HAYNES GENERATING STATION

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

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1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) published Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities on July 9, 2004. 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 Haynes Generating Station (HnGS) previously consisted of six oil/gas steam boiler generating units (Units 1–6) with a station capacity of 1,570 megawatts (MW). In 2002–2003, Units 3&4 were removed from service, a combined cycle generating system (Units 8–10) was constructed, and the capacities of other units were rerated, resulting in a present-day station capacity of 1,619 MW. All units withdraw cooling water from a common bulkhead intake in Long Beach Marina, Alamitos Bay. The maximum permitted cooling water flow is 138.2 mgd per unit at Units 1&2, 230.4 mgd per unit at Units 5&6, and 276.4 mgd at Unit 8. The total maximum permitted flow is approximately 1.014 billion gallons per day. As part of the Proposal for Information Collection (PIC), Phase II facilities 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 HnGS.

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 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, LADWP plans to use a combination of these sources of information to prepare the HnGS Impingement Mortality and Entrainment Characterization Study Report. Although some units at the HnGS have capacity factors less than 15 percent, an impingement mortality and entrainment characterization study is still proposed.

1.1 Environmental Setting

The HnGS (33°45'05" N, 118°06'15" W) is located in the city of Long Beach on the eastern side of the San Gabriel River flood control channel (**Figure 1-1**). All units at Haynes withdraw cooling water from the Long Beach Marina in Alamitos Bay. The AES Alamitos Generating Station (AGS) withdraws cooling water from Los Cerritos Channel at the northern end of Alamitos Bay. Both facilities discharge cooling water into the lower San Gabriel River flood control channel.

Alamitos Bay is a man-made, small-vessel harbor that was constructed at the mouth of the San Gabriel River (Figure 1-1). It is relatively shallow with water depths throughout most of the Bay between 12 and 18 ft (3.6 and 5.5 m). Depth at the intake is approximately 10 ft (3 m). Sediments within the Bay consist of sand, silt, and clay. Eelgrass (*Zostera marina*) is present at locations near the Alamitos Bay entrance channel, near the west end of Naples Island, and in the Marine Stadium arm of the Bay (Valle et al. 1999).

Detailed circulation studies were performed within the Bay and nearshore areas of San Pedro Bay during the original HnGS 316(b) Demonstration (IRC 1981). Recirculation of discharged cooling water at the HnGS was estimated to be about 4%. This relatively low value was attributed to predominant downcoast currents which transport discharged waters away from Alamitos Bay. It was concluded that "*very little of the water entrained into the Haynes Generating Station resided within Alamitos Bay more than five days*." Due to the predominant downcoast water movement, the immediate oceanic source waters for Alamitos Bay were determined to lie in the northern lees of the Long Beach and Middle Breakwaters (Outer Long Beach Harbor), with minor amounts derived from downcoast between Alamitos and Anaheim Bays.

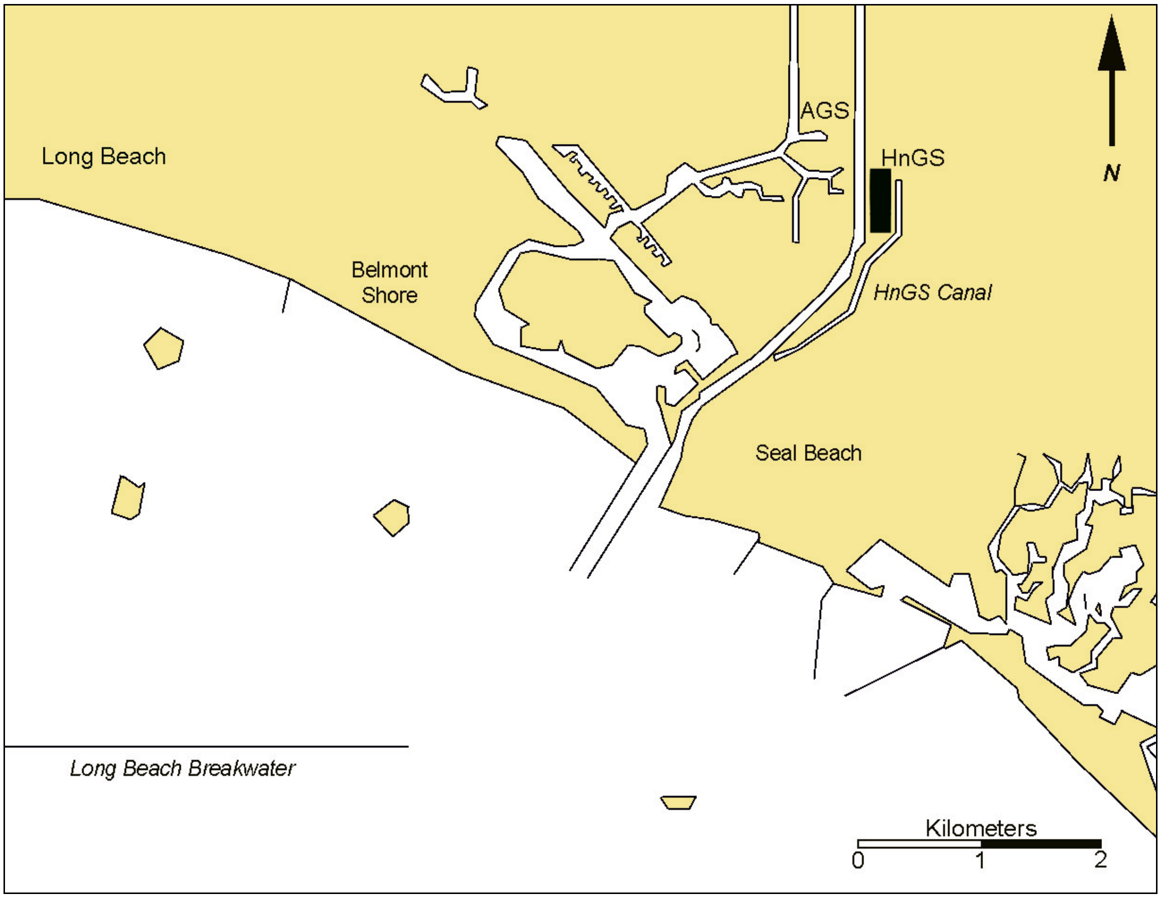

Figure 1-1. Location of the Haynes Generating Station.

2.0 HISTORICAL PHYSICAL AND BIOLOGICAL STUDIES

The following identifies and summarizes previous physical and biological studies conducted at the HnGS and relevant studies from Alamitos Bay. Many studies were performed in cooperation with the AGS, which also withdraws cooling water from Alamitos Bay.

2.1 1978-1979 HnGS 316(b) Demonstration

From 1978 through 1979, the LADWP studied entrainment and impingement at the HnGS cooling water intake systems as part of a 316(b) Demonstration Program (IRC 1981). Entrainment and field (source water) plankton samples were collected biweekly, and impingement samples were collected at varying intervals (daily to weekly) at all of the intake screening structures.

Entrainment and source water samples were collected during day and night. Entrainment samples were collected by pump from mid-depth at the intake structure in Alamitos Bay. At source water stations located in Alamitos Bay and Outer Long Beach Harbor (see Figure 3-1 for a description of station locations), daytime samples were collected from mid-depth by pump and filtered through 0.013-inch (335-μm) mesh during the first seven surveys and through 0.008-inch (202-μm) mesh during the remaining surveys. Nighttime samples were collected using Manta nets (surface), bongo nets (mid-depth), and epibenthic bongo nets (near-bottom) with the same mesh dimensions described for daytime sampling. During each sampling period, two replicates of approximately 15,850 gal (60 m^3) were collected.

Data analysis focused on target (critical) taxa that were selected in consultation with the California Department of Fish and Game and the Los Angeles Regional Water Quality Control Board (LARWQCB) prior to initiation of field sampling. The critical taxa included fish eggs from three taxa (northern anchovy, bay/slough anchovy and croakers), seven larval fish taxa, and five juvenile/adult fish taxa. Entrainment results are presented in **Table 2-1**.

Table 2-1. Annual entrainment estimates and adult equivalent loss estimates reported by IRC (1981) at the HnGS in 1978-1979.

Target Taxa Relevant to New 316(b) Rule		Estimated Annual Entrainment	Estimated Adult Equivalents
Fish eggs			
Engraulis mordax	northern anchovy	228,000,000	5,850
Sciaenid spp complex	croakers	2,560,000,000	
Anchoa spp	anchovies	12,000,000	
Fish larvae			
Atherinid spp complex	silversides	12,200,000	22,200
Engraulid spp complex	anchovies	575,000,000	29,500
Gobiid spp complex	gobies	3,150,000,000	165,000,000
Hypsoblennius spp	combtooth blennies	4,410,000,000	3,770,000
Genyonemus lineatus	white croaker	208,000,000	46,900
Seriphus politus	queenfish	53,400,000	560
Hypsopsetta guttulata	diamond turbot	4,940,000	

Fish eggs were most abundant in winter and spring for most taxa, which agreed with known spawning patterns of the critical taxa (IRC 1981). Highest concentrations of fish larvae were found in winter and spring. Highest numbers of fish eggs were recorded in surface and mid-depth regions of the water column during both day and night sampling periods. Larvae of silversides (Atherinopsidae) were found in highest numbers in surface water samples, combtooth blennies (*Hypsoblennius* spp.) were more abundant in surface and mid-depth samples, and anchovies (Engraulidae), gobies (Gobiidae), white croaker (*Genyonemus lineatus*), and queenfish (*Seriphus politus*) were dominant at mid-depth and from near bottom samples.

Entrainment was highest from January through June, with lowest concentrations occurring from September through December. Nighttime entrainment was significantly greater than daytime entrainment for several fish egg and larval taxa, and probably resulted from nighttime vertical migrations for the fish larvae.

During the one-year study between mid-November 1978 and mid-November 1979, 191 24-hr impingement surveys were conducted. Surveys were performed daily (6–7 days per week) in November and December 1978, and in May, June, September, and October 1979. Surveys were performed weekly (measuring impingement for seven days) from January–April 1979, and July–September 1979. Surveys were performed at all operational units during the study. Only a few samples were collected at Unit 3 since it was not operational for most of the year. A total of 17,637 fish weighing 1,725 lbs (782 kg) was collected during the year (**Table 2-2**). The mean daily impingement rate was 83 fish per day, which extrapolated to an annual impingement estimate of 30,290 fish weighing 2,964 lbs (1,344 kg). The most abundant fish species impinged were shiner perch (*Cymatogaster aggregata*), Pacific pompano (*Peprilus simillimus*), and white seaperch (*Phanerodon furcatus*). Impingement rates varied by species, but peaked in December and February for Pacific pompano and in June and September for juvenile shiner perch and white seaperch.

Table 2-2. Normal operation fish impingement abundance at the HnGS, Nov. 1978–Nov. 1979.

Parameter	Unit 1	Unit 2	Unit 4	Unit 5	Unit 6	Total
Annual fish abundance	2,512	1,282	549	3,427	9,674	17,462
Normal operation period (days)	335	335	335	335	335	335
Fish per day	8	4	2	10	29	52

* Unit 3 excluded from analysis due to infrequent operation during the study (IRC 1981).
Total fish per day differs slightly from sum of unit totals due to rounding.

Impact analyses were conducted using several techniques. Entrainment losses were compared to source water populations (standing stocks). Ichthyoplankton loss estimates were also evaluated using an adult equivalent loss model. Impingement losses were compared with source populations calculated from demersal fish surveys, as well as recreational and commercial fishing landings. Lastly, a fishery production model was used to evaluate losses of queenfish and shiner perch. In summary, there were no significant effects from the HnGS on the standing crop and natural mortality rates of the taxa analyzed. Consistent with the 316(b) guidelines, it was determined that the HnGS cooling water system represented the best technology available.

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 HnGS 316(b) Update

In 1997, available information was synthesized to update the original 316(b) assessment from 1978-1979 for the HnGS; no additional biological data was collected or analyzed (MBC 1997). No additional recent data on through-plant effects on zooplankton, fish eggs, or ichthyoplankton were included in the 316(b) update. Cooling water flow at the HnGS was approximately 73% of maximum design flow during the 1978-1979 316(b) studies, and 72% of design flow between 1982 and 1995. Therefore, estimated losses from the previous 316(b) demonstration were considered representative of conditions during 1997. It was determined that the HnGS was minimizing losses of plankton and fishes through the use of the existing intake system.

2.3 2000–2004 HnGS Fish and Macroinvertebrate Impingement Monitoring

Composition, abundance, and biomass of juvenile and adult fish and macroinvertebrates entrapped and impinged on the traveling/slide screens at the HnGS have been studied for many years as part of a continuing National Pollutant Discharge Elimination System (NPDES) monitoring program. The HnGS NPDES permit required impingement sampling twice per year at each intake pair (Units 1&2, Units 3&4, and Units 5&6) during heat treatments. If two heat treatments were not conducted at an intake during the NPDES study year (October through September), normal operation samples were collected if the unit was operational. From 2000–2004, normal operation and heat treatment impingement surveys occurred periodically as required by the HnGS NPDES permit. In addition, beginning in 2004, generating station personnel preserved impinged fishes during routine traveling screen operations. These organisms were later analyzed by biologists.

The HnGS impingement screens at Units 1 and 2 differ from the traveling screens at Units 3 through 6, though all screens have 3/8-in. mesh. The screens at Units 1 and 2 are paired slide screens that both remain stationary (submerged) until an impingement sample is collected. To collect an impingement sample at one of these two units, the first screen is lifted and rinsed, and impinged organisms are washed into a collection basket. If any organisms fall off the screen as it is lifted, they would most likely be impinged on the second screen (or swim away). However, this second screen cannot be lifted and rinsed, since anything that fell off the screen could potentially damage the circulating water pumps. Therefore, the second screen is usually backflushed of material, and any impinged organisms are flushed back out into the intake canal. Backflushing the screen is carried out by the same procedure used to perform heat treatments. To flush the screen, one of the circulating water pumps is stopped and the discharge conduit is throttled (partially closed), which forces water back through the second condenser half in the reverse direction.

During normal operation surveys, the traveling/slide screens were rotated/removed for an approximate 10-minute rotation, and the impingement collection basket was cleared of accumulated debris. If this was not possible, a tarp was laid across the debris to separate it from the subsequent collection. Approximately 24 hr later, the screens were rotated/removed again, and all material that accumulated from that screen wash, and any other washes that occurred in the prior 24 hr, was considered part of that normal operation sample. All fish and macroinvertebrates were separated from incidental debris, identified, and counted. Up to 200 individuals of each fish species were measured, examined for external parasites, anatomical anomalies, and other abnormalities. Aggregate weights were taken for each fish and macroinvertebrate species. When LADWP collected organisms for impingement samples, the screens were rotated and all impinged fishes were placed in labeled plastic bags and frozen. These samples were transferred to biologists on a regular basis, and the organisms were then identified, enumerated, measured, and weighed.

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 recirculated to the intake until the water temperature rises to approximately 115°F (46°C) in the screenwell area. This temperature is maintained for at least one hour, during which time all biofouling organisms succumb to the heated water. Fishes that are upcurrent of the screens in the intake canal could potentially avoid the areas of higher temperature, however. During heat treatment surveys, all material impinged onto traveling/slide screens was removed. Fish and macroinvertebrates were separated from incidental debris, identified, and counted. Up to 200 individuals of each species were measured, examined for external parasites, anatomical anomalies, and other abnormalities. Aggregate weights were taken by species.

A summary of results from the 2000–2004 impingement monitoring is presented in **Table 2-3**. A total of 55 heat treatment and 32 normal operation impingement surveys were performed during the five-year period (30 of the normal operation surveys were performed by generating station personnel). Of the 840 fish collected during the 87 surveys, 40% occurred during 2004, and 42% of those fish were impinged during a normal operation survey at Unit 6 in April 2004. Of the 143 fish impinged during that survey, 140 (98%) were juvenile topsmelt. Queenfish was the dominant species impinged in 2000, 2002, and 2003. Other common species impinged in 2004 included California grunion (*Leuresthes tenuis*), queenfish, and specklefin midshipman (*Porichthys myriaster*).

Table 2-3. Total fish and macroinvertebrate impingement abundance at the HnGS, 2000–2004.

Parameter	2000	2001	2002	2003	2004	Average
Annual fish abundance	31	242	134	96	337	168
Annual macroinvertebrate abundance	12	74	62	107	8	53
Number of heat treatment surveys	9	16	12	10	8	11
Number of normal operation surveys	0	0	1	1	30	6
Average number of fish	3	15	10	9	9	10
Average number of macroinvertebrates	1	5	5	10	1	5

Of the 263 macroinvertebrates impinged during the surveys, abundance was highest at Unit 5 (65 individuals) and Unit 1 (55 individuals). The species contributing most to abundance at these units included tuberculate pear crab (*Pyromaia tuberculata*), two-spotted octopus (*Octopus bimaculatus/bimaculoides*), and gastropod spiny cup-and-saucer (*Crucibulum spinosum*). In 2004, the most common invertebrate species impinged included the mollusk angular unicorn (*Acanthina spirata*; 39%), two-spotted octopus (36%), and striped shore crab (*Pachygrapsus crassipes*; 10%).

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 HnGS Larval Characterization Study

In preparation for potential 316(b) field studies, a preliminary larval sampling program was conducted to document the composition and density of larval fishes and shellfish in the vicinity of the HnGS cooling water intakes (MBC 2004a). Samples were collected during eight surveys from April 2004 to June 2004. Collections were made from the docks immediately upcurrent from the bulkhead intake structure. The sampling net was a 20-inch (50-cm) inside diameter by 71-inch (180-cm) long plankton net with 0.012-inch (303-μm) mesh. The net was equipped with a General Oceanics flowmeter to allow the calculation of the volume of water sampled by the net. Samples were collected during daytime and nighttime by towing the net in front of the intake. The tow was performed in an oblique fashion by raising the net slowly during sampling from near-bottom to the surface. 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.

A summary of results is presented in **Table 2-4**. Three fish taxa accounted for 93% of the total abundance: combtooth blennies, CIQ gobies, and silversides (Atherinopsidae). The CIQ goby complex is comprised of three species that are morphologically similar during early larval stages: arrow goby, cheekspot goby, and shadow goby. Densities were higher at nighttime than daytime during all eight surveys.

Table 2-4. Estimated densities of the ten most abundant larval fish taxa collected during eight surveys at the HnGS intake, April–June 2004. 1,000 m^3 = 265,000 gal.

Fish taxon		**Mean Density (#/1,000 m^3)**
combtooth blennies	*Hypsoblennius* spp	8,727
CIQ gobies	Gobiidae	4,193
silversides	Atherinopsidae	2,225
topsmelt	*Atherinops affinis*	383
northern anchovy	*Engraulis mordax*	346
labrisomid blennies	Labrisomidae	168
clingfishes	*Gobiesox* spp	78
California grunion	*Leuresthes tenuis*	28
croakers	Sciaenidae	14
bay pipefish	*Syngnathus leptorhynchus*	13
	Total:	16,225
	Number of taxa	19

A set of four target shellfish taxa was selected prior to initiation of the surveys: California spiny lobster (*Panulirus interruptus*), market squid (*Loligo opalescens*), sand crab (*Emerita analoga*), and decapod zoea/megalopae larvae. Market squid was not collected during the eight-week study, and only one California spiny lobster phyllosoma was collected during the study. Concentrations of the other target taxa were: decapod zoea (20,047/1,000 m^3), sand crab zoea and megalops larvae (74/1,000 m^3), and decapod megalopae (18/1,000 m^3). Overall, the larval fish community strongly resembled that collected in 1978-1979. Nighttime densities of fishes and shellfish were substantially higher than daytime densities.

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.

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 Studies on the Physical Environment in the Vicinity of the HnGS

The HnGS withdraws cooling water from Long Beach Marina in Alamitos Bay. Cooling water is withdrawn through a bulkhead intake structure and directed through conduits beneath the San Gabriel River to an open-air, trapezoidal canal that flows to the generating station. Waters within Alamitos Bay are primarily marine (30–35 practical salinity units [PSU]) with water temperatures ranging from about 55°F (13°C) in winter to 77°F (25°C) in summer (Horn and Allen 1975, IRC 1981). The Bay has undergone extensive changes in the last 100 years. Originally an estuary and wetland system, it is now highly developed.

The temperature and salinity of the waters offshore Alamitos Bay have been measured semiannually or annually for many years as part of the HnGS NPDES monitoring program. The monitoring program consists of 9 stations in the nearshore waters off Alamitos Bay and the mouth of the San Gabriel River flood control channel, from depths of 12 to 40 ft (3.6 to 12.2 m). Three additional stations are monitored within the San Gabriel River. 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 2-5.**

Table 2-5. Temperature and salinity of surface and bottom waters off Alamitos Bay, 2001–2004.

Season	Parameter	Surface	Bottom
Winter	Minimum temperature °F (°C)	58.2 (14.5)	56.3 (13.5)
	Average temperature °F (°C)	62.1 (16.7)	58.3 (14.6)
	Maximum temperature °F (°C)	74.2 (23.5)	61.9 (16.6)
Summer	Minimum temperature °F (°C)	65.3 (18.5)	57.1 (13.9)
	Average temperature °F (°C)	70.4 (21.3)	64.6 (18.1)
	Maximum temperature °F (°C)	81.3 (27.4)	71.2 (21.8)
Winter	Minimum salinity (PSU)	28.8	32.4
	Average salinity (PSU)	32.1	33.2
	Maximum salinity (PSU)	33.4	33.6
Summer	Minimum salinity (PSU)	32.3	33.2
	Average salinity (PSU)	33.2	33.5
	Maximum salinity (PSU)	33.6	33.9

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 28.8 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. Lowest salinity typically occurs directly offshore the mouth of the San Gabriel River.

Additional water quality monitoring was performed at the HnGS intake structure during spring and summer (April–June) 2004 (MBC 2004a). Water temperatures at the surface and a depth of one meter ranged from about 64.2°F (17.9°C) to 70.5°F (21.4°C) during sampling, with little or no difference between the two depths. Salinity consistently ranged between 33.2 and 34.2 practical salinity units (PSU).

Hydrodynamic studies of the waters at the HnGS 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 were designed to characterize the zone of influence of the HnGS intake (near-field) as well as current flow in Alamitos Bay outside of the immediate zone of influence of the intake (far-field).

Current meters were deployed at several locations across the face of the intake approximately one foot (30 cm) from the intake opening. During the deployment, the cooling water flow rate was 652,000 gallons per minute (gpm), or 93% of maximum flow. Velocities at the intake structure averaged 0.30 to 0.46 feet per second (fps) (10 to 15 cm/s). Maximum recorded velocities were 0.76 to 0.91 fps (25 to 30 cm/s) but were extremely localized. Highest velocities were measured within one meter from the bottom. Intake velocities can be affected by marine growth on the bar racks, which can reduce the effective cross-sectional area of flow, increasing the average approach velocity. However, the bar racks are routinely removed and cleaned. Within the intake canal, water velocity is generally 0.5 to 2.0 fps (15 to 60 cm/s), averaging 1.0 fps (30 cm/s).

IRC (1981) used results from the dye experiments, current meter data, and meteorological data to estimate the probability of entrainment for the near- and far-field zones of influence for the HnGS intake. The probability of entrainment was 50% for an area which extended up to 2,300 ft (700 m) from the intake structure. The model results also suggested that approximately 4 percent of the cooling water that is discharged into the San Gabriel River is recirculated back into the plant after it is discharged out into San Pedro Bay just south from the opening into Alamitos Bay. This relatively low value was attributed to predominant downcoast currents which transport discharged waters away from Alamitos Bay. It was concluded that "*very little of the water entrained into the Haynes Generating Station resided within Alamitos Bay more than five days*." Due to the predominant downcoast water movement, the immediate oceanic source waters for Alamitos Bay were determined to lie in the northern lees of the Long Beach and Middle Breakwaters (Outer Long Beach Harbor), with minor amounts derived from downcoast between Alamitos and Anaheim Bays. Since there have been no major modifications to Alamitos Bay since the IRC study, and cooling water flows have remained relatively constant, these results are still applicable today (Flow Science 2004).

3.0 PROPOSED NEW BIOLOGICAL STUDIES

The proposed impingement mortality and entrainment (IM&E) studies will examine losses at HnGS 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 (Tenera, in progress). 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 HnGS. 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 HnGS intake exceeds this value, so LADWP 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 cooling water intake structure (CWIS). The §316(b) Final Regulations allow the use of "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 HnGS.

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 AGS since it also withdraws cooling water from Alamitos Bay. 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 both facilities.

3.1 Impingement Study

Impingement sampling has been conducted at the HnGS since 2000. Methods and results of those sampling efforts from the 2000 through 2004 NPDES annual reporting periods (January 2000 through September 2004) are summarized in Section 2.3. The proposed impingement sampling is similar to the NPDES impingement studies, but sampling will be more frequent (weekly) and is also designed to collect additional information on diel variation in impingement and sizes of impinged shellfishes.

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, shrimp, lobsters, and squid) impinged by the HnGS CWIS. The sampling program is designed to provide current estimates on the abundance, biomass, taxonomic composition, diel periodicity, and seasonality of the fishes and shellfishes impinged at the HnGS. 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/slide 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 will be recorded on an hourly basis during the collection period. At Units 3–6, each 24-hour sampling period 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. At the Units 1 and 2 slide screens, sampling will occur only once per 24-hr period. At all units, the impinged material from the 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 or shellfishes, sampling may continue for one or two additional days to obtain a more representative estimate of the impingement rate for the sampling period.

If the traveling screens at Units 3–6 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/slide 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. Based on the frequency of heat treatments since 2000, between 6 and 20 heat treatments are likely to 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 will be recorded to the nearest 0.04 in. (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. Shellfishes and other macroinvertebrates will be identified to species and their presence recorded, but they are not 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 will not be measured.

- The linear measurements of up to 200 individuals of each taxon 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 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.

3.2 Entrainment Study

As a result of the present uncertainties surrounding the use of restoration for compliance with the new rule, the proposed entrainment study plan incorporates two design elements 1) cooling water intake system sampling and 2) source water sampling. If restoration is not upheld by the court as an alternative to comply with entrainment mortality reduction requirements, then only 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 adults. In this case, the commercial and recreational values of adult fish and shellfish 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. However, if restoration prevails, the source water populations of entrained fish and shellfish larvae will be sampled to estimate the proportional entrainment losses, using a conditional mortality model that could be used to determine appropriate restoration projects for offsetting entrainment.

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

Ocean water for cooling purposes is conveyed to the generating station from the northeast corner of Long Beach Marina in Alamitos Bay. The bulkhead intake structure is 350 ft (107 m) long and consists of seven separate but adjoining structures, each 50 ft wide by 7.5 ft high (15.2 m by 2.3 m). The intake openings are located between -2.0 and –9.5 ft (-0.6 and -2.9 m) Mean Lower Low Water (MLLW), and water depth at the intake structure is about -9.8 ft (–3.0 m) MLLW. Water flows from the bulkhead intake structure through seven 8.0-ft (2.4-m) long. After passing under the San Gabriel River, the conduits feed into a single 1.5-mi. (2.4-km) long intake canal that extends to the generating station. The canal is an open, earth trapezoidal channel that was constructed by the LADWP. After passing through the condensers, cooling water is discharged through three discharge structures (each consisting of two outfalls) located on the eastern bank of the San Gabriel River.

To determine composition and abundance of ichthyoplankton and shellfish entrained by the generating station, sampling in the immediate proximity of the bulkhead intake structure is proposed to be conducted every two weeks from January through December 2006 (**Figure 3-1**). During the previous 316(b) demonstration, horizontal inflow at the intake structure was measured at all intake depths (-2 ft to –9.5 ft [-0.6 to –2.9 m]), though velocities were highest just above bottom (IRC 1981). Therefore, entrainment samples will be collected using an oblique tow through the water column at two stations along the bulkhead intake. At each station, the net will be towed from the docks (parallel to the bulkhead) approximately 10 ft (3 m) upcurrent from the intake. The net will be towed until a volume of 4,000 to 5,300 gal (15 to 20 m^3) has been filtered. This is the same procedure employed during entrainment sampling in 2004 (MBC 2004a). Two replicate tows will be performed at each entrainment station. Sampling will be conducted four times per 24-hr period--once every six hours.

Entrainment samples will be collected at the intake with a single 0.013 in. (333 *u*m) mesh plankton net. The net will be fitted with a Dacron sleeve and a cod-end container to retain the organisms. The net 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. The net will be equipped with a calibrated General Oceanics flowmeter, allowing the calculation of the amount of water filtered. At the end of each tow, the contents of the net will be 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 and preserved in 4 to 10 percent buffered formalin-seawater.

3.2.2 Source Water Sampling

The source water study area is designed to 1) characterize the larvae of fishes and shellfishes potentially entrained by the HnGS cooling water intake, and 2) be representative of the habitats in Alamitos Bay and the nearshore waters just outside Alamitos Bay.

To determine composition and abundance of ichthyoplankton in the source water, source water sampling will be done monthly on the same day that the entrainment stations are sampled. The scope of 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. IRC (1981) estimated that 32% of the water passing through the Alamitos Bay entrance is entrained in the HnGS intake system; therefore, the source water sampling area extends into the nearshore waters of San Pedro Bay. Besides the entrainment stations, we propose that source water sampling occur at nine additional source water stations: three within Alamitos Bay and six in the nearshore waters of San Pedro Bay (**Figure 3-1**). In the previous 316(b) demonstration, current measurements from 0.9 mi (1.5 km) off the bay entrance at mid-depth indicated a mean downcoast flow of approximately 0.63 in./s (1.6 cm/s), or about 0.9 mi./day (1.4 km/day). The six nearshore source water stations are positioned to sufficiently characterize the waters within 0.9 mi. (1.4 km) of the bay entrance and could allow for extrapolating the sampled source water data over a larger area.

All stations will be sampled using a wheeled bongo plankton net using an oblique tow that samples the water column from approximately 5 in. (13 cm) off the seafloor to the sea surface. The bongo or wheeled bongo frame proposed for sampling has 24 in. (60 cm) diameter net rings with plankton nets constructed of 0.013 in. (333-μm) Nitex® nylon mesh, similar to the nets used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). 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 and preserved in 4 to 10 percent buffered formalin-seawater.

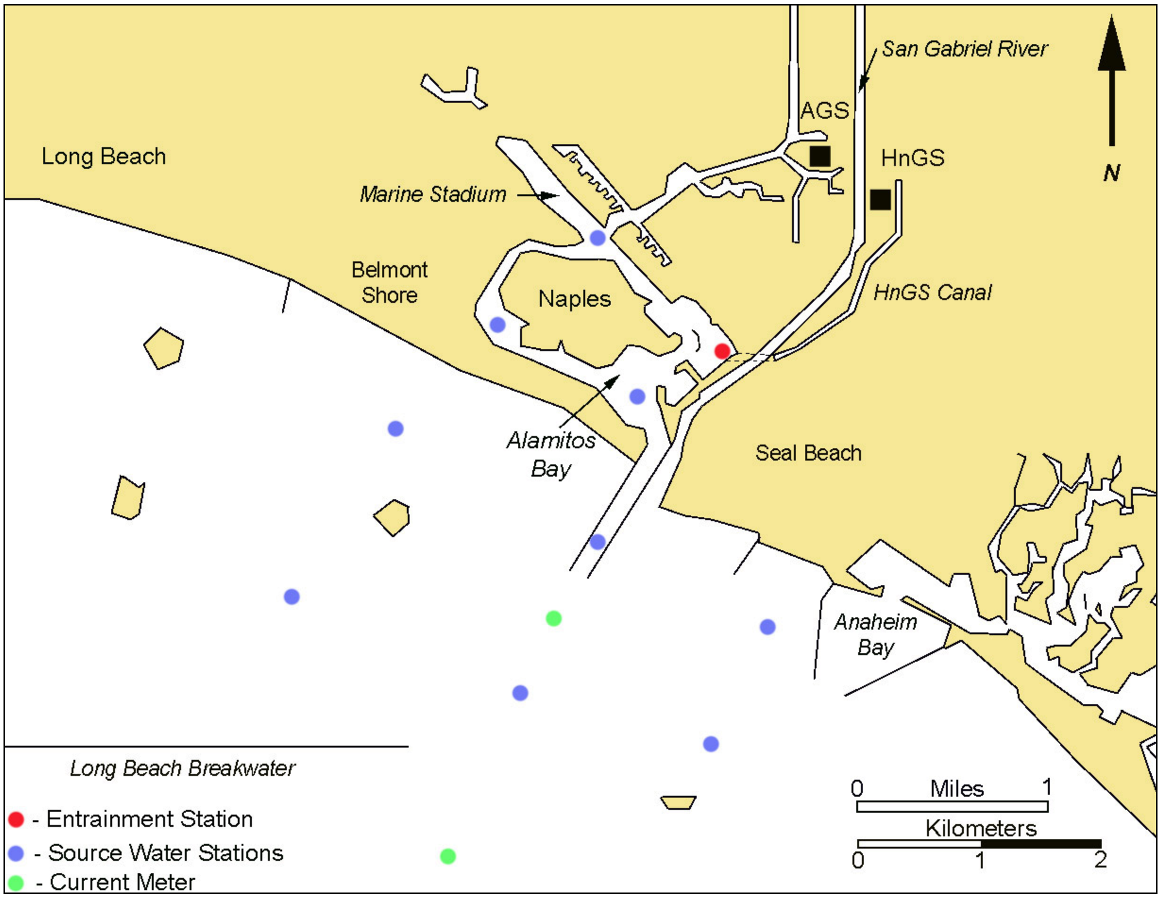

Figure 3-1. Location of the HnGS and AGS (black squares), the entrainment sampling stations (red dot), source water stations (blue dots), and current meter locations (green dots). IRC's source water stations from 1978-1979 were located <0.5 km west of the entrainment stations (Near-Field) and approximately 2 km west of the study area in Outer Long Beach Harbor (Far-Field).

During each source water survey, the additional 9 source water stations (plus the entrainment stations) 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 to 10 percent buffered formalin-seawater will be transferred to 70 to 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 HnGS 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 used in the source water sampling 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 HnGS. 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 HnGS 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 HnGS 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 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 both use and forage entrainment losses. 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 HnGS.

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 HnGS will be calculated from data collected at the entrainment stations. 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 HnGS 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 HnGS 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 loss modeling (*AEL* and *FH*) is an accepted method that may be used at HnGS 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 propose the potential use of two different but related demographic approaches in assessing entrainment effects at the HnGS: *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 HnGS will be based on the biweekly sampling where E_T is the estimate of total entrainment and E_i is the biweekly 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, $P_M = 1 - \sum_{i=1}^{N} f_i \left(1 - PE_i\right)^q$, it is conceptually easy to convert these numbers to an equivalent number of adults lost (AEL) at some specified age class from the formula:

$$AEL = \sum_{j=1}^{n} E_j S_j \quad (1)$$

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.

An alternative expression of adult-equivalent loss would be to standardize AEL by the size of the adult population of interest to estimate the relative magnitude of the equivalent adult loss such that,

$$RAEL = \frac{AEL}{P} \tag{2}$$

where P = estimated size of the adult population of interest. Information on adult source populations will be limited for many species and thereby limit the utility of Equation (2), although the same approach will be used to place the estimated losses into context for taxa with published commercial or recreational fishery catch data.

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 HnGS. The estimated number of breeding females FH whose fecundity is equal to the total loss of entrained larvae would be calculated as follows:

$$FH = \frac{E_T}{TLF \cdot \prod_{j=1}^{n} S_j} \tag{3}$$

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 (3) 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.

Similar to *AEL*, an alternative interpretation of *FH* is possible by expressing the estimate in terms of the relative size of the adult fish stock in the source populations where

$$RFH = \frac{FH}{P} \quad (4)$$

where P = estimated size of the adult population of interest. Information on adult source populations will be limited for many species and thereby limit the utility of Equation (4), although the same approach can be used to place the estimated losses into context for taxa with published commercial or recreational fishery catch data where *RFH* is the proportion of the breeding females whose fecundity was lost due to entrainment by the HnGS.

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 nearshore waters around the HnGS 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

$$PE_i = \frac{E_i}{R_i} \quad (5)$$

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

$$R_i = V_i \overline{\rho}_{S_i} \quad (6)$$

where V_i denotes the static volume of the source water (S_i), and $\overline{\rho}_{S_i}$ 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

$$P_M = 1 - \sum_{i=1}^{n} f_i (1 - PE_i)^q \quad (7)$$

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 5 and 6 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 taxon. 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 if it is justified to use a fixed source water volume for the calculations or whether the offshore portion of the source water should be based on the current data and the distance a larva 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 each taxon 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 off Alamitos Bay will be measured using current meters positioned within and just offshore the entrance channel. 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. In the nearshore, the distance upcoast will be limited by the Los Angeles - Long Beach Harbor complex, while offshore, current movement is limited by the San Pedro, Middle, and Long Beach breakwaters. These physical measurements will be used to determine the source water estimate.

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 selected taxa. The report will be submitted as part of the Comprehensive Demonstration Study for the HnGS. 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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