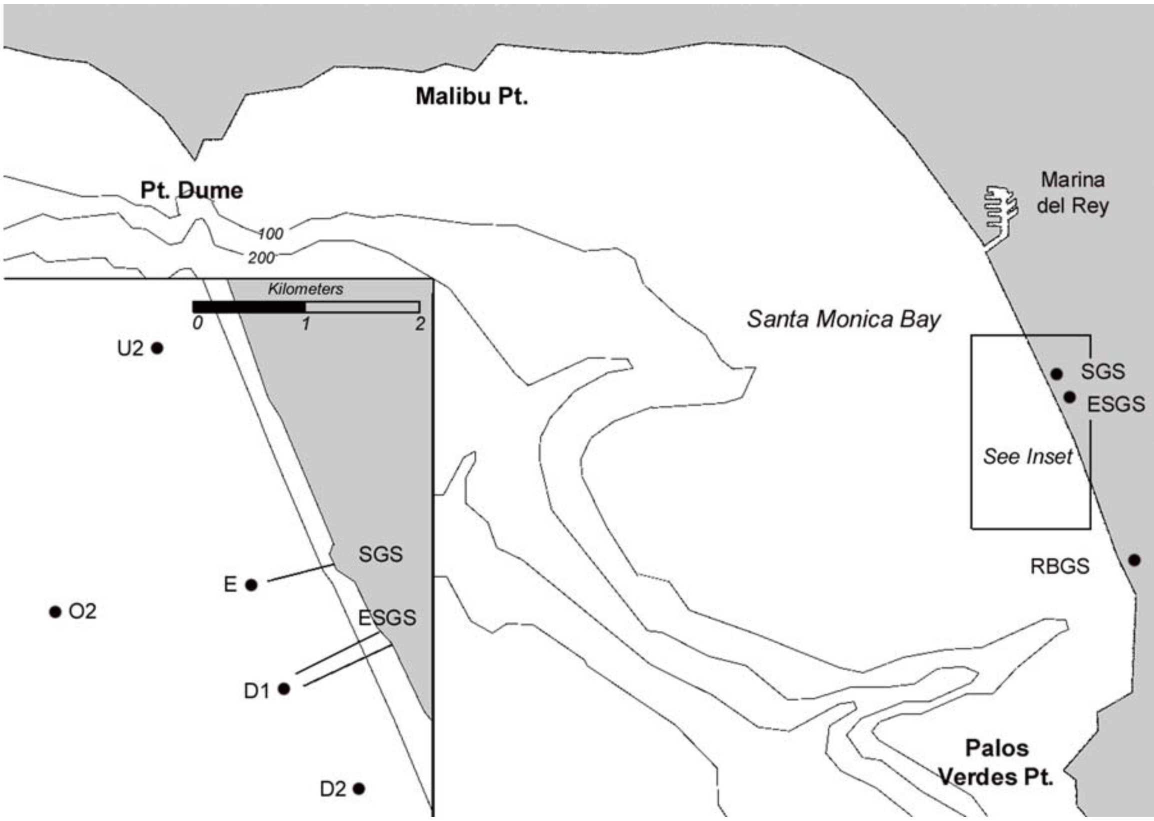

Figure 2-1. Location of larval fish and shellfish sampling stations, May-July 2004 (MBC 2005).

Abundance near the SGS intake was dominated by unidentified gobies (79%), combtooth blennies (6%), queenfish (5%), and northern anchovy (5%) (**Table 2-5**). The composition of larval fishes at the offshore station, located at the 69 ft isobath, differed markedly from that at the nearshore stations on the 33 ft isobath. The offshore larval fish community was more diverse, with 33 species collected at the offshore station and 21 species at the SGS intake. The offshore community consisted primarily of northern anchovy (41%), combtooth blennies (11%), sculpins (*Icelinus* spp.; 7%), California halibut (6%), and bay goby (5%). Only one of the three target shellfish taxa was collected at the SGS intake: sand crab (*Emerita analoga*). Market squid paralarvae (*Loligo opalescens*) and California spiny lobster phyllosoma larvae (*Panulirus interruptus*) were collected infrequently at the offshore station and were not collected on the intake isobath

The results from this preliminary study were used in the design of the Entrainment Sampling Plan presented in this PIC. The following measures were employed to ensure proper sample collection, preservation, and processing in the field:

- Flowmeters were regularly calibrated to ensure accurate sample volume calculations;
- Nets and cod-ends were regularly inspected for damage and wear;
- Stations were located using a Global Positioning System that provided accuracy to within one meter;
- Tows where the difference in sample volumes between the two bongo nets were >20% were redone;
- Samples were transferred to prelabeled containers with preprinted internal labels.

Table 2-5. Estimated densities of the most abundant larval fishes and target shellfishes off the SGS based on samples collected during nine surveys from May 2004 through July 2004.

Fish Taxa		**SGS Intake Estimates Average Density (No. / 1,000 m^3)**	**Study Area (All 5 stations) Average Density (No. / 1,000 m^3)**
unidentified gobies	Gobiidae	869.9	254.0
combtooth blennies	*Hypsoblennius* spp.	63.0	48.7
queenfish	*Seriphus politus*	53.9	21.6
Northern anchovy	*Engraulis mordax*	52.8	54.6
silverside	Atherinopsidae	17.4	6.8
Clingfish	*Gobiesox* sp.	12.8	5.2
white croaker	*Genyonemus lineatus*	9.3	9.2
Shellfish Taxa			
decapod megalops	Decapoda, unidentified	96.1	108.2
sand crab	*Emerita analoga*	68.0	55.7

Once the samples were returned to the laboratory, the following measures were employed to ensure proper sample identifications: The first ten samples of fish identified by an individual taxonomist were completely re-identified by a designated QA/QC taxonomist. A total of at least 50 individual fish larvae from at least five taxa must have been present in these first ten samples; if not, additional samples were reidentified until this criterion was met. Taxonomists were required to maintain a 95 percent identification accuracy level in these first ten samples. After the taxonomist identified ten consecutive samples with greater than 95 percent accuracy, they had one of their next ten samples checked by a QA/QC taxonomist. If the taxonomist maintained an accuracy level of 95 percent then they continued to have one of each ten samples checked by a QA/QC taxonomist. If they fell below this level then ten consecutive samples they identified were checked for accuracy. Samples were re-identified until ten consecutive samples meet the 95 percent criterion. Identifications were crosschecked against taxonomic voucher collections maintained by MBC and Tenera Environmental.

The following measures were employed to ensure accuracy of all data entered into computer databases and spreadsheets:

- Upon return from the field, all field data sheets were checked by the Project Manager for completeness and any obvious errors;
- Data were entered into pre-formatted spreadsheets;
- After data were entered, copies of the spreadsheets were checked against the field data sheets;
- The same protocol was followed for entry of larval fish/shellfish data.

2.5 Other Relevant Biological Studies

2.5.1 1979-1980 Southern California Edison Velocity Cap Effectiveness Study

The effectiveness of the velocity caps of the Huntington Beach Generating Station (HBGS) and Ormond Beach Generating Station (OBGS) cooling water intake structures, which are similar in design to the intake structure at the SGS, was studied in July 1979 and July 1980 (Thomas et al. 1980). The study examined entrapment (the entry of fishes into the cooling water intake system) during periods of normal flow (with the velocity cap) and reverse flow (without the velocity cap). Researchers also examined differences between entrapment rates during daytime and nighttime. Results are summarized in **Table 2-6**.

Table 2-6. Entrapment Densities at the HBGS and OBGS during the 1979 and 1980 Velocity Cap Studies (Thomas et al. 1980).

Year	Station	Velocity Cap?	Species (time)	Entrapment Density	Velocity Cap Effectiveness
1980	HBGS	No	All (daytime)	47.2 kg/hr	
1980	HBGS	Yes	All (daytime)	0.65 kg/hr	99%
1980	HBGS	No	All (nighttime)	52.99 kg/hr	
1980	HBGS	Yes	All (nighttime)	6.78 kg/hr	87%
				Average:	***93%***
1979	HBGS	No	All (day/night 18-hr)	20.45 kg/hr	
1979	HBGS	Yes	All (day/night 18-hr)	1.97 kg/hr	90%
1979	HBGS	No	All (nighttime)	32.93 kg/hr	
1979	HBGS	Yes	All (nighttime)	15.53 kg/hr	53%
				Average:	***72%***
1980	OBGS	No	All (daytime)	0.95 kg/hr	
1980	OBGS	Yes	All (daytime)	0.12 kg/hr	87%
1980	OBGS	No	All (nighttime)	4.99 kg/hr	
1980	OBGS	Yes	All (nighttime)	1.97 kg/hr	61%
				Average:	***74%***

During both study periods, entrapment rates were substantially lower when the velocity cap was in use. Entrapment was also higher at nighttime than during daytime. On average, the velocity cap resulted in an 82% reduction in entrapment at the HBGS, and 74% at the OBGS.

2.5.2 SGS Velocity Cap Effectiveness Study

Pender (1975) examined the effectiveness of the velocity caps used at the SGS. A velocity cap was added to the cooling water intake structure in 1958 (the “old” velocity cap), but was damaged beyond repair in June 1970. The old velocity cap was removed from service in August 1970. After this time, the generating station operated in reverse flow, withdrawing cooling water from the discharge and discharging through the intake. This was done to minimize any further damage to the intake velocity cap. While operating in this configuration, fish impingement was substantially higher than in the past, and the California Department of Fish and Game (CDFG) requested the generating station continue operating in reverse configuration to document the effectiveness of the velocity cap. Results indicated that the velocity cap reduced impingement by about “a factor of ten”. After reviewing this data, the CDFG requested that LADWP install a new velocity cap on the intake structure as soon as possible.

The new intake velocity cap at the LADWP was designed similarly to those in use at San Onofre Nuclear Generating Station Units 2 and 3, and put in place in October 1974. A comparison of data collected before and after showed that impingement was reduced by a factor of about 2.4. The surveys conducted before the cap was replaced were mostly done with two units operating, while four of the five surveys done after the cap was replaced were done with three units in operation, and one with two units in operation.

2.6 Physical Studies at the SGS Intake

The temperature and salinity of the waters in the vicinity of the SGS intake structure have been measured semiannually or annually for many years as part of the SGS NPDES monitoring program. The monitoring program consists of 12 stations in the nearshore waters of Santa Monica Bay, extending between Marina del Rey and the Manhattan Beach Pier from depths of 20 to 60 ft. Beginning in 2002 an additional five stations were added in the vicinity of the SGS and ESGS discharges to verify compliance with State Thermal Plan objectives. From 2000 through 2004, all stations were sampled during both ebb and flood tides during five winter surveys and five summer surveys. Salinity is not a required monitoring component but results have been measured and reported since 2001. Results are summarized in Table 2-7.

Table 2-7. Temperature and salinity of surface and bottom waters off the SGS and ESGS, 2000-2004.

		Santa Monica Bay	
Season	**Parameter**	**Surface**	**Bottom**
Winter	Minimum temperature (°C)	12.47	10.57
	Average temperature (°C)	15.77	13.63
	Maximum temperature (°C)	18.60	17.72
Summer	Minimum temperature (°C)	19.40	11.70
	Average temperature (°C)	20.93	16.12
	Maximum temperature (°C)	23.95	22.34
Winter	Minimum salinity (PSU)	33.07	33.12
	Average salinity (PSU)	33.31	33.43
	Maximum salinity (PSU)	33.65	33.86
Summer	Minimum salinity (PSU)	33.20	33.20
	Average salinity (PSU)	33.52	33.52
	Maximum salinity (PSU)	33.70	33.90

In general, temperatures in the study area are usually several degrees warmer in summer than in winter, with bottom waters consistently colder than surface waters. Temperatures throughout the water column in the study area are usually warmest in the afternoon due to solar heating, and the formation of a thermocline is especially common during summer, though thermoclines may also develop in winter. Salinity in the study area is relatively uniform, ranging from 33.1 to 33.9 practical salinity units (PSU), typical for nearshore waters of southern California. Salinity is usually slightly higher near bottom than at the surface.

Intake Zone of Influence

Hydrodynamic studies of the SGS intake structure were performed during the 1978–1979 316(b) Demonstration (IRC 1981). Current meter studies, as well as point-source and continuous flow dye studies using Rhodamine WT, were designed to characterize the zone of influence of the SGS intake (near-field) as well as the nearshore waters off the SGS outside of the immediate zone of influence of the intake (far-field).

Current meters were deployed in the intake opening 4.2 m from the center of the velocity cap and 0.55 m below the surface of the velocity cap where intake currents would predictably be highest. During the deployment, cooling water flow volume averaged 13.05 m^3/s, or 60% of maximum flow. Intake velocities (averaged over 15-minute intervals) ranged from 30 to 78 cm/s (0.98 to 2.56 fps). However, during the deployment, wave heights were relatively high (up to 2.5 m in height), which could have led to higher than normal velocities.

IRC (1981) developed Probability of Entrainment Isopleths for the SGS based on analytical studies (White 1978), dye experiments, current meter data, and meteorological data. Dye results were normalized to reflect a case where 72.7% of maximum cooling water volume was being used. The Probability of Entrainment Isopleths were temporally averaged. The 50% Probability of Entrainment Isopleth extended 14 m from the center of the velocity cap (9 m from the rim of the velocity cap). Recirculation of cooling water, which is discharged 122 m from the intake, varied between 1.6 and 11.8% (normalized to a flow of 72.7% of maximum).

The source waters most likely to be drawn into the SGS were considered to lie in the upper 15 m between the Santa Monica and Redondo Canyons. Inshore of the canyon heads, the source water region may extend further longshore, especially to the northwest (upcoast):

"*Regionally, a large eddy seems to dominate the near-surface circulation of Santa Monica Bay. During much of the year, surface currents along the seaward edge of the Santa Monica Bay shelf flow in a northwesterly direction while those on the shelf nearshore tend to flow in the opposite direction. The mid- and upper-level flow in Santa Monica Bay is influenced by the two submarine canyons that extend into the several kilometers distant longshore on either side of the Scattergood Generating Station intake site. Upper-level flow (0–15 m) throughout the intervening shelf from somewhat north of Santa Monica Canyon tends to be rather persistently downcoast, as a component of monthly mean wind exists in that direction. Episodes of reverse flow may originate from the headwater region of Redondo Canyon, but these seem uncommon*" (IRC 1981).

3.0 PROPOSED NEW BIOLOGICAL STUDIES

The proposed impingement mortality and entrainment (IM&E) studies will examine losses at SGS resulting from both impingement of juvenile and adult fish and shellfishes on traveling screens at the intake during normal operations and during heat treatment operations and from entrainment of larval fishes and shellfishes into the cooling water intake system. Proposed sampling methodologies and analysis techniques are designed to collect the data necessary for compliance with the §316(b) Phase II Final Rule and are similar to recent impingement and entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station. The studies at Huntington Beach were performed as part of the California Energy Commission CEQA process for permitting power plant modernization projects, while the South Bay and Encina projects were for §316(b) compliance.

The new 316(b) regulations require that new studies include "*Documentation of current impingement mortality and entrainment of all life stages of fish, shellfish, and any protected species identified previously and an estimate of impingement mortality and entrainment to be used as the calculation baseline.*" For the purposes of this study we are defining the term '*shellfish*' as commercially and recreationally important species of crustaceans (crabs, lobsters, shrimp, etc.) and mollusks (clams, squid, and octopus) that are currently being harvested on a regular basis from the coastal areas surrounding the SGS. This would not include organisms such as clams, mussels, and other crustaceans and mollusks that may only be harvested occasionally for recreational purposes. We have included this definition in this plan because '*shellfish*' could also be considered as including all species of shelled invertebrates and clarification of the term is not included in the regulations.

Under the new 316(b) regulations the impingement mortality component of the IM&E studies is not required if a facility's through-screen intake velocity is less than or equal to 0.5 ft/s (15 cm/s). The through-screen velocity at the intake exceeds this value, so SGS is proposing to conduct a yearlong impingement monitoring study at the intake. The goal of the proposed impingement study is to characterize the fishes and shellfishes affected by impingement by the CWIS. The §316(b) Final Regulations allow "historical data that are representative of the current operation of your facility and of biological conditions at the site." Therefore, historical impingement data may be used to supplement results from the 316(b) study for the impingement mortality characterization.

The proposed 316(b) entrainment study plan incorporates design elements that reflect the present uncertainties surrounding the use of restoration for compliance with the new rule. The use of restoration in offsetting IM&E losses under the new 316(b) rules is currently being challenged in the courts. If the use of restoration is not allowed as a result of the court decision, only an estimate of entrainment losses would be required to calculate the commercial and recreational values of adult fish losses in a cost benefit analysis of various technology and operational alternatives to comply with required reductions in entrainment mortality. Larval fish and shellfish abundances can vary greatly through the year and therefore biweekly sampling is proposed for characterizing entrainment. If the restoration option is upheld in the court decision, models of the conditional mortality due to entrainment would be used in designing appropriate restoration projects for offsetting entrainment losses. These models are based on proportional comparisons of entrainment and source water abundances and are theoretically insensitive to seasonal or annual changes in the abundance of entrained species. Therefore, source water sampling is being proposed monthly which is consistent with the sampling frequency for recently completed studies in southern California. The frequency of the entrainment sampling and the continuation of source water sampling may change depending on the outcome of the court decision. Similar to impingement, historical entrainment data may be used to supplement results from the 316(b) study for the entrainment characterization.

The proposed impingement mortality and entrainment (IM&E) studies are designed to optimally sample groups of organisms that have historically been the focus of 316(b) assessments and have been used in recent IM&E studies in southern California, including the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station. The life stages of the fishes and shellfishes collected from impingement and entrainment samples are identified in the sections below (Sections 3.1 and 3.2). Consistent with the regulatory requirements, impingement mortality and entrainment estimates for the fishes and shellfishes identified from the samples will be generated based on cooling water volumes representative of operations during the past five years. A group of organisms from the impingement and entrainment studies will be selected for more detailed assessment (Section 4.0) based on their abundances in the samples, ecological roles, and commercial and/or recreational fisheries importance. Based on studies conducted since the 1970's, no threatened or endangered fish or shellfish species have been entrained or impinged at the SGS.

All of the work for the impingement and entrainment studies will be conducted using a detailed QA/QC program. Procedures for field data collection and laboratory processing will be included with the Comprehensive Demonstration Study Report.

The sampling efforts conducted for this study may be coordinated with similar studies at the AES Redondo Beach Generating Station (RBGS) and the El Segundo Power LLC, El Segundo Generating Station (ESGS). The intakes for the ESGS are located approximately 0.6 mi (0.9 km) down coast from the SGS intake, while the RBGS intakes are located approximately 5.5 mi (9 km) down coast. Coordinating the entrainment and source water sampling will allow for a more comprehensive characterization of the source water and the organisms potentially affected by the CWISs at the three facilities. Although the same data may be shared for the IM&E studies conducted at all three facilities, the data may not necessarily be used or presented in the same way.

3.1 Impingement Study

Impingement sampling during heat treatment operations at the SGS has been conducted since the 1970s. The existing NPDES permit for the plant requires sampling during all heat treatment procedures. No impingement sampling during normal operations is required in the existing NPDES permit and no normal operations impingement data has been collected since the original 316(b) study in 1978 and 1979 (IRC 1981). Heat treatments are operational procedures designed to eliminate mussels, barnacles, and other fouling organisms growing in the cooling water conduit system as described in Section 2.3. The heat treatment data from the 1999 through 2004 NPDES annual reporting periods (October 1998 through September 2004) are summarized in Section 2.3.

3.1.1 Impingement Sampling

The purpose of the proposed 316(b) impingement study will be to characterize the juvenile and adult fishes and shellfishes (e.g., rock crabs, shrimps, lobsters, and squid) impinged by the SGS CWIS. The sampling program is designed to provide current estimates of the abundance, biomass, taxonomic composition, diel periodicity, and seasonality of the fishes and shellfishes impinged at the SGS. In particular, the study will focus on the rates (i.e., number and biomass of organisms per water volume flowing per time into the plant) at which various species of fishes and shellfishes are impinged. The impingement rate is subject to tidal and seasonal influences that vary on several temporal scales (e.g., hourly, daily, and monthly) while the rate of cooling water flow varies with power plant operations and can change at any time.

In accordance with procedures employed in similar studies, impingement sampling will occur over a 24-hour period one day per week. Before each sampling effort, the traveling screens will be rotated and washed clean of all impinged debris and organisms. The sluiceways and collection baskets will also be cleaned before the start of each sampling effort. The operating status of the circulating water pumps on an hourly basis will be recorded during the collection period. Each 24-hour sampling period at the traveling screens will be divided into four 6-hour cycles. The traveling screens will remain stationary for a period of 5.5 hours then they will be rotated and washed for 30 minutes. The impinged material from the traveling screens will be rinsed into the collection baskets associated with each set of screens. If during the 24-hour sampling an extreme event occurs resulting in the impingement of a large number of fishes, we may continue sampling an additional day or two to obtain a more representative estimate of the impingement rate for the sampling period. Based on historical impingement data, an extreme impingement event during normal operation impingement sampling would be defined as a sample comprised of greater than 200 fishes and/or 200 shellfishes impinged in a 24-hr normal operation survey. Large numbers of organisms in impingement samples could potentially result from the entrainment of a school of fish (such as anchovies or sardines). Such events will usually have a short duration and it will be important to identify the duration in order to provide as accurate baseline impingement estimate

If the traveling screens are operating in the continuous mode, then sampling will be coordinated with the intake crew so samples can be collected safely. A log containing hourly observations of the operating status (on or off) of the circulating water pumps for the entire study period will be obtained from the power plant operation staff. This will provide a record of the amount of cooling water pumped by the plant, which will then be used to calculate impingement rates.

Impingement sampling will also be conducted during heat treatment operations. Procedures for heat treatment will involve clearing and rinsing the traveling screens prior to the start of the heat treatment procedure. At the end of the heat treatment procedure normal pump operation will be resumed and the traveling screens rinsed until no more dead fish are collected on the screens. Processing of the samples will occur using the same procedures used for normal impingement sampling. Six to eight heat treatments may occur during the one-year study period.

All fishes and the following shellfishes will be collected from impingement samples, counted, identified, and measured:

- rock crabs
- shrimp
- octopus
- squid
- California spiny lobster

These same shellfishes have been enumerated in other recent impingement studies in southern California. All other macroinvertebrates will be identified from the samples but not enumerated and measured.

Depending on the number of individuals of a given species present in the sample, one of two specific procedures is used, as described below. Each of these procedures involves the following measurements and observations:

1. The appropriate linear measurement for individual fish and shellfish will be determined and recorded. These measurements are recorded to the nearest 1 mm. The following standard linear measurements will be used for the animal groups indicated:

- Fishes - Total body length for sharks and rays and standard lengths for bony fishes.
- Crabs - Maximum carapace width.
- Shrimps & Lobsters - Carapace length, measured from the anterior margin of carapace between the eyes to the posterior margin of the carapace.
- Octopus - Maximum “tentacle” spread, measured from the tip of one tentacle to the tip of the opposite tentacle.
- Squid – Dorsal mantle length, measured from the edge of the mantle to the posterior end of the body.

2. The wet body weight of individual fish and shellfish will be determined after shaking loose water from the body. Total weight of all individuals combined will be determined in the same manner. All weights will be recorded to the nearest 0.035 ounce (1 g).

3. The qualitative body condition of individual fish and shellfish will be determined and recorded, using codes for decomposition and physical damage.

4. Other macroinvertebrates will be identified to species and their presence recorded, but they will not be measured or weighed. Rare occurrences of other impinged animals, such as dead marine birds, will also be recorded.

5. The amount and type of debris (e.g., *Mytilus* shell fragments, wood fragments, etc.) and any unusual operating conditions in the screen well system will be noted by writing specific comments in the “Notes” section of the data sheet. Information on weather, tide and sea conditions will also be recorded during each collection.

The following specific procedures will be used for processing fishes and shellfishes when the number of individuals per species in the sample or subsample is < 30:

- For each individual of a given species the linear measurement, weight, and body condition codes will be determined and recorded.

The following specific subsampling procedures will be used for fishes and shellfishes when the number of individuals per species is >30:

- The linear measurement, individual weight, and body condition codes for a subsample of 30 individuals will be recorded individually on the data sheet. The individuals selected for measurement will be selected after spreading out all of the individuals in a sorting container, making sure that they are well mixed and not segregated into size groups. Individuals with missing heads or other major body parts are eliminated from consideration, since their linear measurements are not representative.
- The linear measurements of up to 200 individuals of each taxa will be recorded.
- The total number and total weight of all the remaining individuals combined will be determined and recorded separately.

3.1.2 Impingement Sampling QA/QC Program

A quality assurance/quality control (QA/QC) program will be implemented to ensure that all of the organisms are removed from the debris and that the correct identification, enumeration, length and weight measurements of the organisms are recorded on the data sheet. Random cycles will be chosen for QA/QC re-sorting to verify that all the collected organisms were removed from the impinged material. Quality control surveys will be done on a quarterly or more frequent basis if necessary during the study. If the count of any of individual taxon made during the QA/QC survey varies by more than 5 percent (or one individual if the total number of individuals is less than 20) from the count recorded by the observer then the next three sampling cycles for that observer will be checked. The survey procedures will be reviewed with all personnel prior to the start of the study and all personnel will be given printed copies of the procedures that will also be included with the final IM&E study report.

3.1.3 Proposed Study on the Effects of the Velocity Cap on Fish Impingement

Based on the high level of effectiveness demonstrated at the HBGS and OBGS, a similar site-specific velocity cap effectiveness study will be conducted at the SGS. The results of the study will be used to develop a quantitative estimate of the velocity caps effectiveness. Surveys will be conducted in succession, initially a 24-hr normal flow sample, followed by a 24-hr reverse flow sample. Each survey would require the removal of all fish species from within the forebay prior to the survey. This may be achieved by raising the water temperature in the forebay to 85-90°F for approximately twenty minutes. Previous preliminary studies of the thermal tolerances of coastal California marine fishes indicate a critical maximum temperature of 84-87°F for most species, such as queenfish.

The aforementioned temperature spike to remove all fishes from the forebay would precede the initial 24-hr normal operation survey. Impinged fish abundance would be monitored to determine when the forebay was cleared of fish. At this time the 24-hr sample would commence. At the end of the 24-hr period, another temperature spike would occur, with all fish counted, weighed and measured. All organisms that may have been impinged in the interim would be included in the overall sample. Once impingement abundance has subsided to near zero, the flow configuration would be reversed. During the period immediately following flow reversal, intake flows may entrain an abnormal number of fish in the vicinity of the discharge structure. It may be necessary to operate in a reverse configuration for an extended period to obviate any such start-up effect from a comparison of impingement rates with and without a velocity cap. The traveling screens would be operated to clear any debris dislodged by the flow reversal. Reverse configuration would be maintained for 24 hours. At the end of the 24-hr cycle, the temperature spike procedure would occur followed by the enumeration of the entrapped/impinged fish. Once all fish were removed from the forebay, the flow would be returned to normal configuration.

Four complete surveys (normal flow-reverse flow-normal flow) will be conducted every other week over a seven-week period from 21 August 2006 to 2 October 2006. This time frame coincides with expected periods of peak operations. Historical impingement data from SGS and the nearby El Segundo Generating Station will be examined to ensure that the proposed schedule does not result in missing important species that may occur seasonally. Scheduling of surveys would be coordinated with the generating station personnel to coincide with normal operations. The scheduling of the surveys also needs to be coordinated with dispatch requirements for generation capacity that will take precedent over the study and may result in modifications to the schedule.

3.2 Entrainment Study

The proposed entrainment study plan incorporates two design elements 1) cooling water intake system sampling and 2) source water sampling, which reflect the present uncertainties surrounding the use of restoration for compliance with the new rule. The source water populations of entrained fish and shellfish larvae are sampled to estimate the proportional entrainment losses, using a conditional mortality model that could be used to determine appropriate restoration projects for offsetting entrainment. However, if restoration is not upheld by the court as an alternative to comply with entrainment mortality reduction requirements, then the number of larval fish and shellfish collected in the entrainment sampling would be used with various demographic modeling techniques to estimate the theoretical loss of adult fish and shellfish. In this case, the commercial and recreational values of the adult losses would be calculated and compared in a cost benefit analysis to the cost of various technology and operational alternatives to comply with required reductions in entrainment mortality.

The study plan also incorporates a sampling frequency strategy that recognizes the basic difference in the statistical uncertainty of the two design elements. Abundances of larval fishes and shellfishes in entrainment vary throughout the year due to changes in composition and the oceanographic environment. The models used to estimate adult equivalents from larval entrainment vary directly with these natural changes in abundance. Therefore, entrainment sampling has been proposed to occur biweekly. In contrast, estimates of conditional mortality, using the Empirical Transport Model (*ETM)* or other proportional loss models, are theoretically insensitive to seasonal or annual changes in the abundance of entrained species, and thus source water sampling can be conducted less frequently on a monthly basis. The monthly sampling frequency is consistent with other recently completed entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera, in progress).

The continuation of the proposed source water sampling and the frequency of the entrainment sampling will depend on the court decision regarding the use of restoration for compliance with the new rule. If restoration is not upheld by the court as an alternative to comply with entrainment mortality reduction requirements, then a decision may be made to discontinue the source water sampling since it would be primarily used in scaling restoration projects. If the use of restoration is upheld, the frequency of entrainment sampling may be reduced so that only the surveys that occur concurrently with source water sampling are continued.

3.2.1 Cooling-Water Intake System Entrainment Sampling

The cooling water intake structure for the SGS is located approximately 1600 ft (500 m) offshore from the generating station at an approximate depth of 30 ft (9.1 m) Mean Lower Low Water (MLLW). The top of the intake velocity cap is approximately 12.5 ft (3.8 m) below the water surface (17.5 ft [5.3 m] above bottom). Cooling water is directed horizontally through the opening between the top of the intake riser and the velocity cap (a distance of approximately 5 ft [1.5 m]) at a design approach velocity of 1.5 ft/s (46 cm/s) at the rim of the velocity cap (IRC 1981). Maximum flow rate at the SGS is 344,000 gallons per minute (gpm), or 495 mgd.

To determine composition and abundance of ichthyoplankton and shellfish larvae (Section 4.1) entrained by the generating station, sampling in the immediate proximity (Station E1, **Figure 3-1**) of the cooling water intake is proposed to be conducted every two weeks from January through December 2006. The SGS intake structure is located in the lower one-half of the water column, and therefore, it is reasonable to assume that the intake draws water from just above the bottom to the middle of the water column. At the AES Redondo Beach L.L.C. generating station, water is drawn into the intake structure from the lower 2/3 of the water column (KLI 1979). However, since no supporting data are available for the SGS, we propose to sample within 164-328 ft (50-100 m) of the intake structure using an oblique tow that will sample the water column from the surface down to approximately 6 inches (13 cm) off the bottom, and back to the surface. Two replicate tows will be taken at the intake with a target sample volume for each net of 4,000 to 5,300 gal (15 to 20 m^3). The nets will be redeployed if the target volume is not collected during the initial tow. Sampling will be conducted four times per 24-hr period--once every six hours.

The wheeled bongo frame proposed for sampling has 2 ft (60 cm) diameter net rings with plankton nets constructed of 333-*u*m Nitex® nylon mesh, similar to the nets used by CalCOFI. These nets will use a smaller mesh than the mesh size used in the sampling done for the EPA 316(b) rule-making. This smaller mesh is being proposed to ensure collection of smaller fish larvae that may be extruded through a larger sized mesh. Each net will be fitted with a Dacron sleeve and a plastic cod-end container to retain the organisms. Each net will be equipped with a calibrated General Oceanics flowmeter, allowing the calculation of the amount of water filtered. If the target volume (4,000 to 5,300 gal [15 to 20 m^3] per net) is not met with one oblique tow, subsequent tows will be performed at the station until the target volume is collected. Coordinates of each sampling station will be determined using a differential global positioning system (DGPS). At the end of each tow, nets will be retrieved and the contents of the net gently rinsed into the cod-end with seawater. Contents will be washed down from the outside of the net to avoid the introduction of plankton from the wash-down water. Samples will then be carefully transferred to prelabeled jars with preprinted internal labels. Samples from the two nets will be preserved in 4 percent buffered formalin-seawater.

3.2.2 Source Water Sampling

The source water study area is designed to 1) characterize the larvae of ichthyoplankton and shellfish larvae potentially entrained by the SGS cooling water intake, and 2) be representative of the nearshore habitats in the vicinity of the SGS intake.

To determine composition and abundance of ichthyoplankton in the source water, sampling will be done monthly on the same day that the entrainment station is sampled. The source water sampling design is being proposed because of the need to extrapolate densities offshore to determine the appropriate source water area during each survey. Besides the entrainment stations, we propose that source water sampling occur at ten additional source water stations upcoast, downcoast, and offshore from the SGS intake structure (Figure 3-1). Two stations will be located 1.2 and 2.4 miles (2 and 4 km) upcoast (Stations N1 and N2) and downcoast (Stations N3 and N4) from the midpoint between the SGS and ESGS intake structures along the 33 ft (10 m) isobath.

The spacing of the samples upcoast and downcoast was based on a review of water current data available from the area. Data from Hickey (1992) showed that nearshore alongshelf water currents in Santa Monica Bay averaged 0.15 ft/s (4.5 cm/s) with a monthly maximum average speed of 0.29 ft/s (8.8 cm/s). Based on these water current speeds, the distances that larvae could be transported alongshore during a day ranged from 2.4 to 4.7 miles (3.9 to 7.6 km). The average value was used to determine the alongshore extent of the source water sampling locations upcoast and downcoast since the proportional entrainment estimate used in the *ETM* is an estimate of the daily entrainment mortality on the available source water population. The length of the sampling area alongshore is also approximately equal to the daily distance larvae travel based on the maximum monthly average water current speed thus ensuring that even at higher water current speeds an adequate source water area is sampled.

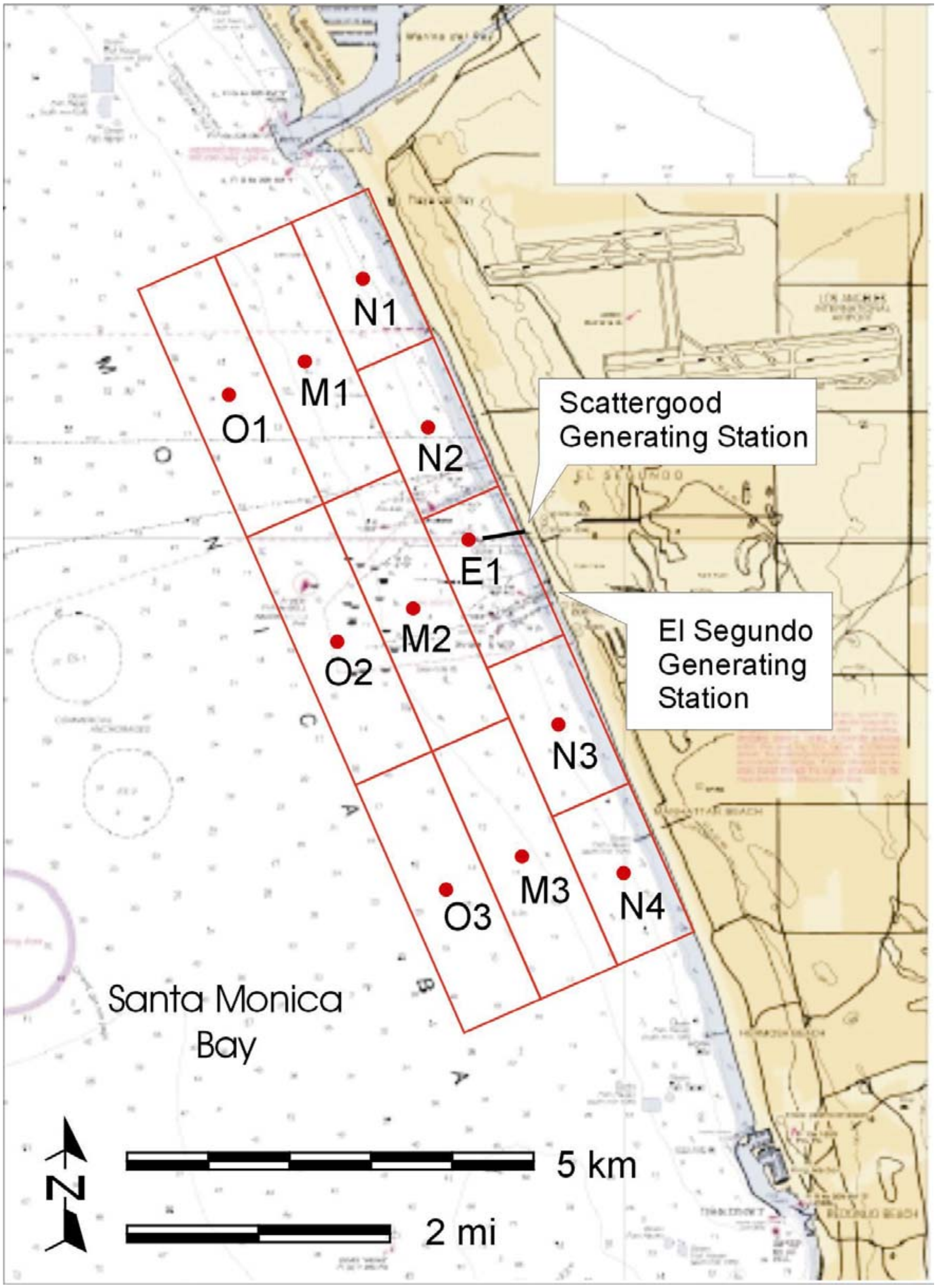

Figure 3-1. Map showing locations of the SGS intake and entrainment (E1) and source water sampling stations (N1-N4, M1-M3, and O1-O3).

Six additional stations will be sampled offshore from the inshore line of stations, with three stations located along the 66 ft (20 m) isobath (Stations M1-M3) and three stations along the 98 ft (30 m) isobath (Stations O1-O3) (**Figure 3-1**). This sampling grid is similar in design to the study of cooling water system effects at the AES Huntington Beach Generating Station (MBC and Tenera 2005), but was modified to allow for a more complete characterization of the distribution of organisms alongshore and offshore. This is necessary because the distribution of organisms within the sampling area is used to extrapolate densities alongshore using water current displacement and offshore using a regression model of density and distance offshore. These extrapolations are used to estimate the plankton populations in the source water. The prevailing alongshore water currents in Santa Monica Bay (Hickey 1992) indicate that there may be less mixing of waters across the shelf close to shore compared with waters well offshore. As a result the data from the stations closest to shore may be poor predictors of the abundance and composition further offshore. The proposed sampling grid provides for at least three stations at each depth contour alongshore that can be used in extrapolating the sampled source water data over a larger area.

All stations will be sampled using a wheeled bongo plankton net using the same oblique tows described for the entrainment sampling (See Section 3.2.1). Samples will also be handled using the same procedures described for entrainment sampling. During each source water survey, the additional 10 source water stations (plus the entrainment station) will be sampled four times per 24-hr period--once every six hours. This allows adequate time to conduct all source water and entrainment sampling. During each sample cycle the order that the stations are sampled will be varied to avoid introducing a systematic bias into the data.

3.2.3 Laboratory Processing

Samples will be returned to the laboratory and after approximately 72 hours the samples preserved in 4 percent buffered formalin-seawater will be transferred to 70–80 percent ethanol. All entrainment and source water samples will be processed. Samples will be examined under dissecting microscopes and all fish larvae and the following shellfish larvae will be removed from debris and other zooplankton and placed in labeled vials:

- rock crab megalopal larvae
- market squid hatchlings [larvae]
- California spiny lobster phyllosoma larvae

These same fishes and shellfishes were processed from samples collected in other entrainment studies recently completed in southern California and are also being proposed in the study plans being prepared for the other LADWP generating stations. These three groups of shellfishes were selected because of their respective ecological roles and commercial and/or recreational fisheries importance. All of these organism groups (fishes, rock crabs, squid, and lobster) will be removed from the samples, counted, and identified to the lowest taxonomic level possible. Fish eggs will not be sorted or identified because they cannot be identified to the same taxonomic levels as fish larvae.

The power plant also entrains numerous other planktonic (phyto- and zooplankton) and larval life forms that will be collected during the sampling, especially since the nets proposed for this study use a finer mesh than was used by EPA in their sampling programs designed to collect data to support the 316(b) rule-making. These other organisms will not be processed from the samples. The samples will potentially include the larvae of other crustaceans and mollusks (shellfish) that will not be processed because they are not part of a local commercial and/or recreational shellfish fishery (see Section 3.0 Introduction). The processing also focuses on specific life stages of crabs and lobster that can be easily identified. The identification of the earlier life stages to the species level is problematic and would likely lead to uncertainty in the estimates of their abundance. Including these other life stages in the processing is also unnecessary because the methods used in the assessment (Section 4.0) account for entrainment of these other life stages in the analyses.

Fish eggs will not be processed from the samples because a full assessment of their abundance would require different sampling techniques and they cannot be identified to the same taxonomic levels as fish larvae. In addition, recent studies at other coastal power plants near estuarine or harbor areas similar to the SGS, as well as at the SGS (MBC 2005), have shown that entrainment is largely dominated by fishes that do not have an entrainable planktonic egg stage. Even though egg life stages will not be quantified from the entrainment and source water samples, entrainment effects on fishes with planktonic egg stages will be accounted for in the assessment models (Section 4.0).

Normally the data from the two nets will be combined for analysis, but if the quantity of material in the two samples is very large only one of the two samples will be processed and analyzed. The samples from the two nets are normally preserved in separate 400 ml jars. If the quantity of material in a jar exceeds 200 ml then the sample is split into multiple jars to ensure that the material is properly preserved. When this quantity of material is collected, only the material from one of the nets would be processed depending upon the nature of the material. In some cases ctenophores, salps, and other larger planktonic organisms may result in samples with large volumes of material, but these can be separated from other plankton and may not be split depending upon the final volume of the material.

A maximum of 200 representative fish larvae from each taxa analyzed in the assessment (see Section 4.0) will be measured using a dissecting microscope and image analysis system. Larvae will be measured to the nearest 0.02 inch (0.5 mm).

3.2.4 Entrainment Sampling QA/QC Program

A QA/QC program will be implemented for the field and laboratory components of the study. Quality control surveys will be done on a quarterly or more frequent basis to ensure that the field sampling is properly conducted. The field survey procedures will be reviewed with all personnel prior to the start of the study and all personnel will be given printed copies of the procedures that will be included with the final IM&E study report.

A more detailed QA/QC program will be applied to all laboratory processing. The first ten samples sorted by an individual will be resorted by a designated quality control (QC) sorter. A sorter is allowed to miss one organism when the total number of organisms in the sample is less than 20. For samples with 20 or greater organisms the sorter must maintain a sorting accuracy of 90 percent. After a sorter has ten consecutive samples with greater than 90 percent accuracy, the sorter will have one of their next ten samples randomly selected for a QA/QC check. If the sorter fails to achieve an accuracy level of 90 percent their next ten samples will be resorted by the QC sorter until they meet the required level of accuracy. If the sorter maintains the required level of accuracy one of their next ten samples will be resorted by QC personnel.

A similar QA/QC program will be conducted for the taxonomists identifying the samples. The first ten samples of fish or shellfish identified by an individual taxonomist will be completely re-identified by a designated QC taxonomist. A total of at least 50 individual fish larvae from at least five taxa must be present in these first ten samples; if not, additional samples will be reidentified until this criterion is met. Taxonomists are required to maintain a 95 percent identification accuracy level in these first ten samples. After the taxonomist has identified ten consecutive samples with greater than 95 percent accuracy, they will have one of their next ten samples checked by a QC taxonomist. If the taxonomist maintains an accuracy level of 95 percent then they will continue to have one of each ten samples checked by a QC taxonomist. If they fall below this level then ten consecutive samples they have identified will be checked for accuracy. Samples will be re-identified until ten consecutive samples meet the 95 percent criterion. Identifications will be cross-checked against taxonomic voucher collections maintained by MBC and Tenera Environmental.

Field and laboratory data will be recorded on preprinted data sheets formatted for entry into a computer database for analysis and archiving. On a monthly basis these data will be transmitted to Tenera Environmental for entry into the project database and eventual analysis. Printed spreadsheets will be checked for accuracy against original field and laboratory data sheets.

4.0 ANALYTICAL METHODS

Power plant intake effects occur due to impingement of larger organisms onto the intake screens and entrainment of organisms into the CWIS that are smaller than the screen mesh on the intake screens. Consistent with the Phase II regulations, we assume for purposes of the entrainment characterization that all entrainable organisms do not survive. Considerable effort among regulatory agencies and the scientific community has been expended on the evaluation of power plant intake effects over the past three decades. The variety of approaches developed reflects the many differences in power plant locations and resource settings. MacCall et al. (1983), in their review of the various approaches, divided them into those that offer a judgment on the presence or absence of impact and those that describe the sensitivity of populations to varying operational conditions. These efforts have helped to establish the context for the modeling approaches that may be used to estimate impingement and entrainment effects at the SGS. Impact assessment approaches that will be considered in the final evaluation in the Comprehensive Demonstration Study (CDS) include:

Methods used in estimating the calculation baseline:

- Annual estimates of total individuals impinged and entrained
- Annual estimates of total biomass impinged

Methods for evaluating CWIS effects and cost benefit analysis:

- Adult-equivalent loss (*AEL*) (Horst 1975; Goodyear 1978)
- Fecundity hindcasting (*FH*) proposed by Alec MacCall, NOAA/NMFS, which is related to the adult-equivalent loss approach
- Production Foregone (*PF*) (Rago 1984)

Methods for evaluating population-level effects and estimating appropriate restoration efforts:

- Empirical transport model (*ETM*), which is similar to the approach described by MacCall et al. (1983), and used by Parker and DeMartini (1989).

The Rule provides flexibility in terms of demonstrating compliance and therefore the need for and nature of additional analysis that may be conducted will be based on the compliance alternative and options selected by LADWP. Consistent with the regulatory requirements, impingement mortality and entrainment estimates for all fish and shellfish species for each life stage will be generated based on cooling water volumes representative of operations during the past five years.

The assessment approach used in the final report that will be submitted as part of the CDS for the SGS will also depend upon the facility's baseline calculations and its method(s) of compliance with the new §316(b) rule's performance standards for reductions in impingement mortality and entrainment. Compliance at SGS may be achieved singly, or in combination, by technological or operational changes to the CWIS (Technology Installation and Operation Plan, or TIOP), restoration methods, and site-specific Best Technology Available (BTA) standards. In order to demonstrate compliance through the TIOP it is only necessary to analyze entrainment data to determine baseline entrainment levels and assess those levels against the improvements achieved through the implementation of the TIOP. In the case where restoration is limited to only commercially or recreationally important species, entrainment data may also be adequate to assess the levels of restoration necessary to offset entrainment and impingement losses, assuming that scientifically valid population models exist for the species providing the lost benefits. In assessing compliance with the performance standard in whole or in part through restoration of habitat to include smaller, forage species in addition to the losses of recreational and commercial species it is necessary to assess the entrainment and impingement losses from the source water using a combination of assessment methods to determine the commensurate level of restoration. The same source water and entrainment data, and assessment methods, would also be used to determine a site-specific BTA standard based on cost-benefit analysis of entrainment losses for both commercially and recreationally important, as well as smaller forage species. Source water data would not be necessary for cost-benefit analysis based simply on the value of commercial and recreational species losses.

4.1 Selection of Taxa for Assessment

The proposed impingement mortality and entrainment (IM&E) studies have been designed to optimally sample fishes and shellfishes that have historically been the focus of 316(b) assessments and have been used in recent IM&E studies in southern California, including the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station. Consistent with the regulatory requirements, impingement mortality and entrainment estimates for all fish and shellfish species will be generated based on cooling water volumes representative of operations during the past five years.

The specific taxa (species or group of species) that will be analyzed in the assessment will be limited to the taxa that are sufficiently abundant to provide reasonable assessment of impacts. For the purposes of this study plan, the taxa analyzed in the assessment will be limited to the most abundant taxa that together comprise 90-95 percent of all larvae entrained and/or juveniles and adults impinged by the generating station. The most abundant taxa are used in the assessment because they provide the most robust and reliable estimates for the purpose of scaling restoration projects or quantification of the ecological benefits under the cost-benefit test. Since the most abundant organisms may not necessarily be the organisms that experience the greatest effects on the population level, the data will be examined carefully before the final selection of taxa to determine if additional taxa should be included in the assessment. This may include commercially or recreationally important taxa, and taxa with limited habitats. In addition, any threatened or endangered fish or shellfish species would be included in the assessment, but since the 1970's no listed species have been entrained or impinged at the SGS.

4.1.1 Impingement

The list of organisms that will be identified, counted, and measured from impingement samples are provided in Section 3.1.1. This same group of organisms has been used in other recent impingement studies in southern California. Estimates of annual impingement will be calculated for all of these organisms. As noted in the Introduction to this section these estimates will be used in estimating the calculation baseline. A more detailed analysis for the purposes of evaluating CWIS effects, cost benefit analyses, population-level effects, and scaling potential restoration efforts will only be conducted on the most abundant taxa in the samples and taxa that may be part of a commercial and/or recreational fishery.

4.1.2 Entrainment

The list of organisms that will be identified, counted, and measured from entrainment samples are provided in Section 3.2.3. This same group of organisms has been used in other recent entrainment studies in southern California. Estimates of annual entrainment will be calculated for all of these organisms and will be used in estimating the calculation baseline. A more detailed analysis for the purposes of evaluating CWIS effects, cost benefit analyses, population-level effects, and scaling potential restoration efforts will only be conducted on the most abundant taxa in the samples and taxa that may be part of a commercial and/or recreational fishery.

The egg stages of fishes and the life stages of the shellfishes that are more difficult to identify, and which are not included in the sample processing, will be included in the entrainment assessment. This will be done by calculating the survival to the sampled life stage in the demographic models and the larval durations of fish egg and earlier life stages of shellfishes in the *ETM* calculations. This approach assumes that the proportional mortality estimate used in the modeling of larval entrainment also applies to these other stages. The *ETM* model also provides a means of examining the potential effects on other organisms not included in the processing or assessment by assuming that they are uniformly distributed in the source water area and are withdrawn at a rate equal to the volumetric ratio of the cooling water flow to the source water volume. The effect of entrainment on these organisms also depends on their larval duration or the time period they are exposed to entrainment.

4.2 Impingement Assessment

The impingement mortality study will estimate the rates (i.e., number and biomass of organisms per water volume flowing per time into the plant) at which various species of fishes and shellfishes are impinged. Annual impingement estimates will be calculated by extrapolating the impingement rates measured during normal operations over the weekly survey periods. The impingement mortality estimates for each period will be added to provide annual estimates of impingement for each species. These estimates would be added to the heat treatment totals to provide estimates of the total annual impingement mortality.

The estimates of total annual impingement can be combined with estimates of equivalent adults from entrainment to provide total impact assessment for a taxon. The demographic models used to calculate these estimates (described in Section 4.3) are limited to taxa that have sufficient life history information available.

4.3 Entrainment Assessment

Estimates of daily and annual larval entrainment at the SGS intake will be calculated from data collected at the entrainment station. Estimates of entrainment loss, in conjunction with available demographic data collected from the fisheries literature, will permit modeling of adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*). Data from sampling of the potential source populations of larvae will be used to calculate estimates of proportional entrainment (*PE*) that are used to estimate the probability of mortality due to entrainment using the Empirical Transport Model (*ETM*). In the SGS entrainment and impingement studies we will use each approach (i.e., *AEL*, *FH*, and *ETM*) as appropriate to assess power plant losses.

The various modeling approaches that will be considered for the assessment at SGS can be placed under the umbrella of two general approaches: demographic models that rely on species life history information such as the equivalent adult model (*EAM*; Horst 1975; Goodyear 1978) which includes adult equivalent loss (*AEL*) and fecundity-hindcasting (*FH*); and models that estimate the conditional mortality on a population resulting from power plant CWIS operations such as the empirical transport model (*ETM*; Boreman et al. 1978).

The application of several models to estimate power plant effects is not unique (Murdoch et al. 1989; PSE&G 1993; Tenera 2000a; Tenera 2000b). Equivalent adult modeling (*AEL* and *FH*) is an accepted method that may be used at SGS and has been applied in other 316(b) demonstrations (PSE&G 1993; Tenera 2000a; Tenera 2000b). The advantage of these demographic modeling approaches, which includes production foregone (*PF*), is that they translate losses into adult fishes that are familiar units to resource managers, but they require life history data that are not available for many species. These estimates can be also combined with estimated losses to adult and juvenile organisms due to impingement to provide combined estimates of cooling water system effects.

The empirical transport model (*ETM*) has been proposed by the U.S. Fish and Wildlife Service to estimate mortality rates resulting from cooling water withdrawals at power plants (Boreman et al. 1978, 1981). Variations of this model have been discussed in MacCall et al. (1983) and used to assess impacts at the San Onofre Nuclear Generating Station (Parker and DeMartini 1989). The *ETM* has also been used to assess impacts at the Diablo Canyon Power Plant and Huntington Beach Generating Station in California (Tenera 2000a, MBC and Tenera 2005), and at the Salem Nuclear Generating Station in Delaware Bay, New Jersey (PSE&G 1993), as well as other power stations along the East Coast. Empirical transport modeling permits the estimation of conditional mortality due to entrainment while accounting for the spatial and temporal variability in distribution and vulnerability of each life stage to power plant withdrawals. The *ETM* provides an estimate of power plant effects that may be less subject to inter-annual variation than demographic model estimates. It also provides an estimate of population-level effects not provided by demographic approaches.

The results of the *ETM* modeling provide the best and most direct estimates of the effects of entrainment on source water populations since the effects are estimated on the larval populations being affected. The *ETM* estimates can be used to appropriately scale restoration projects that might be used to help offset entrainment losses. The estimates can also be used to provide a context for demographic model estimates that are based solely on entrainment estimates. For example, especially in estuarine systems, entrainment estimates may show large losses of fish larvae that are sometimes difficult to interpret and put in context without estimates of the adult or larval source water populations. The *ETM* provides a context for these estimates that can account for some of the uncertainty associated with determining an appropriate level of entrainment reduction.

4.3.1 Demographic Approaches

Adult equivalent loss models evolved from impact assessments that compared power plant losses to commercial fisheries harvests and/or estimates of the abundance of adults. In the case of adult fishes impinged by intake screens, the comparison was relatively straightforward. To compare the numbers of impinged sub-adults and juveniles and entrained larval fishes to adults, it was necessary to convert all these losses to adult equivalents. Horst (1975) provided an early example of the equivalent adult model (*EAM*) to convert numbers of entrained early life stages of fishes to their hypothetical adult equivalency. Goodyear (1978) extended the method to include the extrapolation of impinged juvenile losses to equivalent adults.

Demographic approaches, exemplified by the *EAM*, produce an absolute measure of loss beginning with simple numerical inventories of entrained or impinged individuals and increasing in complexity when the inventory results are extrapolated to estimate numbers of adult fishes or biomass. We will use two different but related demographic approaches in assessing entrainment effects at the SGS: *AEL*, which expresses effects as absolute losses of numbers of adults, and *FH*, which estimates the number of adult females whose reproductive output has been effectively eliminated by entrainment of larvae. Both estimates require an estimate of the age at entrainment. These estimates will be obtained by measuring a random sample of up to 200 larvae of each of the taxa being analyzed from the entrainment samples and using published larval growth rates to estimate the age at entrainment. The age at entrainment will be calculated by dividing the difference between the size at hatching and the average size of the larvae from entrainment by a growth rate obtained from the literature.

Age-specific survival and fecundity rates are required for *AEL* and *FH*. Adult-equivalent loss estimates require survivorship estimates from the age at entrainment to adult recruitment; *FH* requires egg and larval survivorship until entrainment. Furthermore, to make estimation practical, the affected population is assumed to be stable and stationary, and age-specific survival and fecundity rates are assumed to be constant over time. Each of these approaches provides estimates of adult fish loss, which will still need to be placed into context regarding standing stocks of adult fishes.

Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood is limited for many of the taxa likely to be considered in this assessment. Thus, in many cases, these rates must be inferred from the literature along with their measures of uncertainty. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large should be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., northern anchovy), portions of early mortality schedules and fecundity have been reported (e.g., Parker 1980; Zweifel and Smith 1981; Hewitt 1982; Hewitt and Methot 1982; Hewitt and Brewer 1983; Lo 1983, 1985, and 1986; McGurk 1986). Because the accuracy of the estimated entrainment effects from *AEL* and *FH* will depend on the accuracy of age-specific mortality and fecundity estimates, lack of demographic information may limit the utility of these approaches.

The precursor to the *AEL* and *FH* calculations is an estimate of total annual larval entrainment. Estimates of larval entrainment at the SGS will be based on biweekly sampling where E_T is the estimate of total entrainment and E_i is the monthly entrainment estimate. Estimates of total entrainment are based on two-stage sampling designs, with days within each sampling period and cycles within days. The within-day sampling is based on a stratified random sampling scheme with four temporal cycles and two replicates per cycle.

Adult Equivalent Loss *(AEL*)

The *AEL* approach uses estimates of the abundance of the entrained or impinged organisms to project the loss of equivalent numbers of adults based on mortality schedules and age-at-recruitment. The primary advantage of this approach is that it translates power plant-induced early life-stage mortality into numbers of adult fishes that are familiar units to resource managers. Adult equivalent loss does not require source water estimates of larval abundance in assessing effects. This latter advantage may be offset by the need to gather age-specific mortality rates to predict adult losses and the need for information on the adult population of interest for estimating population-level effects (i.e., fractional losses).

Starting with the number of age class j larvae entrained, E_j, it is conceptually easy to convert these numbers to an equivalent number of adults lost (*AEL*) at some specified age class from the formula:

$$AEL = \sum_{j=1}^{n} E_j S_j \tag{1}$$

where

n = number of age classes;

E_j = estimated number of larvae lost in age class j; and

S_j = survival probability for the j th class to adulthood (Goodyear 1978).

Age-specific survival rates from larval stage to recruitment into the fishery must be included in this assessment method. For some commercial species, natural survival rates are known after the fish recruit into the commercial fishery. For the earlier years of development, this information is not well known and may not exist for non-commercial species.

Fecundity Hindcasting (*FH*)

The *FH* approach compares larval entrainment losses with adult fecundity to estimate the amount of adult female reproductive output eliminated by entrainment, hindcasting the numbers of adult females effectively removed from the reproductively active population. The accuracy of *FH* estimates, as with those of the *AEL* above, is dependent upon accurate estimates of age-specific mortality from the egg and early larval stages to entrainment and accurate estimates of the total lifetime female fecundity. If it can be assumed that the adult population has been stable at some current level of exploitation and that the male:female ratio is constant and 50:50, then fecundity and mortality are integrated into an estimate of loss by converting entrained larvae back into females (i.e., hindcasting).

A potential advantage of *FH* is that survivorship need only be estimated for a relatively short period of the larval stage (i.e., egg to larval entrainment). The method requires age-specific mortality rates and fecundities to estimate entrainment effects and some knowledge of the abundance of adults to assess the fractional losses these effects represent. This method assumes that the loss of a single female's reproductive potential is equivalent to the loss of an adult fish.

In the *FH* approach, the total of larval entrainment for a species E_T will be projected backward to estimate the number of breeding females required to provide the numbers of larvae entrained at the SGS. The estimated number of breeding females FH whose fecundity is equal to the total loss of entrained larvae would be calculated as follows:

$$FH = \frac{E_T}{TLF \,\mathrm{g} \prod_{j=1}^{n} S_j} \tag{2}$$

where

E_T = total entrainment estimate;

S_j = survival rate from eggs to entrained larvae of the j th stage ;

TLF = average total lifetime fecundity for females, equivalent to the average number of eggs spawned per female over their reproductive years.

The two key input parameters in Equation (2) are total lifetime fecundity TLF and very early survival rates S_j from spawning to entrainment. Descriptions of these parameters may be limited for many species and are a possible limitation of the method.

4.3.2 Empirical Transport Model (*ETM*)

The *ETM* calculations provide an estimate of the probability of mortality due to power plant entrainment. The calculations require not only the abundance of larvae entrained but also the abundance of the larval populations at risk of entrainment. Sampling at the cooling water intake is used to estimate the total number of larvae entrainment for a given time period, while sampling in the coastal waters around the SGS intake is used to estimate the source population for the same period.

On any one sampling day, the conditional entrainment mortality can be expressed as

$$PE_i = \frac{E_i}{R_i} \tag{3}$$

where

E_i = total numbers of larvae entrained during the *i* th survey; and

R_i = numbers of larvae at risk of entrainment, i.e., abundance of larvae in source water.

The values used in calculating *PE* are population estimates based on the respective densities and volumes of the cooling water system flow and source water areas. The abundance of larvae at risk in the source water during the *i* th survey can be directly expressed as

$$R_i = V_S \cdot \overline{\rho_{S_i}} \quad (4)$$

where V_S denotes the static volume of the source water (S_i), and $\bar{\rho}$ denotes an estimate of the average density in the source water.

Regardless of whether the species has a single spawning period per year or multiple overlapping spawnings the estimate of total larval entrainment mortality can be expressed by

$$P_M = 1 - \sum_{i=1}^{N} f_i \left(1 - PE_i\right)^q \quad (5)$$

where

q = number of days that the eggs and larvae are susceptible to entrainment, and

f_i = estimated annual fraction of total larvae hatched during the i th survey period.

To establish independent survey estimates, it is assumed that during each survey a new and distinct cohort of larvae is subject to entrainment. Each of the monthly surveys is weighted by f_i and estimated as the proportion of the total source population present during the i th survey period.

As shown in Equations 3 and 4 the estimates of *PE* are based on population estimates of specific volumes of water. While a reasonably accurate estimate of the volume of the cooling water intake flow can be obtained, estimating the volume of the source water is more difficult and will vary depending upon oceanographic conditions and taxa. Source water volumes will be estimated separately for each taxon during each survey. Onshore and alongshore current vectors measured during each survey period will be used to determine the maximum distance a larvae could travel based on the estimated maximum larval duration for each taxon. The maximum age at entrainment will be calculated using the lengths of a random sample of up to 200 larvae from the entrainment samples for the taxa being analyzed. The maximum age will be calculated based on the upper 95th percentile value of the lengths measured from the samples. The maximum age at entrainment will be calculated by dividing the difference between the upper 95th percentile value of the lengths measured from the samples minus the hatch length by the growth rate.

Alongshore and onshore current velocities will be measured using current meters positioned offshore from the SGS intake. The final position and depth of the current meters will be chosen to ensure that they are outside the influence of the intake flow. The direction in degrees true from north and speed in cm per second will be estimated for each hour of the source water survey periods. The hourly current meter data will be analyzed by rotating the current vectors so that they are orthogonal to the coast and then tracking the movement of water during each survey period. A total alongshore length or displacement in kilometers will be calculated from these data using the range of both upcoast and downcoast movement over the larval duration period prior to each survey period. The maximum upcoast and downcoast displacement measured prior to each survey period will be added together to obtain an estimate of total alongshore movement.

Onshore movement, excluding periods of offshore movement, will be similarly calculated for the egg and larval duration periods for each species.

Data from the source water sampling will be used to extrapolate densities onshore and offshore using the following approaches:

1. For species where the regression of density versus offshore distance has a negative slope, the offshore distance predicted where density is zero (i.e., integral of zero) will be calculated. The alongshore distance will be calculated from the cumulative current data vectors for the duration based on the maximum larval length.

2. For species where the regression of density versus offshore distance has a slope of ≥ 0, either the offshore distance from the water current data or an average distance based on literature values on the depth distribution of the adults offshore will be used. Literature values (e.g., CalCOFI) will be used to place a ceiling on both the distance and density values used in the offshore extrapolation.

3. The offshore distance of the source water study area will be used when the onshore water current displacement is less than the width of the study area unless the limits of the regression or the depth distribution for the taxa is less than the distance offshore.

These three approaches will use the same regression coefficients to extrapolate source water densities to the shoreline. Survey specific regression coefficients will be calculated by fitting either a linear, quadratic, or other model to the density data. For example, a linear model would be fit as follows:

$$\rho_{ij} = \alpha + \beta w_i + \varepsilon_{ij}$$

where

$\rho_{ij} =$ larval density for the j^{th} observation in the i^{th} survey,
$w_i =$ distance for the i^{th} survey, and
$\alpha, \beta =$ regression coefficients.

The regression analysis will treat the four six-hour cycles during each source water survey as sampling strata according to Cochran (1977). The data collected during the surveys will be converted to counts per m^3 using the sample volumes from the flow meters in the bongo nets. Depths at each station will be recorded and used to convert, by multiplication, these data on larval concentration to densities in counts per m^2. The larval densities (ρ_{ij}) will be analyzed using a model to define density as a function of distance from shore ($\rho_{ij} = f(w_i)$). This function will then be used to extrapolate density as a function of distance from shore by integrating from the offshore margin of the sampling area to a point estimated by the maximum current vector, or where the extrapolated larval density is zero or biologically limited. This point may occur beyond the offshore extent of the study area. A similar integration of the function will occur from the inshore edge of the study area towards the shoreline. This integration will result in units of counts per m. When multiplied by the alongshore distance from the cumulative current vectors we obtain our final estimate for the source water (R_i). This is used in Equation 3 to obtain an estimate of *PE* for the survey. Alternatively, the sampling locations within the source water study area could be treated as spatial strata and an estimate of counts per m obtained.

5.0 REPORTING

Tenera Environmental and MBC Applied Environmental Sciences will produce a final Impingement Mortality and Entrainment Characterization report on the findings from the entrainment and impingement studies. This report will include results from field surveys will be presented, and loss estimates derived from one or more of the assessment methods will be presented for each of the analyzed taxa. The report will be submitted as part of the Comprehensive Demonstration Study for the SGS. Depending on the final compliance alternative(s) selected additional analysis as described in Section 4 will be provided in support of the necessary CDS documents (i.e. Restoration Plan, Benefit Valuation Study, etc).

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