Appendix A. Ocean Plan with the proposed Desalination Amendment and other non-substantive changes in blue strikeout or underline

Associated with the Draft Staff Report Including the Draft Substitute Environmental Documentation for the Proposed Desalination Amendment

WATER QUALITY CONTROL PLAN

OCEAN WATERS OF CALIFORNIA

201~~2~~4

STATE WATER RESOURCES CONTROL BOARD

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

State of California
Edmund G. Brown Jr. Governor

California Environmental Protection Agency
Matthew Rodriquez, Secretary

State Water Resources Control Board
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Sacramento, CA 95814
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Cover Art by:
Ivy Liao, 10th Grade, 2012
California Coastal Art & Poetry Contest
California Coastal Commission
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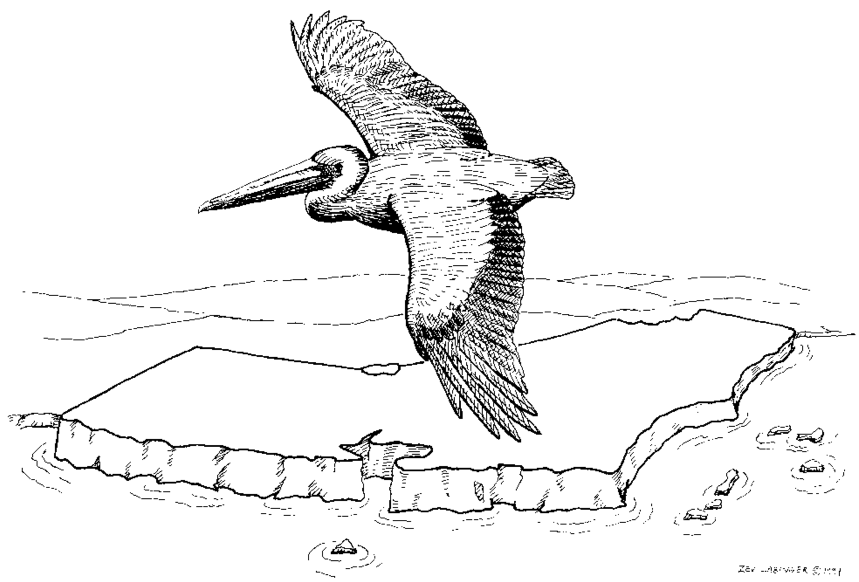
State of California

STATE WATER RESOURCES CONTROL BOARD



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CALIFORNIA OCEAN PLAN

WATER QUALITY CONTROL PLAN

OCEAN WATERS OF CALIFORNIA

Effective August 19, 2013

Adopted October 16, 2012

Approved by the Office of Administrative Law on July 03, 2013

STATE WATER RESOURCES CONTROL BOARD
RESOLUTION NO. 2012-0056

ADOPTING THE CALIFORNIA OCEAN PLAN AMENDMENT IMPLEMENTING STATE WATER BOARD RESOLUTIONS 2010-0057 AND 2011-0013 REGARDING STATE WATER QUALITY PROTECTION AREAS AND MARINE PROTECTED AREAS

WHEREAS:

1. The State Water Resources Control Board (State Water Board) adopted the California Ocean Plan (Ocean Plan) in 1972 and revised it in 1978, 1983, 1988, 1990, 1997, 2001, 2005 and 2009.

2. The State Water Board is responsible for reviewing Ocean Plan water quality standards and for modifying and adopting standards in accordance with Section 303 (c)(1) of the federal Clean Water Act and section 13170.2(b) of the California Water Code.

3. On November 16, 2010, the State Water Board adopted Resolution No. 2010–0057, Marine Protected Areas and State Water Quality Protection Areas. The Resolution directed State Water Board staff to propose amendments to the Ocean Plan to address designation of new State Water Quality Protection Areas and to clarify requirements for existing discharges relative to Marine Protected Areas.

4. On March 15, 2011, the State Water Board adopted the Triennial Review Workplan 2011-2013, in Resolution No. 2011-0013, which included under Issue 1 direction to staff to propose an amendment to the Ocean Plan addressing State Water Quality Protection Areas and Marine Protected Areas.

5. On July 8, 2011, the State Water Board held a scoping meeting regarding potential Ocean Plan Amendments to solicit input from public agencies and members of the public on the scope and content of the substitute environmental documentation to be prepared in support of the amendment.

6. On May 1, 2012, the State Water Board conducted a public hearing. Twenty- four written public comments were received and reviewed. Staff considered comments and input from Board Members and the public and drafted revisions to the proposed amendments and draft SED, which were circulated on February 28, 2012.

7. On August 22, 2012, the State Water Board conducted a public workshop to consider changes proposed by staff in response to comments received. A written comment period from July 31, 2012 through August 31, 2012, allowed for submission of comments on the changes from the earlier draft documents.

8. The Ocean Plan is clear that there shall not be degradation of marine communities or other exceedances of water quality objectives due to waste discharges. This is true for all near coastal ocean waters, regardless of whether a Marine Protected Area is present. If sound scientific information becomes available demonstrating that discharges are causing or contributing to the degradation of marine communities, or causing or contributing to the exceedance of narrative or numeric water quality objectives, then new or modified limitations or conditions may be placed in the NPDES permit to provide protections for marine life, both inside and outside of Marine Protected Areas.

9. The State Water Board prepared and circulated a draft Substitute Environmental Document (SED) in accordance with the provisions of the California Environmental Quality Act and title 14, California Code of Regulations section 15251(g) and in compliance with State Water Board regulations governing certified regulatory programs. (See Cal. Code Regs., tit. 23, § 3777) The SED consists of the draft SED dated January 6, 2012, and updated on February 23 and July 25, 2012, and responses to comments on the draft SED and the proposed project. Together, these documents constitute the required environmental documentation under CEQA. (See Cal. Code Regs., tit. 14, §§ 15250, 15252; Cal. Code of Regs., tit. 23, § 3777.)

10. The State Water Board has considered the SED, which analyzes the project, alternatives to the project and reasonably foreseeable methods of compliance with the proposed amendments and concludes that the project will not result in adverse environmental impacts.

11. These amendments to the Ocean Plan do not become effective until approved by the Office of Administrative Law (OAL).

THEREFORE BE IT RESOLVED THAT:

The State Water Board:

1. After considering the entire record, including oral comments at the public hearing, adopts the State Water Quality Protection Areas and Marine Protected Areas amendment to the Ocean Plan.

2. Approves the final SED, which includes the responses to comments, and directs the Executive Director or designee to transmit the Notice of Decision to the Secretary of Resources.

3. Authorizes the Executive Director or designee to submit the amended Ocean Plan to OAL for review and approval.

4. Directs the Executive Director or designee to make minor, non-substantive modifications to the language of the amendment, if OAL determines during its

approval process that such changes are needed, and inform the State Water Board of any such changes.

CERTIFICATION

The undersigned Clerk to the Board does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on October 16, 2012.

AYE:	Chairman Charles R. Hoppin
	Vice Chair Frances Spivy-Weber
	Board Member Tam M. Doduc
	Board Member Steven Moore
	Board Member Felicia Marcus
NAY:	None
ABSENT:	None
ABSTAIN:	None

Jeanine Townsend

Jeanine Townsend
Clerk to the Board

STATE WATER RESOURCES CONTROL BOARD RESOLUTION NO. 2012-0057

ADOPTION OF THE CALIFORNIA OCEAN PLAN AMENDMENTS REGARDING MODEL MONITORING, VESSEL DISCHARGES, AND NON-SUBSTANTIVE CHANGES

WHEREAS:

1. The State Water Resources Control Board (State Water Board) adopted the California Ocean Plan (Ocean Plan) in 1972 and revised it in 1978, 1983, 1988, 1990, 1997, 2001, 2005 and 2009.

2. The State Water Board is responsible for reviewing Ocean Plan water quality standards and for modifying and adopting standards in accordance with Section 303 (c)(1) of the federal Clean Water Act and section 13170.2(b) of the California Water Code.

3. On August 1, 8, and 15, of 2006, the State Water Board conducted public scoping meetings in Santa Rosa, Los Angeles, and Monterey respectively to receive public comments for potential revisions to the Ocean Plan.

4. On June 26, 2007, the State Water Board held a public scoping meeting in San Francisco regarding potential Ocean Plan Amendments and solicited public comments on the scope and content of the environmental information that the State Water Board must consider.

5. On March 15, 2011, the State Water Board adopted the Ocean Plan Triennial Review Work Plan for 2011-2013 by Resolution 2011-0013. The work plan identifies issues for which further action is needed, including model monitoring, vessel discharges, and non- substantive changes, which are addressed by the proposed amendments to the Ocean Plan.

6. On November 1, 2011, the State Water Board conducted a public hearing for the proposed amendments to the Ocean Plan. Public comments were received and reviewed, and staff developed edits based on these comments.

7. On August 22, 2012, the State Water Board conducted a public workshop, where the State Water Board solicited comments on staff edits to the proposed amendments to the Ocean Plan related to model monitoring, vessel discharges and non-substantive changes.

8. The State Water Board prepared and circulated a draft Substitute Environmental Document (SED) in accordance with the provisions of the California Environmental Quality Act and title 14, California Code of Regulations section 15251(g) and in compliance with State Water Board regulations governing certified regulatory programs. (See Cal. Code Regs., tit. 23, § 3777) The SED consists of the draft SED

dated January 6, 2012, and updated on February 23 and July 25, 2012, and responses to comments on the draft SED and the proposed project. Together, these documents constitute the required environmental documentation under CEQA. (See Cal. Code Regs., tit. 14, §§ 15250, 15252; Cal. Code of Regs., tit. 23, § 3777.)

9. The State Water Board has considered the SED, which analyzes the project, alternative to the project and reasonably foreseeable methods of compliance with the proposed amendments and concludes that the project will not result in adverse environmental impacts.

10. These amendments to the Ocean Plan do not become affective until approved by the Office of Administrative Law (OAL).

THEREFORE BE IT RESOLVED THAT:

The State Water Board:

1. After considering the entire record, including oral comments at the public hearing, adopts the proposed amendments to the Ocean Plan regarding model monitoring, vessel discharges and non-substantive administrative changes.

2. Approve the final SED, which includes the response to comments and directs the Executive Director or designee to transmit the Notice of Decision to the Secretary of Resources.

3. Authorizes the Executive Director or designee to submit the amended Ocean Plan to OAL for review and approval.

4. Directs the Executive Director or designee to make minor, non-substantive modifications to the language of the Policy, if during the OAL approval process, OAL determines that such changes are needed for clarity or consistency, and inform the State Water Board of any changes.

CERTIFICATION

The undersigned Clerk to the Board does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on October 16, 2012.

AYE:	Chairman Charles R. Hoppin
	Vice Chair Frances Spivy-Weber
	Board Member Tam M. Doduc
	Board Member Steven Moore
	Board Member Felicia Marcus
NAY:	None
ABSENT:	None
ABSTAIN:	None

Jeanine Townsend

Jeanine Townsend
Clerk to the Board

CALIFORNIA OCEAN PLAN

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CALIFORNIA OCEAN PLAN

WATER QUALITY CONTROL PLAN FOR OCEAN WATERS OF CALIFORNIA

INTRODUCTION

A. Purpose and Authority

1. In furtherance of legislative policy set forth in Ssection 13000 of Division 7 of the California Water Code (CWC) (Stats. 1969, Chap. 482) pursuant to the authority contained in Ssection 13170 and 13170.2 (Stats. 1971, Chap. 1288) the State Water Resources Control Board (State Water Board) hereby finds and declares that protection of the quality of the ocean* waters* for use and enjoyment by the people of the State requires control of the discharge of waste* to ocean* waters and control of the intake of seawater* in accordance with the provisions contained herein. The Board finds further that this plan shall be reviewed at least every three years to guarantee that the current standards are adequate and are not allowing degradation* to marine species or posing a threat to public health.

B. Principles

1. Harmony Among Water Quality Control Plans and Policies.

   a. In the adoption and amendment of water quality control plans, it is the intent of this Board that each plan will provide for the attainment and maintenance of the water quality standards of downstream waters.*

   b. To the extent there is a conflict between a provision of this plan and a provision of another statewide plan or policy, or a regional water quality control plan (basin plan), the more stringent provision shall apply except where pursuant to chapter III.J of this Plan, the State Water Board has approved an exception to the Plan requirements; and except in chapter III.L, in which the provisions of this plan shall govern.

C. Applicability

1. This plan is applicable, in its entirety, to point source discharges to the ocean*.* Nonpoint sources of waste* discharges to the ocean* are subject to Chapter I Beneficial Uses, Chapter II - WATER QUALITY OBJECTIVES (wherein compliance with water quality objectives shall, in all cases, be determined by direct measurements in the receiving waters*) and Chapter III - PROGRAM OF IMPLEMENTATION Parts A.2, D, E, and I.

2. This plan is not applicable to discharges to enclosed* bays and estuaries* or inland waters or the control of dredged* material.*

* See Appendix I for definition of terms.

3. Provisions regulating the thermal aspects of waste* discharged to the ocean* are set forth in the Water Quality Control Plan for the Control of Temperature in the Coastal and Interstate Waters and Enclosed* Bays and Estuaries* of California.

4. Provisions regulating the intake of seawater* for desalination facilities* are established pursuant to the authority contained in section 13142.5, subdivision (b) of the California Water Code (Stats. 1976, Chap. 1330).

5. Within this Plan, references to the State Board or State Water Board shall mean the State Water Resources Control Board. References to a Regional Board or Regional Water Board shall mean a California Regional Water Quality Control Board. References to the Environmental Protection Agency, USEPA, or EPA shall mean the federal Environmental Protection Agency.

* See Appendix I for definition of terms.

I. BENEFICIAL USES

A. The beneficial uses of the ocean* waters of the State that shall be protected include industrial water supply; water contact and non-contact recreation, including aesthetic enjoyment; navigation; commercial and sport fishing; mariculture*; preservation and enhancement of designated Areas* of Special Biological Significance (ASBS); rare and endangered species; marine habitat; fish migration; fish spawning and shellfish* harvesting.

* See Appendix I for definition of terms.

II. WATER QUALITY OBJECTIVES

A. General Provisions

1. This chapter sets forth limits or levels of water quality characteristics for ocean* waters to ensure the reasonable protection of beneficial uses and the prevention of nuisance. The discharge of waste* shall not cause violation of these objectives.

2. The Water Quality Objectives and Effluent Limitations are defined by a statistical distribution when appropriate. This method recognizes the normally occurring variations in treatment efficiency and sampling and analytical techniques and does not condone poor operating practices.

3. Compliance with the water quality objectives of this chapter shall be determined from samples collected at stations representative of the area within the waste* field where initial* dilution is completed.

B. Bacterial Characteristics

1. Water-Contact Standards

Both the State Water Board and the California Department of Public Health (CDPH) have established standards to protect water contact recreation in coastal waters from bacterial contamination. Subsection a of this section contains bacterial objectives adopted by the State Water Board for ocean waters* used for water contact recreation. Subsection b describes the bacteriological standards adopted by CDPH for coastal waters adjacent to public beaches and public water contact sports areas in ocean waters.

a. State Water Board Water-Contact Standards

(1) Within a zone bounded by the shoreline and a distance of 1,000 feet from the shoreline or the 30-foot depth contour, whichever is further from the shoreline, and in areas outside this zone used for water contact sports, as determined by the Regional Board (i.e., waters designated as REC-1), but including all kelp* beds,* the following bacterial objectives shall be maintained throughout the water column:

30-day Geometric Mean – The following standards are based on the geometric mean of the five most recent samples from each site:

i. Total coliform density shall not exceed 1,000 per 100 mL;
ii. Fecal coliform density shall not exceed 200 per 100 mL; and
iii. Enterococcus density shall not exceed 35 per 100 mL.

Single Sample Maximum:

i. Total coliform density shall not exceed 10,000 per 100 mL;
ii. Fecal coliform density shall not exceed 400 per 100 mL;
iii. Enterococcus density shall not exceed 104 per 100 mL; and

* See Appendix I for definition of terms.

iv. Total coliform density shall not exceed 1,000 per 100 mL when the fecal coliform/total coliform ratio exceeds 0.1.

(2) The "Initial* Dilution* Zone" of wastewater outfalls shall be excluded from designation as "kelp* beds*" for purposes of bacterial standards, and Regional Boards should recommend extension of such exclusion zone where warranted to the State Water Board (for consideration under Cchapter III.J.). Adventitious assemblages of kelp plants on waste discharge structures (e.g., outfall pipes and multiport diffusers*) do not constitute kelp* beds* for purposes of bacterial standards.

b. CDPH Standards

CDPH has established minimum protective bacteriological standards for coastal waters adjacent to public beaches and for public water-contact sports areas in ocean waters.* These standards are found in the California Code of Regulations, title 17, section 7958, and they are identical to the objectives contained in subsection a. above. When a public beach or public water-contact sports area fails to meet these standards, CDPH or the local public health officer may post with warning signs or otherwise restrict use of the public beach or public water-contact sports area until the standards are met. The CDPH regulations impose more frequent monitoring and more stringent posting and closure requirements on certain high-use public beaches that are located adjacent to a storm drain that flows in the summer.

For beaches not covered under AB 411 regulations, CDPH imposes the same standards as contained in Title 17 and requires weekly sampling but allows the county health officer more discretion in making posting and closure decisions.

2. Shellfish* Harvesting Standards

a. At all areas where shellfish* may be harvested for human consumption, as determined by the Regional Board, the following bacterial objectives shall be maintained throughout the water column:

(1) The median total coliform density shall not exceed 70 per 100 mL, and not more than 10 percent of the samples shall exceed 230 per 100 mL.

C. Physical Characteristics

1. Floating particulates and grease and oil shall not be visible.

2. The discharge of waste* shall not cause aesthetically undesirable discoloration of the ocean* surface.

3. Natural* light* shall not be significantly* reduced at any point outside the initial* dilution zone as the result of the discharge of waste*.*

* See Appendix I for definition of terms.

4. The rate of deposition of inert solids and the characteristics of inert solids in ocean* sediments shall not be changed such that benthic communities are degraded*.*

D. Chemical Characteristics

1. The dissolved oxygen concentration shall not at any time be depressed more than 10 percent from that which occurs naturally, as the result of the discharge of oxygen demanding waste* materials.*

2. The pH shall not be changed at any time more than 0.2 units from that which occurs naturally.

3. The dissolved sulfide concentration of waters in and near sediments shall not be significantly* increased above that present under natural conditions.

4. The concentration of substances set forth in Cchapter II, Table 1, in marine sediments shall not be increased to levels which would degrade* indigenous biota.

5. The concentration of organic materials* in marine sediments shall not be increased to levels that would degrade* marine life.

6. Nutrient materials* shall not cause objectionable aquatic growths or degrade* indigenous biota.

7. Numerical Water Quality Objectives

   a. Table 1 water quality objectives apply to all discharges within the jurisdiction of this Plan. Unless otherwise specified, all metal concentrations are expressed as total recoverable concentrations.

   b. Table 1 Water Quality Objectives

* See Appendix I for definition of terms.

TABLE 1 (formerly TABLE B)
WATER QUALITY OBJECTIVES

	Units of Measurement	Limiting Concentrations: 6-Month Median	Limiting Concentrations: Daily Maximum	Limiting Concentrations: Instantaneous Maximum
OBJECTIVES FOR PROTECTION OF MARINE AQUATIC LIFE				
Arsenic	µg/L	8.	32.	80.
Cadmium	µg/L	1.	4.	10.
Chromium (Hexavalent) (see below, a)	µg/L	2.	8.	20.
Copper	µg/L	3.	12.	30.
Lead	µg/L	2.	8.	20.
Mercury	µg/L	0.04	0.16	0.4
Nickel	µg/L	5.	20.	50.
Selenium	µg/L	15.	60.	150.
Silver	µg/L	0.7	2.8	7.
Zinc	µg/L	20.	80.	200.
Cyanide (see below, b)	µg/L	1.	4.	10.
Total Chlorine Residual (For intermittent chlorine sources see below, c)	µg/L	2.	8.	60.
Ammonia (expressed as nitrogen)	µg/L	600.	2400.	6000.
Acute* Toxicity*	TUa	N/A	0.3	N/A
Chronic* Toxicity*	TUc	N/A	1.	N/A
Phenolic Compounds (non-chlorinated)	µg/L	30.	120.	300.
Chlorinated Phenolics	µg/L	1.	4.	10.
Endosulfan*	µg/L	0.009	0.018	0.027
Endrin	µg/L	0.002	0.004	0.006
HCH*	µg/L	0.004	0.008	0.012
Radioactivity	Not to exceed limits specified in Title 17, Division 1, Chapter 5, Subchapter 4, Group 3, Article 3, ~~S~~section 30253 of the California Code of Regulations. Reference to ~~S~~section 30253 is prospective, including future changes to any incorporated provisions of federal law, as the changes take effect.			

* See Appendix I for definition of terms.

TABLE 1 (formerly TABLE B) Continued

Chemical	30-day Average (µg/L)	
	Decimal Notation	Scientific Notation
OBJECTIVES FOR PROTECTION OF HUMAN HEALTH – NONCARCINOGENS		
acrolein	220.	2.2×10^{2}
antimony	1,200.	1.2×10^{3}
bis(2-chloroethoxy) methane	4.4	4.4×10^{0}
bis(2-chloroisopropyl) ether	1,200.	1.2×10^{3}
chlorobenzene	570.	5.7×10^{2}
chromium (III)	190,000.	1.9×10^{5}
di-n-butyl phthalate	3,500.	3.5×10^{3}
dichlorobenzenes*	5,100.	5.1×10^{3}
diethyl phthalate	33,000.	3.3×10^{4}
dimethyl phthalate	820,000.	8.2×10^{5}
4,6-dinitro-2-methylphenol	220.	2.2×10^{2}
2,4-dinitrophenol	4.0	4.0×10^{0}
ethylbenzene	4,100.	4.1×10^{3}
fluoranthene	15.	1.5×10^{1}
hexachlorocyclopentadiene	58.	5.8×10^{1}
nitrobenzene	4.9	4.9×10^{0}
thallium	2.	$2. \times 10^{0}$
toluene	85,000.	8.5×10^{4}
tributyltin	0.0014	1.4×10^{-3}
1,1,1-trichloroethane	540,000.	5.4×10^{5}
OBJECTIVES FOR PROTECTION OF HUMAN HEALTH – CARCINOGENS		
acrylonitrile	0.10	1.0×10^{-1}
aldrin	0.000022	2.2×10^{-5}
benzene	5.9	5.9×10^{0}
benzidine	0.000069	6.9×10^{-5}
beryllium	0.033	3.3×10^{-2}
bis(2-chloroethyl) ether	0.045	4.5×10^{-2}
bis(2-ethylhexyl) phthalate	3.5	3.5×10^{0}
carbon tetrachloride	0.90	9.0×10^{-1}
chlordane*	0.000023	2.3×10^{-5}
chlorodibromomethane	8.6	8.6×10^{0}

* See Appendix I for definition of terms.

TABLE 1 (formerly TABLE B) Continued

	30-day Average (µg/L)	
Chemical	Decimal Notation	Scientific Notation
OBJECTIVES FOR PROTECTION OF HUMAN HEALTH – CARCINOGENS		
chloroform	130.	1.3×10^{2}
DDT*	0.00017	1.7×10^{-4}
1,4-dichlorobenzene	18.	1.8×10^{1}
3,3'-dichlorobenzidine	0.0081	8.1×10^{-3}
1,2-dichloroethane	28.	2.8×10^{1}
1,1-dichloroethylene	0.9	9×10^{-1}
dichlorobromomethane	6.2	6.2×10^{0}
dichloromethane	450.	4.5×10^{2}
1,3-dichloropropene	8.9	8.9×10^{0}
dieldrin	0.00004	4.0×10^{-5}
2,4-dinitrotoluene	2.6	2.6×10^{0}
1,2-diphenylhydrazine	0.16	1.6×10^{-1}
halomethanes*	130.	1.3×10^{2}
heptachlor	0.00005	5×10^{-5}
heptachlor epoxide	0.00002	2×10^{-5}
hexachlorobenzene	0.00021	2.1×10^{-4}
hexachlorobutadiene	14.	1.4×10^{1}
hexachloroethane	2.5	2.5×10^{0}
isophorone	730.	7.3×10^{2}
N-nitrosodimethylamine	7.3	7.3×10^{0}
N-nitrosodi-N-propylamine	0.38	3.8×10^{-1}
N-nitrosodiphenylamine	2.5	2.5×10^{0}
PAHs*	0.0088	8.8×10^{-3}
PCBs*	0.000019	1.9×10^{-5}
TCDD equivalents*	0.0000000039	3.9×10^{-9}
1,1,2,2-tetrachloroethane	2.3	2.3×10^{0}
tetrachloroethylene	2.0	2.0×10^{0}
toxaphene	0.00021	2.1×10^{-4}
trichloroethylene	27.	2.7×10^{1}
1,1,2-trichloroethane	9.4	9.4×10^{0}
2,4,6-trichlorophenol	0.29	2.9×10^{-1}
vinyl chloride	36.	3.6×10^{1}

* See Appendix I for definition of terms.

Table 1 Notes:

a) Dischargers may at their option meet this objective as a total chromium objective.

b) If a discharger can demonstrate to the satisfaction of the Regional Water Board (subject to EPA approval) that an analytical method is available to reliably distinguish between strongly and weakly complexed cyanide, effluent limitations for cyanide may be met by the combined measurement of free cyanide, simple alkali metal cyanides, and weakly complexed organometallic cyanide complexes. In order for the analytical method to be acceptable, the recovery of free cyanide from metal complexes must be comparable to that achieved by the approved method in 40 CFR PART 136, as revised May 14, 1999.

c) Water quality objectives for total chlorine residual applying to intermittent discharges not exceeding two hours, shall be determined through the use of the following equation:

$$\log y = -0.43 (\log x) + 1.8$$

where: y = the water quality objective (in µg/L) to apply when chlorine is being discharged;
x = the duration of uninterrupted chlorine discharge in minutes.

E. Biological Characteristics

1. Marine communities, including vertebrate, invertebrate, algae, and plant species, shall not be degraded*.*

2. The natural taste, odor, and color of fish, shellfish,*, or other marine resources used for human consumption shall not be altered.

3. The concentration of organic materials* in fish, shellfish* or other marine resources used for human consumption shall not bioaccumulate to levels that are harmful to human health.

F. Radioactivity

1. Discharge of radioactive waste* shall not degrade* marine life.

* See Appendix I for definition of terms.

III. PROGRAM OF IMPLEMENTATION

A. General Provisions

1. Effective Date

a. The *Water Quality Control Plan, Ocean Waters of California, California Ocean Plan* was adopted and has been effective since 1972. There have been multiple amendments of the Ocean Plan since its adoption.

2. General Requirements For Management Of Waste Discharge To The Ocean*

a. Waste* management systems that discharge to the ocean* must be designed and operated in a manner that will maintain the indigenous marine life and a healthy and diverse marine community.

b. Waste* discharged* to the ocean* must be essentially free of:

(1) Material* that is floatable or will become floatable upon discharge.

(2) Settleable material* or substances that may form sediments which will degrade* benthic communities or other aquatic life.

(3) Substances which will accumulate to toxic levels in marine waters, sediments or biota.

(4) Substances that significantly* decrease the natural* light* to benthic communities and other marine life.

(5) Materials* that result in aesthetically undesirable discoloration of the ocean* surface.

c. Waste* effluents shall be discharged in a manner which provides sufficient initial* dilution to minimize the concentrations of substances not removed in the treatment.

d. Location of waste* discharges must be determined after a detailed assessment of the oceanographic characteristics and current patterns to assure that:

(1) Pathogenic organisms and viruses are not present in areas where shellfish* are harvested for human consumption or in areas used for swimming or other body-contact sports.

(2) Natural water quality conditions are not altered in areas designated as being of special biological significance or areas that existing marine laboratories use as a source of seawater.*

(3) Maximum protection is provided to the marine environment.

* See Appendix I for definition of terms.

e. Waste* that contains pathogenic organisms or viruses should be discharged a sufficient distance from shellfishing* and water-contact sports areas to maintain applicable bacterial standards without disinfection. Where conditions are such that an adequate distance cannot be attained, reliable disinfection in conjunction with a reasonable separation of the discharge point from the area of use must be provided. Disinfection procedures that do not increase effluent toxicity and that constitute the least environmental and human hazard should be used.

3. Areas of Special Biological Significance*

a. ASBS* shall be designated by the State Water Board following the procedures provided in Appendix IV. A list of ASBS* is available in Appendix V.

4. Combined Sewer Overflow: Not withstanding any other provisions in this plan, discharges from the City of San Francisco's combined sewer system are subject to the US EPA's Combined Sewer Overflow Policy.

B. Table 2 Effluent Limitations

TABLE 2 (formerly TABLE A)
EFFLUENT LIMITATIONS

		Limiting Concentrations		
	Unit of Measurement	Monthly (30-day Average)	Weekly (7-day Average)	Maximum at any time
Grease and Oil	mg/L	25.	40.	75.
Suspended Solids			See below +	
Settleable Solids	mL/L	1.0	1.5	3.0
Turbidity	NTU	75.	100.	225.
pH	Units		Within limit of 6.0 to 9.0 at all times	

Table 2 Notes:

\+ Suspended Solids: Dischargers shall, as a 30-day average, remove 75% of suspended solids from the influent stream before discharging wastewaters to the ocean.*~~,~~ except that the effluent limitation to be met shall not be lower than 60 mg/l. Regional Boards may recommend that the State Water Board (~~C~~chapter III~~.~~ section J), with the concurrence of the Environmental Protection Agency, adjust the lower effluent concentration limit (the 60 mg/l above) to suit the environmental and effluent characteristics of the discharge. As a further consideration in making such recommendation for adjustment, Regional Water Boards should evaluate effects on existing and potential water* reclamation projects.

If the lower effluent concentration limit is adjusted, the discharger shall remove 75% of suspended solids from the influent stream at any time the influent concentration exceeds four times such adjusted effluent limit.

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1. Table 2 effluent limitations apply only to publicly owned treatment works and industrial discharges for which Effluent Limitations Guidelines have not been established pursuant to ~~S~~sections 301, 302, 304, or 306 of the Federal Clean Water Act.

* See Appendix I for definition of terms.

2. Table 2 effluent limitations shall apply to a discharger's total effluent, of whatever origin (i.e., gross, not net, discharge), except where otherwise specified in this Plan.
3. The State Water Board is authorized to administer and enforce effluent limitations established pursuant to the Federal Clean Water Act. Effluent limitations established under Ssections 301, 302, 306, 307, 316, 403, and 405 of the aforementioned Federal Act and administrative procedures pertaining thereto are included in this plan by reference. Compliance with Table 2 effluent limitations, or Environmental Protection Agency Effluent Limitations Guidelines for industrial discharges, based on Best Practicable Control Technology, shall be the minimum level* of treatment acceptable under this plan, and shall define reasonable treatment and waste* control technology.

C. Implementation Provisions for Table 1

1. Effluent concentrations calculated from Table 1 water quality objectives shall apply to a discharger's total effluent, of whatever origin (i.e., gross, not net, discharge), except where otherwise specified in this Plan.
2. If the Regional Water Board determines, using the procedures in Appendix VI, that a pollutant is discharged into ocean* waters at levels which will cause, have the reasonable potential to cause, or contribute to an excursion above a Table 1 water quality objective, the Regional Water Board shall incorporate a water quality-based effluent limitation in the Waste Discharge Requirement for the discharge of that pollutant.
3. Effluent limitations shall be imposed in a manner prescribed by the State Water Board such that the concentrations set forth below as water quality objectives shall not be exceeded in the receiving water* upon completion of initial* dilution, except that objectives indicated for radioactivity shall apply directly to the undiluted waste* effluent.
4. Calculation of Effluent Limitations

   a. Effluent limitations for water quality objectives listed in Table 1, with the exception of acute* toxicity and radioactivity shall be determined through the use of the following equation:

   Equation 1: $Ce = Co + Dm\ (Co - Cs)$

   where:

   Ce = the effluent concentration limit, µg/L

   Co = the concentration (water quality objective) to be met at the completion of initial* dilution, µg/L

   Cs = background seawater* concentration (see Table 3 below, with all metals expressed as total recoverable concentrations), µg/L

   Dm = minimum probable initial* dilution expressed as parts seawater* per part wastewater.

* See Appendix I for definition of terms.

TABLE 3 (formerly TABLE C) BACKGROUND SEAWATER* CONCENTRATIONS (Cs)	
Waste Constituent	Cs (µg/L)
Arsenic	3.
Copper	2.
Mercury	0.0005
Silver	0.16
Zinc	8.
For all other Table 1 parameters, Cs = 0.	

b. Determining a Mixing Zone for the Acute* Toxicity* Objective

The mixing zone for the acute* toxicity* objective shall be ten percent (10%) of the distance from the edge of the outfall structure to the edge of the chronic mixing zone (zone of initial dilution*). There is no vertical limitation on this zone. The effluent limitation for the acute* toxicity* objective listed in Table 1 shall be determined through the use of the following equation:

Equation 2: $Ce = Ca + (0.1)\ Dm\ (Ca)$

where:

Ca = the concentration (water quality objective) to be met at the edge of the acute mixing zone.

Dm = minimum probable initial* dilution expressed as parts seawater* per part wastewater (This equation applies only when Dm > 24).

c. Toxicity Testing Requirements based on the Minimum Initial* Dilution Factor for Ocean Waste* Discharges

(1) Dischargers shall conduct acute* toxicity* testing if the minimum initial* dilution of the effluent is greater than 1,000:1 at the edge of the mixing zone.

(2) Dischargers shall conduct either acute* or chronic* toxicity* testing if the minimum initial* dilution ranges from 350:1 to 1,000:1 depending on the specific discharge conditions. The Regional Water Board shall make this determination.

(3) Dischargers shall conduct chronic* toxicity* testing for ocean waste* discharges with minimum initial* dilution factors ranging from 100:1 to 350:1. The Regional Water Board may require that acute toxicity* testing be conducted in addition to chronic as necessary for the protection of beneficial uses of ocean waters.*

(4) Dischargers shall conduct chronic toxicity* testing if the minimum initial* dilution of the effluent falls below 100:1 at the edge of the mixing zone.

* See Appendix I for definition of terms.

d. For the purpose of this Plan, minimum initial* dilution is the lowest average initial* dilution within any single month of the year. Dilution estimates shall be based on observed waste* flow characteristics, observed receiving water* density structure, and the assumption that no currents, of sufficient strength to influence the initial* dilution process, flow across the discharge structure.

e. The Executive Director of the State Water Board shall identify standard dilution models for use in determining Dm, and shall assist the Regional Board in evaluating Dm for specific waste* discharges. Dischargers may propose alternative methods of calculating Dm, and the Regional Board may accept such methods upon verification of its accuracy and applicability.

f. The six-month median shall apply as a moving median of daily values for any 180-day period in which daily values represent flow weighted average concentrations within a 24-hour period. For intermittent discharges, the daily value shall be considered to equal zero for days on which no discharge occurred.

g. The daily maximum shall apply to flow weighted 24 hour composite samples.

h. The instantaneous maximum shall apply to grab sample determinations.

i. If only one sample is collected during the time period associated with the water quality objective (e.g., 30-day average or 6-month median), the single measurement shall be used to determine compliance with the effluent limitation for the entire time period.

j. Discharge requirements shall also specify effluent limitations in terms of mass emission rate limits utilizing the general formula:

Equation 3: lbs/day = 0.00834 x Ce x Q

where:

Ce = the effluent concentration limit, µg/L

Q = flow rate, million gallons per day (MGD)

k. The six-month median limit on daily mass emissions shall be determined using the six-month median effluent concentration as Ce and the observed flow rate Q in millions of gallons per day. The daily maximum mass emission shall be determined using the daily maximum effluent concentration limit as Ce and the observed flow rate Q in millions of gallons per day.

l. Any significant* change in waste* flow shall be cause for reevaluating effluent limitations.

5. Minimum* Levels

For each numeric effluent limitation, the Regional Board must select one or more Minimum* Levels (and their associated analytical methods) for inclusion in the permit.

* See Appendix I for definition of terms.

The “reported” Minimum* Level is the Minimum* Level (and its associated analytical method) chosen by the discharger for reporting and compliance determination from the Minimum* Levels included in their permit.

a. Selection of Minimum* Levels from Appendix II

The Regional Water Board must select all Minimum* Levels from Appendix II that are below the effluent limitation. If the effluent limitation is lower than all the Minimum* Levels in Appendix II, the Regional Board must select the lowest Minimum* Level from Appendix II.

b. Deviations from Minimum* Levels in Appendix II

The Regional Board, in consultation with the State Water Board’s Quality Assurance Program, must establish a Minimum* Level to be included in the permit in any of the following situations:

1. A pollutant is not listed in Appendix II.
2. The discharger agrees to use a test method that is more sensitive than those described in 40 CFR 136 (revised May 14, 1999).
3. The discharger agrees to use a Minimum* Level lower than those listed in Appendix II.
4. The discharger demonstrates that their calibration standard matrix is sufficiently different from that used to establish the Minimum* Level in Appendix II and proposes an appropriate Minimum* Level for their matrix.
5. A discharger uses an analytical method having a quantification practice that is not consistent with the definition of Minimum* Level (e.g., US EPA methods 1613, 1624, 1625).

6. Use of Minimum* Levels

a. Minimum* Levels in Appendix II represent the lowest quantifiable concentration in a sample based on the proper application of method-specific analytical procedures and the absence of matrix interferences. Minimum* Levels also represent the lowest standard concentration in the calibration curve for a specific analytical technique after the application of appropriate method-specific factors.

Common analytical practices may require different treatment of the sample relative to the calibration standard. Some examples are given below:

Substance or Grouping	Method-Specific Treatment	Most Common Factor
Volatile Organics	No differential treatment	1
Semi-Volatile Organics	Samples concentrated by extraction	1000
Metals	Samples diluted or concentrated	½ , 2 , and 4
Pesticides	Samples concentrated by extraction	100

b. Other factors may be applied to the Minimum* Level depending on the specific sample preparation steps employed. For example, the treatment typically applied when there are matrix effects is to dilute the sample or sample aliquot by a factor of ten. In such cases, this additional factor must be applied during the

* See Appendix I for definition of terms.

computation of the reporting limit. Application of such factors will alter the reported Minimum* Level.

c. Dischargers are to instruct their laboratories to establish calibration standards so that the Minimum* Level (or its equivalent if there is differential treatment of samples relative to calibration standards) is the lowest calibration standard. At no time is the discharger to use analytical data derived from *extrapolation* beyond the lowest point of the calibration curve. In accordance with ~~S~~section 4b, above, the discharger's laboratory may employ a calibration standard lower than the Minimum* Level in Appendix II.

7. Sample Reporting Protocols

a. Dischargers must report with each sample result the reported Minimum* Level (selected in accordance with ~~S~~section 4, above) and the laboratory's current MDL~~*~~.*

b. Dischargers must also report the results of analytical determinations for the presence of chemical constituents in a sample using the following reporting protocols:

(1) Sample results greater than or equal to the reported Minimum* Level must be reported "as measured" by the laboratory (i.e., the measured chemical concentration in the sample).

(2) Sample results less than the reported Minimum* Level, but greater than or equal to the laboratory's MDL~~,~~*~~,~~ must be reported as "Detected, but Not Quantified", or DNQ. The laboratory must write the estimated chemical concentration of the sample next to DNQ as well as the words "Estimated Concentration" (may be shortened to "Est. Conc.").

(3) Sample results less than the laboratory's MDL* must be reported as "Not Detected", or ND.

8. Compliance Determination

Sufficient sampling and analysis shall be required to determine compliance with the effluent limitation.

a. Compliance with Single-Constituent Effluent Limitations

Dischargers are out of compliance with the effluent limitation if the concentration of the pollutant (see ~~S~~section 7c, below) in the monitoring sample is greater than the effluent limitation and greater than or equal to the reported Minimum* Level.

b. Compliance with Effluent Limitations expressed as a Sum of Several Constituents

Dischargers are out of compliance with an effluent limitation which applies to the sum of a group of chemicals (e.g., PCB~~'~~s*) if the sum of the individual pollutant concentrations is greater than the effluent limitation. Individual pollutants of the group will be considered to have a concentration of zero if the constituent is reported as ND or DNQ.

c. Multiple Sample Data Reduction

* See Appendix I for definition of terms.

The concentration of the pollutant in the effluent may be estimated from the result of a single sample analysis or by a measure of central tendency (arithmetic mean, geometric mean, median, etc.) of multiple sample analyses when all sample results are quantifiable (i.e., greater than or equal to the reported Minimum* Level). When one or more sample results are reported as ND or DNQ, the central tendency concentration of the pollutant shall be the median (middle) value of the multiple samples. If, in an even number of samples, one or both of the middle values is ND or DNQ, the median will be the lower of the two middle values.

d. Powerplants and Heat Exchange Dischargers

Due to the large total volume of powerplant and other heat exchange discharges, special procedures must be applied for determining compliance with Table 1 objectives on a routine basis. Effluent concentration values (Ce) shall be determined through the use of equation 1 considering the minimal probable initial* dilution of the combined effluent (in-plant waste* streams plus cooling water flow). These concentration values shall then be converted to mass emission limitations as indicated in equation 3. The mass emission limits will then serve as requirements applied to all in-plant waste* streams taken together which discharge into the cooling water flow, except that limits for total chlorine residual, acute* (if applicable per ~~S~~section (3)(c)) and chronic* toxicity* and instantaneous maximum concentrations in Table 1 shall apply to, and be measured in, the combined final effluent, as adjusted for dilution with ocean water. The Table 1 objective for radioactivity shall apply to the undiluted combined final effluent.

9. Pollutant Minimization Program

a. Pollutant Minimization Program Goal

The goal of the Pollutant Minimization Program is to reduce all potential sources of a pollutant through pollutant minimization (control) strategies, including pollution prevention measures, in order to maintain the effluent concentration at or below the effluent limitation.

Pollution prevention measures may be particularly appropriate for persistent bioaccumulative priority pollutants where there is evidence that beneficial uses are being impacted. The completion and implementation of a Pollution Prevention Plan, required in accordance with CA Water Code ~~S~~section 13263.3 (d) will fulfill the Pollution Minimization Program requirements in this section.

b. Determining the need for a Pollutant Minimization Program

1. The discharger must develop and conduct a Pollutant Minimization Program if all of the following conditions are true:

(a) The calculated effluent limitation is less than the reported Minimum~~*~~ Level*

(b) The concentration of the pollutant is reported as DNQ

* See Appendix I for definition of terms.

(c) There is evidence showing that the pollutant is present in the effluent above the calculated effluent limitation.

2. Alternatively, the discharger must develop and conduct a Pollutant Minimization Program if all of the following conditions are true:

   (a) The calculated effluent limitation is less than the Method Detection Limit*.*

   (b) The concentration of the pollutant is reported as ND.

   (c) There is evidence showing that the pollutant is present in the effluent above the calculated effluent limitation.

c. Regional Water Boards may include special provisions in the discharge requirements to require the gathering of evidence to determine whether the pollutant is present in the effluent at levels above the calculated effluent limitation. Examples of evidence may include:

   1. health advisories for fish consumption,
   2. presence of whole effluent toxicity,
   3. results of benthic or aquatic organism tissue sampling,
   4. sample results from analytical methods more sensitive than methods included in the permit (in accordance with Ssection 4b, above).
   5. the concentration of the pollutant is reported as DNQ and the effluent limitation is less than the MDL*

d. Elements of a Pollutant Minimization Program

   The Regional Board may consider cost-effectiveness when establishing the requirements of a Pollutant Minimization Program. The program shall include actions and submittals acceptable to the Regional Board including, but not limited to, the following:

   1. An annual review and semi-annual monitoring of potential sources of the reportable pollutant, which may include fish tissue monitoring and other bio-uptake sampling;
   2. Quarterly monitoring for the reportable pollutant in the influent to the wastewater treatment system;
   3. Submittal of a control strategy designed to proceed toward the goal of maintaining concentrations of the reportable pollutant in the effluent at or below the calculated effluent limitation;
   4. Implementation of appropriate cost-effective control measures for the pollutant, consistent with the control strategy; and,
   5. An annual status report that shall be sent to the Regional Board including:

      (a) All Pollutant Minimization Program monitoring results for the previous year;

      (b) A list of potential sources of the reportable pollutant;

* See Appendix I for definition of terms.

(c) A summary of all action taken in accordance with the control strategy; and,

(d) A description of actions to be taken in the following year.

10. Toxicity Reduction Requirements

a. If a discharge consistently exceeds an effluent limitation based on a toxicity objective in Table 1, a toxicity reduction evaluation (TRE) is required. The TRE shall include all reasonable steps to identify the source of toxicity. Once the source(s) of toxicity is identified, the discharger shall take all reasonable steps necessary to reduce toxicity to the required level.

b. The following shall be incorporated into waste* discharge requirements: (1) a requirement to conduct a TRE if the discharge consistently exceeds its toxicity effluent limitation, and (2) a provision requiring a discharger to take all reasonable steps to reduce toxicity once the source of toxicity is identified.

D. Implementation Provisions for Bacterial Characteristics

1. Water-Contact Monitoring

a. Weekly samples shall be collected from each site. The geometric mean shall be calculated using the five most recent sample results.

b. If a single sample exceeds any of the single sample maximum (*SSM*) standards, repeat sampling at that location shall be conducted to determine the extent and persistence of the exceedance. Repeat sampling shall be conducted within 24 hours of receiving analytical results and continued until the sample result is less than the SSM standard or until a sanitary survey is conducted to determine the source of the high bacterial densities.

i) Total coliform density will not exceed 10,000 per 100 mL; or
ii) Fecal coliform density will not exceed 400 per 100 mL; or
iii) Total coliform density will not exceed 1,000 per 100 mL when the ratio of fecal/total coliform exceeds 0.1;
iv) enterococcus density will not exceed 104 per 100 mL.

When repeat sampling is required because of an exceedance of any one single sample density, values from all samples collected during that 30-day period will be used to calculate the geometric mean.

c. It is state policy that the geometric mean bacterial objectives are strongly preferred for use in water body assessment decisions, for example, in developing the Clean Water Act section 303(d) list of impaired waters, because the geometric mean objectives are a more reliable measure of long-term water body conditions. In making assessment decisions on bacterial quality, single sample maximum data must be considered together with any available geometric mean data. The use of only single sample maximum bacterial data is generally inappropriate unless there is a limited data set, the water is subject to short-term spikes in bacterial

* See Appendix I for definition of terms.

concentrations, or other circumstances justify the use of only single sample maximum data.

d. For monitoring stations outside of the defined water-contact recreation zone (REC-1), samples will be analyzed for total coliform only.

E. Implementation Provisions for Marine Managed Areas*

1. Section E addresses the following Marine Managed Areas*:

(a) State Water Quality Protection Areas (SWQPAs)* consisting of:

(1) SWQPA – Areas of Special Biological Significance (ASBS)* designated by the State Water Board that require special protections as defined under section 4 below.

(2) SWQPA – General Protection (GP) designated by the State Water Board to protect water quality within Marine Protected Areas (MPAs) that require protection under the provisions described under section 5 below.

(b) Marine Protected Areas as defined in the California Public Resources Code as State Marine Reserves, State Marine Parks and State Marine Conservation Areas, established by the Fish and Game Commission, or the Parks and Recreation Commission.

2. The designation of State Marine Parks and State Marine Conservation Areas may not serve as the sole basis for new or modified limitations, substantive conditions, or prohibitions upon existing municipal point source wastewater discharge outfalls. This provision does not apply to State Marine Reserves.

3. The State Water Board may designate SWQPAs* to prevent the undesirable alteration of natural water quality within MPAs. These designations may include either SWQPA-ASBS or SWQPA-GP or in combination. In considering the designation of SWQPAs over MPAs, the State Water Board will consult with the affected Regional Water Quality Control Board, the Department of Fish and Game and the Department of Parks and Recreation, in accordance with the requirements of Appendix IV.

4. Implementation Provisions For SWQPA-ASBS*

(a) Waste* shall not be discharged to areas designated as being of special biological significance. Discharges shall be located a sufficient distance from such designated areas to assure maintenance of natural water quality conditions in these areas.

(b) Regional Water Boards may approve waste* discharge requirements or recommend certification for limited-term (i.e. weeks or months) activities in ASBS*.* Limited-term activities include, but are not limited to, activities such as maintenance/repair of existing boat facilities, restoration of sea walls, repair of existing storm water pipes, and replacement/repair of existing bridges. Limited-

* See Appendix I for definition of terms.

term activities may result in temporary and short-term changes in existing water quality. Water quality degradation shall be limited to the shortest possible time. The activities must not permanently degrade* water quality or result in water quality lower than that necessary to protect existing uses, and all practical means of minimizing such degradation shall be implemented.

5. Implementation Provisions for SWQPAs-GP*

(a) Implementation provisions for existing point source wastewater discharges (NPDES)

(1) An SWQPA-GP shall not be designated over existing permitted point source wastewater outfalls or encroach upon the zone of initial dilution* associated with an existing discharge. This requirement does not apply to discharges less than one million gallons per day.

(2) Designation of an SWQPA-GP shall not include conditions to move existing point source wastewater outfalls.

(3) Where a new SWQPA-GP is established in the vicinity of existing municipal wastewater outfalls, there shall be no new or modified limiting condition or prohibitions for the SWQPA-GP relative to those wastewater outfalls.

(4) Regulatory requirements for discharges from existing treated municipal wastewater outfalls shall be derived from the Chapter II – Water Quality Objectives and Chapter III – Program of Implementation.

(b) Implementation provisions for existing seawater* intakes

(1) Existing permitted seawater* intakes other than those serving desalination facilities* must be controlled to minimize entrainment and impingement by using best technology available. Existing permitted seawater* intakes with a capacity less than one million gallons per day are excluded from this requirement.

(2) Existing permitted seawater* intakes serving desalination facilities are governed by the provisions set forth in chapter III.L of this Plan.

(c) Implementation provisions for permitted separate storm sewer system (MS4) discharges and nonpoint source discharges.

(1) Existing waste* discharges are allowed, but shall not cause an undesirable alteration in natural water quality. For purposes of SWQPA-GP, an undesirable alteration in natural water quality means that for intermittent (e.g. wet weather) discharges, Table 1 instantaneous maximum concentrations for chemical constituents, and daily maximum concentrations for chronic toxicity,* must not be exceeded in the receiving water.*

(2) An NPDES permitting authority* may authorize NPDES-permitted non-storm water discharges* to an MS4 with a direct discharge to an SWQPA-GP only to the

* See Appendix I for definition of terms.

extent the NPDES permitting authority* finds that the discharge does not cause an undesirable alteration in natural water quality in an SWQPA-GP.

(3) Non-storm water (dry weather) flows are effectively prohibited as required by the applicable permit. Where capacity and infrastructure exists, all dry weather flows shall be diverted to municipal sanitary sewer systems. The permitting authority* may allow discharges essential for emergency response purposes, structural stability, and slope stability, which may include but are not limited to the following:

a. Discharges associated with emergency fire-fighting operations.
b. Foundation and footing drains.
c. Water from crawl space or basement pumps.
d. Hillside dewatering.

(4) The following naturally occurring discharges are allowed:

a. Naturally occurring groundwater seepage via a storm drain
b. Non-anthropogenic flows from a naturally occurring stream via a culvert or storm drain, as long as there are no contributions of anthropogenic runoff.

(5) Existing storm water discharges into an SWQPA-GP shall be characterized and assessed to determine what effect if any these inputs are having on natural water quality in the SWQPA-GP. Such assessments shall include an evaluation of cumulative impacts as well as impacts stemming from individual discharges. Information to be considered shall include:

a. Water quality;
b. Flow;
c. Watershed pollutant sources; and
d. Intertidal and/ or subtidal biological surveys.

Within each SWQPA-GP the assessment shall be used to rank these existing discharges into low, medium and high threat impact categories. Cumulative impacts will be ranked similarly as well.

(6) An initial analysis shall be performed for pre- and post-storm receiving water* quality of Table 1 constituents and chronic toxicity* If post-storm receiving water* quality has larger concentrations of constituents relative to pre-storm, and Table 1 instantaneous maximum concentrations for chemical constituents, and daily maximum concentrations for chronic toxicity,* are exceeded, then receiving water* shall be re-analyzed along with storm runoff (end of pipe) for the constituents that are exceeded.

(7) If undesirable alterations of natural water quality and/or biological communities are identified, control strategies/measures shall be implemented for those discharges characterized as a high threat or those contributing to higher threat cumulative impacts first.

* See Appendix I for definition of terms.

(8) If those strategies fail, additional control strategies/measures will be implemented for discharges characterized as medium impact discharges. If these strategies do not result in improvement of water quality, those discharges classified as low threat shall also implement control strategies/measures.

(d) Implementation Provisions for New Discharges

(1) Point Source Wastewater Outfalls
No new point source wastewater outfalls shall be established within an SWQPA-GP.

(2) Seawater* intakes
No new surface water seawater* intakes shall be established within an SWQPA-GP. This does not apply to sub-seafloor intakes where studies are prepared showing there is no predictable entrainment or impingement of marine life.

(3) All Other New Discharges
There shall be no increase in nonpoint sources or permitted storm drains directly into an SWQPA-GP.

6. Impaired Tributaries to MPAs, SWQPA-ASBS and SWQPA-GP

All water bodies draining to, or that are designated as, MPAs and SWQPAs that appear on the State's CWA ~~S~~section 303(d) list shall be given a high priority to have a TMDL developed and implemented.

F. Revision of Waste* Discharge Requirements

1. The Regional Water Boards may establish more restrictive water quality objectives and effluent limitations than those set forth in this Plan as necessary for the protection of beneficial uses of ocean* waters.

2. Regional Water Boards may impose alternative less restrictive provisions than those contained within Table 1 of the Plan, provided an applicant can demonstrate that:

   a. Reasonable control technologies (including source control, material* substitution, treatment and dispersion) will not provide for complete compliance; or

   b. Any less stringent provisions would encourage water* reclamation;

3. Provided further that:

   a. Any alternative water quality objectives shall be below the conservative estimate of chronic* toxicity,* as given in Table 4 (with all metal concentrations expressed as total recoverable concentrations), and such alternative will provide for adequate protection of the marine environment;

   b. A receiving water* quality toxicity objective of 1 TUc is not exceeded; and

   c. The State Water Board grants an exception (~~C~~chapter III.J~~.~~) to the Table 1 limits as established in the Regional Board findings and alternative limits.

* See Appendix I for definition of terms.

G. Compliance Schedules in National Pollutant Discharge Elimination System (NPDES) Permits

1. Compliance schedules in NPDES permits are authorized in accordance with the provisions of the State Water Board's Policy for Compliance Schedules in [NPDES] Permits (2008).

TABLE 4 (formerly TABLE D)
CONSERVATIVE ESTIMATES OF CHRONIC TOXICITY*

Constituent	**Estimate of Chronic Toxicity* (µg/L)**
Arsenic	19.
Cadmium	8.
Hexavalent Chromium	18.
Copper	5.
Lead	22.
Mercury	0.4
Nickel	48.
Silver	3.
Zinc	51.
Cyanide	10.
Total Chlorine Residual	10.0
Ammonia	4000.0
Phenolic Compounds (non-chlorinated)	a) (see below)
Chlorinated Phenolics	a)
Chlorinated Pesticides and PCB's*	b)

Table 4 Notes:

a) There are insufficient data for phenolics to estimate chronic toxicity* levels. Requests for modification of water quality objectives for these waste* constituents must be supported by chronic toxicity* data for representative sensitive species. In such cases, applicants seeking modification of water quality objectives should consult the Regional Water Quality Control Board to determine the species and test conditions necessary to evaluate chronic effects.

b) Limitations on chlorinated pesticides and PCB's* shall not be modified so that the total of these compounds is increased above the objectives in Table 1.

H. Monitoring Program

1. The Regional Water Boards shall require dischargers to conduct self-monitoring programs and submit reports necessary to determine compliance with the waste* discharge requirements, and may require dischargers to contract with agencies or persons acceptable to the Regional Water Board to provide monitoring reports.

* See Appendix I for definition of terms.

Monitoring provisions contained in waste* discharge requirements shall be in accordance with the Monitoring Procedures provided in Appendices III and VI.

2. The Regional Water Board may require monitoring of bioaccumulation of toxicants in the discharge zone. Organisms and techniques for such monitoring shall be chosen by the Regional Water Board on the basis of demonstrated value in waste* discharge monitoring.

I. Discharge Prohibitions

1. Hazardous Substances

a. The discharge of any radiological, chemical, or biological warfare agent or high-level radioactive waste* into the ocean* is prohibited.

2. Areas Designated for Special Water Quality Protection

a. Waste* shall not be discharged to designated Areas* of Special Biological Significance except as provided in Cchapter III.E. Implementation Provisions for Marine Managed Areas*.*

3. Sludge

a. Pipeline discharge of sludge to the ocean* is prohibited by federal law; the discharge of municipal and industrial waste* sludge directly to the ocean,*, or into a waste* stream that discharges to the ocean,*, is prohibited by this Plan. The discharge of sludge digester supernatant directly to the ocean,*, or to a waste* stream that discharges to the ocean* without further treatment, is prohibited.

b. It is the policy of the State Water Board that the treatment, use and disposal of sewage sludge shall be carried out in the manner found to have the least adverse impact on the total natural and human environment. Therefore, if federal law is amended to permit such discharge, which could affect California waters, the State Water Board may consider requests for exceptions to this section under Cchapter III.J of this Plan, provided further that an Environmental Impact Report on the proposed project shows clearly that any available alternative disposal method will have a greater adverse environmental impact than the proposed project.

4. By-Passing

a. The by-passing of untreated wastes* containing concentrations of pollutants in excess of those of Table 2 or Table 1 to the ocean* is prohibited.

5. Vessels

a. Discharges of hazardous waste (as defined in California Health and Safety Code section§ 25117 et seq. [but not including sewage]), oily bilge water,* medical waste (as defined in section§ 117600 et seq. of the California Health and Safety Code) dry-cleaning waste, and film-processing waste from large passenger vessels* and oceangoing vessels* are prohibited.

* See Appendix I for definition of terms.

b. Discharges of graywater* and sewage* from large passenger vessels* are prohibited.

c. Discharges of sewage and sewage sludge from vessels are prohibited in No Discharge Zones* promulgated by U.S. EPA.

J. State Board Exceptions to Plan Requirements

1. The State Water Board may, in compliance with the California Environmental Quality Act, subsequent to a public hearing, and with the concurrence of the Environmental Protection Agency, grant exceptions where the Board determines:

   a. The exception will not compromise protection of ocean* waters for beneficial uses, and,

   b. The public interest will be served.

2. All exceptions issued by the State Water Board and in effect at the time of the Triennial Review will be reviewed at that time. If there is sufficient cause to re-open or revoke any exception, the State Water Board may direct staff to prepare a report and to schedule a public hearing. If after the public hearing the State Water Board decides to re-open, revoke, or re-issue a particular exception, it may do so at that time.

K. Implementation Provisions for Vessel Discharges

1. Vessel discharges must comply with State Lands Commission (SLC) requirements for ballast water discharges and hull fouling to control and prevent the introduction of non-indigenous species, found in the Public Resources Code sections 71200 et seq. and title 2, California Code of Regulations, section 22700 et. seq.

2. Discharges incidental to the normal operation large passenger vessels* and ocean-going vessels must be covered and comply with an individual or general NPDES permit.

3. Vessel discharges must not result in violations of water quality objectives in this plan.

4. Vessels subject to the federal NPDES Vessel General Permit (VGP) which are not large passenger vessels* must follow the best management practices for graywater* as required in the VGP, including the use of only those cleaning agents (e.g., soaps and detergents) that are phosphate-free, non-toxic, and non-bioaccumulative.

L. Implementation Provisions for Desalination Facilities*

1. Applicability and General Provisions

   a. Chapter III.L applies to desalination facilities* using seawater.* Chapter III.L.2 does not apply to desalination facilities* operated by a federal agency. Chapter III.L.2, L.3, and L.4 do not apply to portable desalination facilities*

* See Appendix I for definition of terms.

that produce less than 0.05 MGD of desalinated water and are operated by a governmental agency. These standards do not alter or limit in any way the authority of any public agency to implement its statutory obligations. The Executive Director of the State Water Board may temporarily waive the application of chapter III.L to desalination facilities* that are operating to serve as a critical short term water supply during a state of emergency as declared by the Governor.

b. Definitions of New, Expanded, and Existing Facilities:

(1) For purposes of chapter III.L, "existing facilities" means desalination facilities* that have been issued an NPDES permit and all building permits and other governmental approvals necessary to commence construction for which the owner or operator has relied in good faith on those previously-issued permits and approvals and commenced construction of the facility beyond site grading prior to [effective date of this Plan]. Existing facilities do not include a facility for which permits and approvals were issued and construction commenced after January 1, 1977, but for which a regional water board did not make a determination of the best site, design, technology, and mitigations measures feasible, pursuant to Water Code section 13142.5, subdivision (b) (hereafter Water Code section 13142.5(b)).

(2) For purposes of chapter III.L, "expanded facilities" means existing facilities for which, after [effective date of the Plan], the owner or operator does either of the following in a manner that could increase intake or mortality of marine life: 1) increases the amount of seawater* used either exclusively by the facility or used by the facility in conjunction with other facilities or uses, or 2) changes the design or operation of the facility. To the extent that the desalination facility* is co-located with another facility that withdraws water for a different purpose and that other facility reduces the volume of water withdrawn to a level less than the desalination facility's* volume of water withdrawn, the desalination facility* is considered to be an expanded facility.

(3) For purposes of chapter III.L, "new facilities" means desalination facilities* that are not existing facilities or expanded facilities.

c. Chapter III.L.2 (Water Code §13142.5(b) Determinations for New and Expanded Facilities: Site, Design, Technology, and Mitigation Measures) applies to new and expanded desalination facilities* withdrawing seawater.*

* See Appendix I for definition of terms.

d. Chapter III.L.3 (Receiving Water Limitation for Salinity*) applies to all desalination facilities* that discharge into ocean waters.*

e. Chapter III.L.4 (Monitoring and Reporting Programs) applies to all desalination facilities* that discharge into ocean waters.*

f. References to the regional water board include the regional water board acting under delegated authority. For provisions that require consultation between regional water board and State Water Board staff, the regional water board shall notify and consult with the State Water Board staff prior to making a final determination on the item requiring consultation.

2. Water Code section 13142.5(b) Determinations for New and Expanded Facilities: Site, Design, Technology, and Mitigation Measures Feasibility Considerations

a. General Considerations

(1) The owner or operator shall submit a request for a Water Code section 13142.5(b) determination to the appropriate regional water board as early as practicable. This request shall include sufficient information for the regional water board to conduct the analyses described below. The regional water board in consultation with the State Water Board staff may require an owner or operator to provide additional studies or information if needed. Studies and models are subject to the approval of the regional water board in consultation with State Water Board staff.

(2) The regional water board shall conduct a Water Code section 13142.5(b) analysis of all new and expanded desalination facilities.* A Water Code section 13142.5(b) analysis may include future expansions at the facility. The regional water board shall first analyze separately as independent considerations a range of feasible alternatives for the best site, the best design, the best technology, and the best mitigation measures to minimize intake and mortality of marine life. Then, the regional water board shall consider all four factors collectively, and include the best combination of alternatives that in combination minimize intake and mortality of marine life. The best combination of alternatives may not always include the best alternative under each individual factor because some alternatives may be mutually exclusive, redundant, or infeasible in combination.

(3) The regional water board's 13142.5(b) analysis for expanded facilities may be limited to those expansions or other changes that result in the increased intake or mortality of marine life, unless the regional water

* See Appendix I for definition of terms.

board determines that additional measures that minimize intake and mortality of marine life are feasible for the existing portions of the facility.

(4) In conducting the Water Code section 13142.5(b) determination, the regional water boards shall consult with other state agencies involved in the permitting of that facility, including, but not limited to: California Coastal Commission, California State Lands Commission, California Department of Fish and Wildlife, and California Department of Public Health. The regional water board shall consider project-specific decisions made by other state agencies; however, the regional water board is not limited to project-specific requirements set forth by other agencies and may include additional requirements in a Water Code section 13142.5(b) determination.

(5) A regional water board may expressly condition a Water Code section 13142.5(b) determination based on the expectation of the occurrence of a future event. Such future events may include, but are not limited to, the permanent shutdown of a co-located power plant with intake structures shared with the desalination facility* or a reduction in the volume of wastewater available for the dilution of brine.* The regional water board must make a new Water Code section 13142.5(b) determination if the foreseeable future event occurs.

(a) The owner or operator shall provide notice to the regional water board as soon as it becomes aware that the expected future event will occur, and shall submit a new request for a Water Code section 13142.5(b) determination to the regional water board at least one year prior to the event occurring. If the owner or operator does not become aware that the event will occur at least one year prior to the event occurring, the owner or operator shall submit the request as soon as possible.

(b) The regional water board may allow up to five years from the date of the event for the owner or operator to make modifications to the facility required by a new Water Code 13142.5(b) determination, provided that the regional water board finds that any water supply interruption resulting from the facility modifications requires additional time for water users to obtain a temporary replacement supply.

(c) If the regional water board makes a Water Code section 13142.5(b) determination for a desalination facility* that will be

* See Appendix I for definition of terms.

co-located with a power plant, the regional water board shall condition its determination on the power plant remaining in compliance with the Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling.

b. Site is the general onshore and offshore location of a new or expanded facility. There may be multiple potential facility design configurations within any given site. For each potential site, in order to determine whether a proposed facility site best minimizes intake and mortality of marine life, the regional water board shall require the owner or operator to:

(1) Consider whether the identified regional need for desalinated* water identified is consistent with any applicable general or coordinated plan for the development, utilization or conservation of the water resources of the state, such as a county general plan, an integrated regional water management plan or an urban water management plan. A design capacity in excess of the identified regional water need for desalinated* water shall not be used by itself to declare subsurface intakes as infeasible.

(2) Analyze the feasibility of placing intake, discharge, and other facility infrastructure in a location that avoid impacts to sensitive habitats* and sensitive species.

(3) Analyze the direct and indirect effects on marine life resulting from facility construction and operation, individually and in combination with potential anthropogenic effects on marine life resulting from other past, present, and reasonably foreseeable future activities within the geographic scope of the area affected by the facility.

(4) Analyze oceanographic, bathymetric, geologic, hydrogeologic, and seafloor topographic conditions, so the siting of a facility, including the intakes and discharges, minimize the intake and mortality of marine life.

(5) Analyze the presence of existing infrastructure, and the availability of wastewater to dilute the facility's brine* discharge.

(6) Ensure that the intake and discharge structures are not located within a MPA or SWQPA.* Discharges shall be sited at a sufficient distance

* See Appendix I for definition of terms.

from a MPA or SWQPA* so that there are no impacts from the discharge on a MPA or SWQPA* and so that the salinity* within the boundaries of a MPA or SWQPA* does not exceed natural background salinity.* To the extent feasible, intakes shall be sited so as to maximize the distance from a MPA or SWQPA.*

c. Design is the layout, form, and function of a facility, including the configuration and type of infrastructure, including intake and outfall structures. The regional water board shall require that the owner or operator perform the following in determining whether a proposed facility design best minimizes intake and mortality of marine life:

(1) For each potential site, analyze the potential design configurations of the intake, discharge, and other facility infrastructure to avoid impacts to sensitive habitats* and sensitive species.

(2) If the regional water board determines that subsurface intakes are infeasible and surface water intakes are proposed instead, analyze potential designs for those intakes in order to minimize the Area Production Forgone* (APF). The intake shall be designed to minimize entrainment of organisms when operational.

(3) Design the outfall so that the brine mixing zone* does not encompass or otherwise adversely affect existing sensitive habitat.*

(4) Design the outfall so that discharges do not result in dense, negatively-buoyant plumes that result in adverse effects due to elevated salinity* or anoxic conditions occurring outside the brine mixing zone.* An owner or operator must demonstrate that the outfall meets this requirement through plume modeling and/or field studies. Modeling and field studies shall be approved by the regional water board in consultation with State Water Board staff.

(5) Design outfall structures to minimize the suspension of benthic sediments.

d. Technology is the type of equipment, materials,* and methods that are used to construct and operate the design components of the desalination facility.* The regional water board shall apply the following considerations in determining whether a proposed technology best minimizes intake and mortality of marine life:

(1) Considerations for Intake Technology:

* See Appendix I for definition of terms.

(a) Subject to Section L.2.a.(2), the regional water board shall require subsurface* intakes unless it determines that subsurface* intakes are infeasible based upon an analysis of the criteria listed below, in consultation with State Water Board staff.

i. The regional water board shall consider the following criteria in determining feasibility of subsurface* intakes: geotechnical data, hydrogeology, benthic topography, oceanographic conditions, presence of sensitive habitats,* presence of sensitive species, energy use; impact on freshwater aquifers, local water supply, and existing water users; desalinated* water conveyance, existing infrastructure, co-location with sources of dilution water, design constraints (engineering, constructability), and project life cycle cost. Project life cycle cost shall be determined by evaluating the total cost of planning, design, land acquisition, construction, operations, maintenance, mitigation, equipment replacement and disposal over the lifetime of the facility, in addition to the cost of decommissioning the facility. In addition, the regional water board may evaluate other site- and facility-specific factors.

ii. The regional water board may find that a combination of subsurface* and surface intakes is the best feasible alternative to minimize intake and mortality of marine life.

(b) Installation and maintenance of a subsurface* intake shall avoid, to the maximum extent feasible, the disturbance of sensitive habitats* and sensitive species.

(c) If subsurface* intakes are not feasible, the regional water board may approve a surface water intake subject to the following conditions.

i. The regional water board shall require that surface water intakes be screened. Screens must be functional while the facility is withdrawing seawater.*

ii. In order to reduce entrainment, all surface water intakes must be screened with a [*0.5 mm (0.02 in)/ 0.75 (0.03 in)/ 1.0 mm (0.04 in)*] or smaller slot size screen when the desalination facility* is withdrawing seawater.* [*NOTE: The State Water*

* See Appendix I for definition of terms.

Board intends to select a single slot size, but is soliciting comments on whether 0.5 mm, 0.75 mm, 1.0 mm, or some other slot size is most appropriate to minimize intake and mortality of marine life.]

iii. An owner or operator may use an alternative method of preventing entrainment so long as the alternative method provides equivalent protection of eggs, larvae, and juvenile organisms as is provided by a [*0.5 mm (0.02 in)/ 0.75 (0.03 in)/ 1.0 mm (0.04 in)*] slot size screen [*see note above*]. The owner or operator must demonstrate the effectiveness of the alternative method to the regional water board. The owner or operator must conduct a pilot study to demonstrate the effectiveness of the alternative method, and use an Empirical Transport Model* (ETM)/ Area of Production Forgone* (APF) approach* to estimate entrainment at the pilot study location. The study period shall be at least 36 consecutive months and sampling shall be designed to account for variation in oceanographic conditions and larval abundance and diversity such that abundance estimates are reasonably accurate. Samples must be collected using a mesh size no larger than 335 microns and individuals collected shall be identified to the lowest taxonomical level practicable. The ETM/APF analysis* shall be representative of the entrained species. At their discretion, the regional water boards may permit the use of existing entrainment data from the facility to meet this requirement.

(d) In order to minimize impingement, through-screen velocity at the surface water intake shall not exceed 0.15 meters per second (0.5 feet per second).

(2) Considerations for Brine* Discharge Technology:

(a) The preferred technology for minimizing intake and mortality of marine life resulting from brine* disposal is to commingle brine* with wastewater (e.g., agricultural, sewage, industrial, power plant cooling water, etc.) that would otherwise be discharged to the ocean, unless the wastewater is of suitable quality and quantity to support domestic or irrigation uses.

(b) Multiport diffusers* are the next best method for disposing of brine* when the brine* cannot be diluted by wastewater and when there are no live organisms in the discharge. Multiport diffusers*

* See Appendix I for definition of terms.

shall be engineered to maximize dilution, minimize the size of the brine mixing zone,* minimize the suspension of benthic sediments, and minimize marine life mortality.

(c) The regional water board shall require the owner or operator to analyze the brine* disposal technology or combination of brine* disposal technologies that best reduces the effects of the discharge of brine* on marine life due to intake-related entrainment, osmotic stress from elevated salinity,* turbulence that occurs during water conveyance and mixing, and shearing stress at the point of discharge.

(d) Brine* disposal technologies other than wastewater dilution and multiport diffusers,* such as flow augmentation,* may be used if an owner or operator can demonstrate to the regional water board that the technology provides a comparable level of protection. The owner or operator must evaluate all of the individual and cumulative effects of the proposed alternative discharge method on marine life mortality, including (where applicable); intake-related entrainment, osmotic stress, turbulence that occurs during water conveyance and mixing, and shearing stress at the point of discharge. When determining the level of protection provided by a brine* disposal technology or combination of technologies, the regional water board shall require the owner or operator to use empirical studies or modeling to:

i. Estimate intake entrainment impacts using an ETM/APF approach.*

ii. Estimate degradation of marine life from elevated salinity within the brine mixing zone,* including osmotic stresses, the size of impacted area, and the duration that marine life are exposed to the toxic conditions. Considerations shall be given to the most sensitive species, and community structure and function.

iii. Estimate marine life mortality that occurs as a result of water conveyance, in-plant turbulence or mixing, and waste discharge.

(e) An owner or operator proposing to use flow augmentation* as an alternative brine* discharge technology must:

* See Appendix I for definition of terms.

i. Use low turbulence intakes (e.g., screw centrifugal pumps or axial flow pumps) and conveyance pipes.

ii. Convey and mix dilution water in a manner that limits thermal stress, osmotic stress, turbulent shear stress, and other factors that could cause marine life mortality.

iii. Within three years of beginning operation, submit to the regional water board an empirical study that evaluates intake and mortality of marine life associated with flow augmentation.* The study must evaluate impacts caused by augmented intake volume, intake and pump technology, water conveyance, waste brine* mixing, and effluent discharge. Unless demonstrated otherwise, organisms entrained by flow augmentation* are assumed to have a mortality rate of 100 percent.

iv. If the empirical study shows that flow augmentation* is less protective of marine life than a facility using wastewater dilution or multiport diffusers,* then the facility must either (1) cease using flow augmentation* technology and install and use wastewater dilution or multiport diffusers* to discharge brine* waste, or (2) re-design the flow augmentation* system to minimize intake and mortality of marine life to a level that is comparable with wastewater dilution or multiport diffusers,* subject to regional water board approval.

v. Facilities proposing to use flow augmentation* must comply with chapter III.L.2.d.(1).

vi. Facilities proposing to use flow augmentation* through surface intakes are prohibited from discharging through multiport diffusers.*

(f) Facilities that use subsurface* intakes to supply augmented flow water for dilution are exempt from the requirements of chapter III.L.2.d.(2) if the facility meets the receiving water limitation for salinity in chapter III.L.3.

e. Mitigation for the purposes of this section is the replacement of marine life or habitat that is lost due to the construction and operation of a desalination facility* after minimizing marine life mortality through site, design, and technology measures. The owner or operator may choose whether to satisfy

* See Appendix I for definition of terms.

a facility's mitigation measures pursuant to chapter III.L.2.e.(3) or, if available, L.2.e.(4). The owner or operator shall fully mitigate for all marine life mortality associated with the desalination facility.*

(1) *Marine Life Mortality Report.* The owner or operator of a facility shall submit a report to the regional water board projecting the marine life mortality resulting from construction and operation of the facility after implementation of the facility's required site, design, and technology measures.

(a) For operational mortality related to intakes, the report shall include a detailed entrainment study. The entrainment study period shall be at least 36 consecutive months and sampling shall be designed to account for variation in oceanographic conditions and larval abundance and diversity such that abundance estimates are reasonably accurate. At their discretion, the regional water boards may permit the use of existing entrainment data from the facility to meet this requirement. Samples must be collected using a mesh size no larger than 335 microns and individuals collected shall be identified to the lowest taxonomical level practicable. Additional samples shall also be collected using a 200 micron mesh to provide a broader characterization of other entrained organisms. The ETM/APF analysis* shall be representative of the entrained species collected using the 335 micron net. The APF* shall be calculated using a 90 percent confidence level. An owner or operator with subsurface* intakes is not required to do an ETM/APF analysis* for their intakes and is not required to mitigate for intake-related operational mortality.

(b) For operational mortality related to discharges, the report shall estimate the area in which salinity* exceeds 2.0 parts per thousand above natural background salinity* or a facility-specific alternative receiving water limitation (see § L.3). The area in excess of the receiving water limitation for salinity* shall be determined by modeling and confirmed with monitoring. The report shall use any acceptable approach for evaluating mortality that occurs due to shearing stress resulting from the facility's discharge, including any incremental increase in mortality resulting from a commingled discharge.

(c) For construction-related mortality, the report shall use any acceptable approach for evaluating the mortality that occurs within the area disturbed by the facility's construction. The

* See Appendix I for definition of terms.

regional water board may determine that the construction-related disturbance does not require mitigation because the disturbance is temporary and the habitat is naturally restored.

(d) Upon approval of the report by the regional water board in consultation with State Water Board staff, the calculated marine life mortality shall form the basis for the mitigation provided pursuant to this section.

(2) The owner or operator shall mitigate for the marine life mortality determined in the report above by choosing to either complete a mitigation project as described in chapter III.L.2.e.(3) or, if an appropriate fee-based mitigation program is available, provide funding for the program as described in chapter III.L.2.e.(4). The mitigation project or the use of a fee-based mitigation program and the amount of the fee that the owner or operator must pay is subject to regional water board approval.

(3) *Mitigation Option 1: Complete a Mitigation Project.* The mitigation project must satisfy the following provisions:

(a) The owner or operator shall submit a Mitigation Plan. Mitigation Plans shall include: project objectives, site selection, site protection instrument (the legal arrangement or instrument that will be used to ensure the long-term protection of the compensatory mitigation project site), baseline site conditions, a mitigation work plan, a maintenance plan, a long-term management plan, an adaptive management plan, performance standards and success criteria, monitoring requirements, and financial assurances.

(b) The mitigation project must meet the following requirements:

i. Mitigation shall be accomplished through expansion, restoration or creation of one or more of the following: kelp beds, estuaries, coastal wetlands, natural reefs, MPAs, or other projects approved by the regional water board that will mitigate for intake and mortality of marine life associated with the facility.

ii. The owner or operator shall demonstrate that the project fully mitigates for intake-related marine life mortality by including acreage that is at least equivalent in size to the APF* calculated in the Marine Life Mortality Report above. The owner or operator shall do modeling to evaluate the

* See Appendix I for definition of terms.

areal extent of the mitigation project's production area* to confirm that it overlaps the facility's source water body.* Impacts on the mitigation project due to entrainment by the facility must be offset by adding compensatory acreage to the mitigation project. The regional water boards may require additional habitat be mitigated to compensate for the annual entrainment of organisms between 200 and 335 microns.

iii. The owner or operator shall demonstrate that the project also fully mitigates for the discharge-related marine life mortality projected in the Marine Life Mortality Report above. For each acre of discharge-related disturbance as determined in the Marine Life Mortality Report, an owner or operator shall restore one acre of habitat unless the regional water board determines that a mitigation ratio greater than 1:1 is needed.

iv. The owner or operator shall demonstrate that the project also fully mitigates for the construction-related marine life mortality identified in the Marine Life Mortality Report above. For each acre of construction-related disturbance, an owner or operator shall restore one acre of habitat unless the regional water board determines that a mitigation ratio greater than 1:1 is needed.

(c) The Mitigation Plan is subject to approval by the regional water board in consultation with State Water Board staff and with other agencies having authority to permit the project and require mitigation.

(4) *Mitigation Option 2: Fee-based Mitigation Program*. If the regional water board determines that an appropriate fee-based mitigation program has been established by a public agency, and that payment of a fee to the mitigation program will result in the creation and ongoing implementation of a mitigation project that meets the requirements of section L.2.e.(3), the owner or operator may pay a fee to the mitigation program in lieu of completing a mitigation project.

(a) The agency that manages the fee-based mitigation program must have legal and budgetary authority to accept and spend mitigation funds, a history of successful mitigation projects documented by having set and met performance standards for

* See Appendix I for definition of terms.

past projects, and stable financial backing in order to manage mitigation sites for the operational life of the facility.

(b) The amount of the fee shall be based on the cost of the mitigation project, or if the project is designed to mitigate cumulative impacts from multiple desalination facilities or other development projects, the amount of the fee shall be based on the desalination facility's fair share of the cost of the mitigation project.

(c) The manager of the fee-based mitigation program must consult with the California Department of Fish and Wildlife, Ocean Protection Council, Coastal Commission, State Lands Commission, and State and regional water boards to develop mitigation projects that will best compensate for intake and mortality of marine life caused by the desalination facility.* Mitigation projects that increase or enhance the viability and sustainability of marine life in Marine Protected Areas are preferred, if feasible.

(5) California Department of Fish and Wildlife, the regional water board, and State Water Board may perform audits or site inspections of any mitigation project.

(6) An owner or operator, or a manager of a fee-based mitigation program, must submit a mitigation project performance report to the regional water board 180 days prior to the expiration date of their NPDES permit.

3. Receiving Water Limitation for Salinity*

a. Chapter III.L.3 is applicable to all desalination facilities discharging brine* into ocean waters,* including facilities that commingle brine* and wastewater.

b. The receiving water limitation for salinity* shall be established as described below:

(1) Discharges shall not exceed a daily maximum of 2.0 parts per thousand above natural background salinity* to be measured as total dissolved solids (mg/L) measured no further than 100 meters (328 ft) horizontally from the discharge. There is no vertical limit to this zone.

* See Appendix I for definition of terms.

(2) In determining an effluent limit necessary to meet this receiving water limitation, permit writers shall use the formula in chapter III.C.4 that has been modified for brine* discharges as follows:

Equation 1: Ce= (2,000 mg/l + Cs) + Dm(2,000 mg/l)

Where:

Ce= the effluent concentration limit, mg/L
Co= the salinity* concentration to be met at the completion of initial* dilution= 2,000 mg/l + Cs
Cs= the natural background salinity* mg/L
Dm= minimum probable initial*dilution expressed as parts seawater* per part brine* discharge

(a) The fixed distance referenced in the initial dilution* definition shall be no more than 100 meters (328 feet).

(b) In addition, the owner or operator shall develop a dilution factor (Dm) based on the distance of 100 meters (328 feet) or initial*dilution, whichever is smaller.

(c) The value 2,000 mg/l in Equation 1 is the maximum incremental increase above ambient background salinity* (Cs) allowed at the edge of the brine* mixing zone. A regional water board may substitute an alternative numeric value for 2,000 mg/l in Equation 1 based upon the results of a facility-specific alternative salinity* receiving water limitation study, as described in chapter III.L.3.c below.

c. An owner or operator may submit a proposal to the regional water board for approval of an alternative salinity* receiving water limitation.

(1) To determine whether a proposed facility-specific alternative receiving water limitation is adequately protective of beneficial uses, an owner or operator shall:

(a) Establish baseline biological conditions at the discharge location and at reference locations over a 36-month period prior to commencing brine* discharge. The biologic surveys must characterize the ecologic composition of habitat and marine life using measures established by the regional water board. At their discretion, the regional water boards may permit the use of existing data from the facility to meet this requirement.

* See Appendix I for definition of terms.

(b) Conduct at least the following Whole Effluent Toxicity (WET) tests: germination and growth for giant kelp (*Macrocystis pyrifera*); development for red abalone (*Haliotis refescens*); development and fertilization for purple urchin (*Strongleocentrotus purpuratus*); development and fertilization for sand dollar (*Dendraster excentricus*); larval growth rate for topsmelt (*Atherniops affinis*).

(c) The regional water board in consultation with State Water Board staff may require an owner or operator to do additional toxicity studies if needed.

(2) The regional water board in consultation with the State Water Board staff may require an owner or operator to provide additional studies or information in order to approve a facility-specific alternative receiving water limitation for salinity.*

(3) The facility-specific alternative receiving water limitation shall be based on the no observed effect level (NOEL) for the most sensitive species and toxicity endpoint as determined in the chronic toxicity* studies. The regional water board in consultation with State Water Board staff has discretion to approve the proposed facility-specific alternative receiving water limitation for salinity.*

(4) The regional water board may eliminate or revise a facility-specific alternative receiving water limitation for salinity* based on a facility's monitoring data, the results from their Before-After Control-Impact study as required in chapter III.L.4 below, or based on any other information that the regional water board deems to be relevant.

d. Existing facilities that do not meet the receiving water limitation at the edge of the brine mixing zone* and throughout the water column by [the effective date of this plan] must either: 1) establish a facility-specific alternative receiving water limitation for salinity* as described in chapter III.L.3.(c); or, 2) upgrade the facility's brine* discharge method in order to meet the receiving water limitation in chapter III.L.3.b in accordance with the State Water Board's Compliance Schedule Policy, as set forth in (e) below. An owner or operator that chooses to upgrade the facility's method of brine* disposal:

(1) Must demonstrate to the regional water board that the brine* discharge does not negatively impact sensitive habitats,* sensitive species, MPAs, or SWQPAs.

* See Appendix I for definition of terms.

(2) Is subject to the Considerations for Brine* Discharge Technology described in chapter III.L.2.e.(2).

e. The regional water board may grant compliance schedules for the requirements for brine* waste discharges for existing desalination facilities.* All compliance schedules shall be in accordance with the State Water Board's Compliance Schedule Policy, except that the salinity* receiving water limitation set forth in chapter III.L.3.(b) shall be considered to be a "new water quality objective" as used in the Compliance Schedule Policy.

4. Monitoring and Reporting Programs

a. The owner or operator of a desalination facility* must submit a Monitoring and Reporting Plan to the regional water board for approval. The Monitoring and Reporting Plan shall include monitoring of effluent and receiving water characteristics and impacts to marine life. The Monitoring and Reporting Plan shall, at a minimum, include monitoring for benthic community health, aquatic life toxicity, and receiving water characteristics consistent with Appendix III of this Plan and for compliance with the receiving water limitation in chapter III .L.3. Receiving water monitoring for salinity* shall be conducted at times when the monitoring locations are most likely affected by the discharge. For new or expanded facilities the following additional requirements apply:

(1) An owner or operator must perform facility-specific monitoring to demonstrate compliance with the receiving water limitation for salinity,* and evaluate the potential effects of the discharge within the water column, bottom sediments, and the benthic communities. Facility-specific monitoring is required until the regional water board determines that a regional monitoring program is adequate to ensure compliance with the receiving water limitation. The monitoring and reporting plan shall be reviewed, and revised if necessary, upon NPDES permit renewal.

(2) Baseline biological conditions shall be established at the discharge location and at a reference location prior to commencement of construction. The owner or operator is required to conduct Before-After Control-Impact biological surveys that will evaluate the differences between biological communities at a reference site and at the discharge location before and after the discharge commences. The regional water board will use the data and results from the Before-After Control-Impact surveys for evaluating and renewing the requirements set forth in a facility's NPDES permit.

* See Appendix I for definition of terms.

APPENDIX I
DEFINITION OF TERMS

ACUTE TOXICITY

a. Acute Toxicity (TUa)

Expressed in Toxic Units Acute (TUa)

$$TUa = \frac{100}{\text{96-hr LC 50\%}}$$

b. Lethal Concentration 50% (LC 50)

LC 50 (percent waste giving 50% survival of test organisms) shall be determined by static or continuous flow bioassay techniques using standard marine test species as specified in Appendix III. If specific identifiable substances in wastewater can be demonstrated by the discharger as being rapidly rendered harmless upon discharge to the marine environment, but not as a result of dilution, the LC 50 may be determined after the test samples are adjusted to remove the influence of those substances.

When it is not possible to measure the 96-hour LC 50 due to greater than 50 percent survival of the test species in 100 percent waste, the toxicity concentration shall be calculated by the expression:

$$TUa = \frac{\log (100 - S)}{1.7}$$

where:

S = percentage survival in 100% waste. If S > 99, TUa shall be reported as zero.

AREA PRODUCTION FOREGONE (APF), also known as habitat production foregone, is an estimate of the area that is required to produce (replace) the same amount of larvae or propagules* that are removed via entrainment at a desalination facilities* intakes. APF is calculated by multiplying the proportional mortality* by the source water body,* which are both determined using an empirical transport model.*

AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE (ASBS) are those areas designated by the State Water Board as ocean areas requiring protection of species or biological communities to the extent that maintenance of natural water quality is assured. All Areas of Special Biological Significance are also classified as a subset of STATE WATER QUALITY PROTECTION AREAS.* ASBS are also referred to as State Water Quality Protection Areas* – Areas of Special Biological Significance (SWQPA-ASBS).

BRINE is the byproduct of desalinated* water having a salinity* concentration greater than a desalination facility's* intake source water.

BRINE MIXING ZONE is the area where the salinity* exceeds 2.0 parts per thousand above natural background salinity.* The brine mixing zone shall not exceed 100 meters (328 feet)

* See Appendix I for definition of terms.

laterally from the points of discharge and throughout the water column unless otherwise authorized by the regional water board in accordance with this plan. The brine mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as acutely toxic conditions are prevented and the designated use of the water is not impaired as a result of the brine mixing zone. The brine mixing zone is determined by through a mixing zone study and the use of applicable water quality models that have been approved by the regional water boards in consultation with State Water Board staff.

CHLORDANE shall mean the sum of chlordane-alpha, chlordane-gamma, chlordene-alpha, chlordene-gamma, nonachlor-alpha, nonachlor-gamma, and oxychlordane.

CHRONIC TOXICITY: This parameter shall be used to measure the acceptability of waters for supporting a healthy marine biota until improved methods are developed to evaluate biological response.

a. Chronic Toxicity (TUc)

Expressed as Toxic Units Chronic (TUc)

$$TUc = \frac{100}{NOEL}$$

b. No Observed Effect Level (NOEL)

The NOEL is expressed as the maximum percent effluent or receiving water* that causes no observable effect on a test organism, as determined by the result of a critical life stage toxicity test listed in Appendix III, Table III-1.

DDT shall mean the sum of 4,4'DDT, 2,4'DDT, 4,4'DDE, 2,4'DDE, 4,4'DDD, and 2,4'DDD.

DEGRADE: Degradation shall be determined by comparison of the waste field and reference site(s) for characteristic species diversity, population density, contamination, growth anomalies, debility, or supplanting of normal species by undesirable plant and animal species. Degradation occurs if there are significant* differences in any of three major biotic groups, namely, demersal fish, benthic invertebrates, or attached algae. Other groups may be evaluated where benthic species are not affected, or are not the only ones affected.

DESALINATION FACILITY is an industrial facility that processes water to remove salts and other components from the source water to produce water that is less saline than the source water.

DICHLOROBENZENES shall mean the sum of 1,2- and 1,3-dichlorobenzene.

DOWNSTREAM OCEAN WATERS shall mean waters downstream with respect to ocean currents.

DREDGED MATERIAL: Any material* excavated or dredged from the navigable waters of the United States, including material* otherwise referred to as "spoil".

EELGRASS BEDS are aggregations of the aquatic plant species, *Zostera marina.*

* See Appendix I for definition of terms.

EMPIRICAL TRANSPORT MODEL (ETM) is a methodology for determining the spatial area known as the source water body* that contains the source water population, which are the organisms that are at risk of entrainment as determined by factors that may include but are not limited to biological, hydrodynamic, and oceanographic data. ETM can also be used to estimate proportional mortality,* P_m.

ENCLOSED BAYS are indentations along the coast which enclose an area of oceanic water within distinct headlands or harbor works. Enclosed bays include all bays where the narrowest distance between headlands or outermost harbor works is less than 75 percent of the greatest dimension of the enclosed portion of the bay. This definition includes but is not limited to: Humboldt Bay, Bodega Harbor, Tomales Bay, Drakes Estero, San Francisco Bay, Morro Bay, Los Angeles Harbor, Upper and Lower Newport Bay, Mission Bay, and San Diego Bay.

ENDOSULFAN shall mean the sum of endosulfan-alpha and -beta and endosulfan sulfate.

ESTUARIES AND COASTAL LAGOONS are waters at the mouths of streams that serve as mixing zones for fresh and ocean waters* during a major portion of the year. Mouths of streams that are temporarily separated from the ocean by sandbars shall be considered as estuaries. Estuarine waters will generally be considered to extend from a bay or the open ocean to the upstream limit of tidal action but may be considered to extend seaward if significant* mixing of fresh and salt water occurs in the open coastal waters. The waters described by this definition include but are not limited to the Sacramento-San Joaquin Delta as defined by ~~S~~section 12220 of the California Water Code, Suisun Bay, Carquinez Strait downstream to Carquinez Bridge, and appropriate areas of the Smith, Klamath, Mad, Eel, Noyo, and Russian Rivers.

ETM/APF APPROACH or ANALYSIS. For guidance on how to perform an ETM/APF analysis please see Appendix E of the Staff Report for Amendment to the Water Quality Control Plan For Ocean Waters of California Addressing Desalination Facility Intakes, Brine Discharges, And The Incorporation Of Other Non-substantive Changes.

FLOW AUGMENTATION is a type of in-plant dilution and occurs when a desalination facility* withdraws additional source water for the specific purpose of diluting brine* prior to discharge.

GRAYWATER is drainage from galley, dishwasher, shower, laundry, bath, and lavatory wash basin sinks, and water fountains, but does not include drainage from toilets, urinals, hospitals, or cargo spaces.

HALOMETHANES shall mean the sum of bromoform, bromomethane (methyl bromide) and chloromethane (methyl chloride).

HCH shall mean the sum of the alpha, beta, gamma (lindane) and delta isomers of hexachlorocyclohexane.

INDICATOR BACTERIA includes total coliform bacteria, fecal coliform bacteria (or *E. coli*), and/or Enterococcus bacteria.

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* See Appendix I for definition of terms.

INITIAL DILUTION is the process which results in the rapid and irreversible turbulent mixing of wastewater with ocean water around the point of discharge.

For a submerged buoyant discharge, characteristic of most municipal and industrial wastes that are released from the submarine outfalls, the momentum of the discharge and its initial buoyancy act together to produce turbulent mixing. Initial dilution in this case is completed when the diluting wastewater ceases to rise in the water column and first begins to spread horizontally.

For shallow water submerged discharges, surface discharges, and nonbuoyant discharges, characteristic of cooling water wastes and some individual discharges, turbulent mixing results primarily from the momentum of discharge. Initial dilution, in these cases, is considered to be completed when the momentum induced velocity of the discharge ceases to produce significant* mixing of the waste, or the diluting plume reaches a fixed distance from the discharge to be specified by the Regional Board, whichever results in the lower estimate for initial dilution.

KELP BEDS, for purposes of the bacteriological standards of this plan, are aggregations of marine algae of the order Laminariales, including species in the genera *Macrocystis*, *Nereocystis*, and *Pelagophycus*. Kelp beds include the total foliage canopy throughout the water column. ~~are significant aggregations of marine algae of the genera Macrocystis and Nereocystis. Kelp beds include the total foliage canopy of Macrocystis and Nereocystis plants throughout the water column.~~

LARGE PASSENGER VESSELS are vessels of 300 gross registered tons or greater engaged in carrying passengers for hire. The following vessels are not large passenger vessels:
(1) Vessels without berths or overnight accommodations for passengers;
(2) Noncommercial vessels, warships, vessels operated by nonprofit entities as determined by the Internal Revenue Service, and vessels operated by the state, the United States, or a foreign government;
(3) Oceangoing vessels,* as defined below (e.g. those used to transport cargo).

MARICULTURE is the culture of algae, plants, and animals in marine waters independent of any pollution source.

MARINE MANAGED AREAS are named, discrete geographic marine or estuarine areas along the California coast designated by law or administrative action, and intended to protect, conserve, or otherwise manage a variety of resources and their uses. According to the California Public Resources Code (~~sections~~§§ 36600 et~~.~~ seq.) there are six classifications of marine managed areas, including State Marine Reserves, State Marine Parks and State Marine Conservation Areas, State Marine Cultural Preservation Areas, State Marine Recreational Management Areas, and State Water Quality Protection Areas.*

MARKET SQUID NURSURIES are comprised of numerous egg capsules, each containing approximately 200 developing embryos, attached in clusters or mops to sandy substrate with moderate water flow. Market squid (*Doryteuthis opalescens*) nurseries occur at a wide range of depths; however, mop densities are greatest in shallow, nearshore waters between ten and 100 meters (328 feet) deep. *D. opalescens* egg nurseries commonly occur within a few hundred meters of the same location every year.

* See Appendix I for definition of terms.

MATERIAL: (a) In common usage: (1) the substance or substances of which a thing is made or composed (2) substantial; (b) For purposes of this Ocean Plan relating to waste disposal, dredging and the disposal of dredged material* and fill, MATERIAL means matter of any kind or description which is subject to regulation as waste, or any material dredged from the navigable waters of the United States. See also, DREDGED MATERIAL.* For the purposes of chapter III.L.2.d, materials relates to the common usage in (a).

METHOD DETECTION LIMIT (Method Detection Limit) is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, as defined in 40 CFR PART 136 Appendix B.

MINIMUM LEVEL (ML) is the concentrations at which the entire analytical system must give a recognizable signal and acceptable calibration point. The ML is the concentration in a sample that is equivalent to the concentration of the lowest calibration standard analyzed by a specific analytical procedure, assuming that all the method-specified sample weights, volumes and processing steps have been followed.

MULTIPORT DIFFUSERS are linear structures consisting of many spaced ports or nozzles that are installed on submerged marine outfalls. Multiport diffusers discharge brine* waste into an ambient receiving water* body and enable rapid mixing, dispersal, and dilution of brine* within a relatively small area.

NATURAL BACKGROUND SALINITY is the salinity* of at a location that results from naturally occurring processes and is without apparent human influence. Natural background salinity shall be determined by averaging 20 years of historical salinity* data at a location. When historical data are not available, natural background salinity shall be determined by measuring salinity* at depth of proposed discharge for three years, on a weekly basis prior to a desalination facility* discharging brine,* and the average salinity* shall be used to determine natural background salinity.* Facilities shall establish a reference location with similar natural background salinity* to be used for comparison in ongoing monitoring of brine* discharges.

NATURAL LIGHT: Reduction of natural light may be determined by the Regional Board by measurement of light transmissivity or total irradiance, or both, according to the monitoring needs of the Regional Board.

NO DISCHARGE ZONE (NDZ) is an area in which both treated and untreated sewage discharges from vessels are prohibited. Within NDZ boundaries, vessel operators are required to retain their sewage discharges onboard for disposal at sea (beyond three miles from shore) or onshore at a pump-out facility.

NON-STORM WATER DISCHARGE is any runoff that is not the result of a precipitation event. This is often referred to as “dry weather flow.”

OCEAN WATERS are the territorial marine waters of the State as defined by California law to the extent these waters are outside of enclosed bays,* estuaries, and coastal lagoons.* If a discharge outside the territorial waters of the State could affect the quality of the waters of the State, the discharge may be regulated to assure no violation of the Ocean Plan will occur in ocean waters.

* See Appendix I for definition of terms.

OCEANGOING VESSELS (i.e., oceangoing ships) means commercial vessels of 300 gross registered tons or more calling on California ports or places, excluding active military vessels.

OILY BILGE WATER includes bilge water that contains used lubrication oils, oil sludge and slops, fuel and oil sludge, used oil, used fuel and fuel filters, and oily waste.

PAHs (polynuclear aromatic hydrocarbons) shall mean the sum of acenaphthylene, anthracene, 1,2-benzanthracene, 3,4-benzofluoranthene, benzo[k]fluoranthene, 1,12-benzoperylene, benzo[a]pyrene, chrysene, dibenzo[ah]anthracene, fluorene, indeno[1,2,3-cd]pyrene, phenanthrene and pyrene.

PCBs (polychlorinated biphenyls) shall mean the sum of chlorinated biphenyls whose analytical characteristics resemble those of Aroclor-1016, Aroclor-1221, Aroclor-1232, Aroclor-1242, Aroclor-1248, Aroclor-1254 and Aroclor-1260.

PERMITTING AUTHORITY means the State Water Board or Regional Water Board, whichever issues the permit.

PROPAGULES are structures that are capable of propagating an organism to the next stage in its life cycle via dispersal. Dispersal is the movement of individuals from their birth site to their reproductive grounds.

PROPORTIONAL MORTALITY, Pm, is percentage of larval organisms or propagules* in the source water body* that is expected to be entrained at a desalination facility's* intake. It is assumed that all entrained larvae or propagules* die as a result of entrainment.

RECEIVING WATER, for permitted storm water discharges and nonpoint sources, should be measured at the point of discharge(s), in the surf zone immediately where runoff from an outfall meets the ocean water (a.k.a., at point zero).

SALINITY is a measure of the dissolved salts in a volume of water. For the purposes of this Plan, salinity shall be measured as total dissolved solids in mg/l.

SEAWATER is salt water that is in or from the ocean. For the purposes chapter III.L, seawater includes tidally influenced waters in coastal estuaries and coastal lagoons* and underground salt water beneath the seafloor, beach, or other contiguous land with hydrologic connectivity to the ocean.

SENSITIVE HABITATS, for the purposes of this Plan, are kelp beds,* rocky substrate, surfgrass beds,* eelgrass beds,* oyster beds, spawning grounds for state or federally managed species, market squid nurseries,* or other habitats in need of special protection as determined by the Water Boards.

SHELLFISH are organisms identified by the California Department of Public Health as shellfish for public health purposes (i.e., mussels, clams and oysters).

SIGNIFICANT difference is defined as a statistically significant difference in the means of two distributions of sampling results at the 95 percent confidence level.

* See Appendix I for definition of terms.

SOURCE WATER BODY is the spatial area that contains the organisms that are at risk of entrainment at a desalination facility* as determined by factors that may include but are not limited to biological, hydrodynamic, and oceanographic data.

STATE WATER QUALITY PROTECTION AREAS (SWQPAs) are nonterrestrial marine or estuarine areas designated to protect marine species or biological communities from an undesirable alteration in natural water quality. All Areas of Special Biological Significance (ASBS)* that were previously designated by the State Water Board in Resolutions 74-28, 74-32, and 75-61 are now also classified as a subset of State Water Quality Protection Areas and require special protections afforded by this Plan.

STATE WATER QUALITY PROTECTION AREAS – GENERAL PROTECTION (SWQPA-GP) designated by the State Water Board to protect marine species and biological communities from an undesirable alteration in natural water quality within State Marine Parks and State Marine Conservation Areas.

SUBSURFACE, for the purposes of this Plan, is the area beneath the ocean floor or beneath the surface of the earth inland from the ocean.

SURFGRASS BEDS are aggregations of marine flowering plants of the genus *Phyllospadix*.

TCDD EQUIVALENTS shall mean the sum of the concentrations of chlorinated dibenzodioxins (2,3,7,8-CDDs) and chlorinated dibenzofurans (2,3,7,8-CDFs) multiplied by their respective toxicity factors, as shown in the table below.

Isomer Group	Toxicity Equivalence Factor
2,3,7,8-tetra CDD	1.0
2,3,7,8-penta CDD	0.5
2,3,7,8-hexa CDDs	0.1
2,3,7,8-hepta CDD	0.01
octa CDD	0.001
2,3,7,8 tetra CDF	0.1
1,2,3,7,8 penta CDF	0.05
2,3,4,7,8 penta CDF	0.5
2,3,7,8 hexa CDFs	0.1
2,3,7,8 hepta CDFs	0.01
octa CDF	0.001

WASTE: As used in this Plan, waste includes a discharger's total discharge, of whatever origin, i.e., gross, not net, discharge.

WATER RECLAMATION: The treatment of wastewater to render it suitable for reuse, the transportation of treated wastewater to the place of use, and the actual use of treated wastewater for a direct beneficial use or controlled use that would not otherwise occur.

* See Appendix I for definition of terms.

APPENDIX II
MINIMUM* LEVELS

The Minimum* Levels identified in this appendix represent the lowest concentration of a pollutant that can be quantitatively measured in a sample given the current state of performance in analytical chemistry methods in California. These Minimum* Levels were derived from data provided by state-certified analytical laboratories in 1997 and 1998 for pollutants regulated by the California Ocean Plan and shall be used until new values are adopted by the State Water Board. There are four major chemical groupings: volatile chemicals, semi-volatile chemicals, inorganics, pesticides & PCB's.* "No Data" is indicated by "--".

TABLE II-1
MINIMUM* LEVELS – VOLATILE CHEMICALS

Volatile Chemicals	CAS Number	Minimum* Level (µg/L) GC Method [a]	Minimum* Level (µg/L) GCMS Method [b]
Acrolein	107028	2.	5
Acrylonitrile	107131	2.	2
Benzene	71432	0.5	2
Bromoform	75252	0.5	2
Carbon Tetrachloride	56235	0.5	2
Chlorobenzene	108907	0.5	2
Chlorodibromomethane	124481	0.5	2
Chloroform	67663	0.5	2
1,2-Dichlorobenzene (volatile)	95501	0.5	2
1,3-Dichlorobenzene (volatile)	541731	0.5	2
1,4-Dichlorobenzene (volatile)	106467	0.5	2
Dichlorobromomethane	75274	0.5	2
1,1-Dichloroethane	75343	0.5	1
1,2-Dichloroethane	107062	0.5	2
1,1-Dichloroethylene	75354	0.5	2
Dichloromethane	75092	0.5	2
1,3-Dichloropropene (volatile)	542756	0.5	2
Ethyl benzene	100414	0.5	2
Methyl Bromide	74839	1.	2
Methyl Chloride	74873	0.5	2
1,1,2,2-Tetrachloroethane	79345	0.5	2
Tetrachloroethylene	127184	0.5	2
Toluene	108883	0.5	2
1,1,1-Trichloroethane	71556	0.5	2
1,1,2-Trichloroethane	79005	0.5	2
Trichloroethylene	79016	0.5	2
Vinyl Chloride	75014	0.5	2

Table II-1 Notes

a) GC Method = Gas Chromatography
b) GCMS Method = Gas Chromatography / Mass Spectrometry
* To determine the lowest standard concentration in an instrument calibration curve for these techniques, use the given ML* (see Cchapter III, "Use of Minimum* Levels").

* See Appendix I for definition of terms.

TABLE II-2
MINIMUM* LEVELS – SEMI VOLATILE CHEMICALS

		Minimum* Level (µg/L)			
Semi-Volatile Chemicals	**CAS Number**	**GC Method [a, *]**	**GCMS Method [b, *]**	**HPLC Method [c,*]**	**COLOR Method [d]**
Acenapthylene	208968	--	10	0.2	--
Anthracene	120127	--	10	2	--
Benzidine	92875	--	5	--	--
Benzo(a)anthracene	56553	--	10	2	--
Benzo(a)pyrene	50328	--	10	2	--
Benzo(b)fluoranthene	205992	--	10	10	--
Benzo(g,h,i)perylene	191242	--	5	0.1	--
Benzo(k)floranthene	207089	--	10	2	--
Bis 2-(1-Chloroethoxy) methane	111911	--	5	--	--
Bis(2-Chloroethyl)ether	111444	10	1	--	--
Bis(2-Chloroisopropyl)ether	39638329	10	2	--	--
Bis(2-Ethylhexyl) phthalate	117817	10	5	--	--
2-Chlorophenol	95578	2	5	--	--
Chrysene	218019	--	10	5	--
Di-n-butyl phthalate	84742	--	10	--	--
Dibenzo(a,h)anthracene	53703	--	10	0.1	--
1,2-Dichlorobenzene (semivolatile)	95504	2	2	--	--
1,3-Dichlorobenzene (semivolatile)	541731	2	1	--	--
1,4-Dichlorobenzene (semivolatile)	106467	2	1	--	--
3,3-Dichlorobenzidine	91941	--	5	--	--
2,4-Dichlorophenol	120832	1	5	--	--
1,3-Dichloropropene	542756	--	5	--	
Diethyl phthalate	84662	10	2	--	--
Dimethyl phthalate	131113	10	2	--	--
2,4-Dimethylphenol	105679	1	2	--	--
2,4-Dinitrophenol	51285	5	5	--	--
2,4-Dinitrotoluene	121142	10	5	--	--
1,2-Diphenylhydrazine	122667	--	1	--	--
Fluoranthene	206440	10	1	0.05	--
Fluorene	86737	--	10	0.1	--
Hexachlorobenzene	118741	5	1	--	--
Hexachlorobutadiene	87683	5	1	--	--
Hexachlorocyclopentadiene	77474	5	5	--	--

Table II-2 continued on next page…

* See Appendix I for definition of terms.

Table II-2 (Continued)
Minimum* Levels – Semi Volatile Chemicals

Semi-Volatile Chemicals	CAS Number	Minimum* Level (µg/L) GC Method [a, *]	GCMS Method [b, *]	HPLC Method [c,*]	COLOR Method [d]
Hexachloroethane	67721	5	1	--	--
Indeno(1,2,3-cd)pyrene	193395	--	10	0.05	--
Isophorone	78591	10	1	--	--
2-methyl-4,6-dinitrophenol	534521	10	5	--	--
3-methyl-4-chlorophenol	59507	5	1	--	--
N-nitrosodi-n-propylamine	621647	10	5	--	--
N-nitrosodimethylamine	62759	10	5	--	--
N-nitrosodiphenylamine	86306	10	1	--	--
Nitrobenzene	98953	10	1	--	--
2-Nitrophenol	88755	--	10	--	--
4-Nitrophenol	100027	5	10	--	--
Pentachlorophenol	87865	1	5	--	--
Phenanthrene	85018	--	5	0.05	--
Phenol	108952	1	1	--	50
Pyrene	129000	--	10	0.05	--
2,4,6-Trichlorophenol	88062	10	10	--	--

Table II-2 Notes:

a) GC Method = Gas Chromatography
b) GCMS Method = Gas Chromatography / Mass Spectrometry
c) HPLC Method = High Pressure Liquid Chromatography
d) COLOR Method = Colorimetric

* To determine the lowest standard concentration in an instrument calibration curve for this technique, multiply the given ML* by 1000 (see Cchapter III, "Use of Minimum* Levels").

* See Appendix I for definition of terms.

TABLE II-3
MINIMUM* LEVELS - INORGANICS

Inorganic Substances	CAS Number	Minimum* Level (µg/L)								
		COLOR Method[a]	DCP Method[b]	FAA Method[c]	GFAA Method[d]	HYDRIDE Method[e]	ICP Method[f]	ICPMS Method[g]	SPGFAA Method[h]	CVAA Method[i]
Antimony	7440360	--	1000.	10.	5.	0.5	50.	0.5	5.	--
Arsenic	7440382	20.	1000.	--	2.	1.	10.	2.	2.	--
Beryllium	7440417	--	1000.	20.	0.5	--	2.	0.5	1.	--
Cadmium	7440439	--	1000.	10.	0.5	--	10.	0.2	0.5	--
Chromium (total)	--	--	1000.	50.	2.	--	10.	0.5	1.	--
Chromium (VI)	18540299	10.	--	5.	--	--	--	--	--	--
Copper	7440508	--	1000.	20.	5.	--	10.	0.5	2.	--
Cyanide	57125	5.	--	--	--	--	--	--	--	--
Lead	7439921	--	10000.	20.	5.	--	5.	0.5	2.	--
Mercury	7439976	--	--	--	--	--	--	0.5	--	0.2
Nickel	7440020	--	1000.	50.	5.	--	20.	1.	5.	--
Selenium	7782492	--	1000.	--	5.	1.	10.	2.	5.	--
Silver	7440224	--	1000.	10.	1.	--	10.	0.2	2.	--
Thallium	7440280	--	1000.	10.	2.	--	10.	1.	5.	--
Zinc	7440666	--	1000.	20.	--	--	20.	1.	10.	--

Table II-3 Notes

a) COLOR Method = Colorimetric
b) DCP Method = Direct Current Plasma
c) FAA Method = Flame Atomic Absorption
d) GFAA Method = Graphite Furnace Atomic Absorption
e) HYDRIDE Method = Gaseous Hydride Atomic Absorption
f) ICP Method = Inductively Coupled Plasma
g) ICPMS Method = Inductively Coupled Plasma / Mass Spectrometry
h) SPGFAA Method = Stabilized Platform Graphite Furnace Atomic Absorption (i.e., US EPA 200.9)
i) CVAA Method = Cold Vapor Atomic Absorption

* To determine the lowest standard concentration in an instrument calibration curve for these techniques, use the given ML* (see ~~C~~chapter III, "Use of Minimum* Levels").

* See Appendix I for definition of terms.

TABLE II-4
MINIMUM* LEVELS – PESTICIDES AND PCBs*

Pesticides – PCB'-s	CAS Number	Minimum* Level (µg/L) GC Method[a,]*
Aldrin	309002	0.005
Chlordane*	57749	0.1
4,4'-DDD	72548	0.05
4,4'-DDE	72559	0.05
4,4'-DDT	50293	0.01
Dieldrin	60571	0.01
a-Endosulfan	959988	0.02
b-Endosulfan	33213659	0.01
Endosulfan Sulfate	1031078	0.05
Endrin	72208	0.01
Heptachlor	76448	0.01
Heptachlor Epoxide	1024573	0.01
a-Hexachlorocyclohexane	319846	0.01
b-Hexachlorocyclohexane	319857	0.005
d-Hexachlorocyclohexane	319868	0.005
g-Hexachlorocyclohexane (Lindane)	58899	0.02
PCB 1016	--	0.5
PCB 1221	--	0.5
PCB 1232	--	0.5
PCB 1242	--	0.5
PCB 1248	--	0.5
PCB 1254	--	0.5
PCB 1260	--	0.5
Toxaphene	8001352	0.5

Table II-4 Notes

a) GC Method- = Gas Chromatography

* To determine the lowest standard concentration in an instrument calibration curve for this technique, multiply the given ML* by 100 (see Cchapter III, "Use of Minimum* Levels").

* See Appendix I for definition of terms.

APPENDIX III
STANDARD MONITORING PROCEDURES

1. INTRODUCTION

The purpose of this appendix is to provide guidance to the Regional Water Boards on implementing the Ocean Plan and to ensure the reporting of useful information. Monitoring should be question driven rather than just gathering data and should be focused on assuring compliance with narrative and numeric water quality standards, the status and attainment of beneficial uses, and identifying sources of pollution.

It is not feasible to prescribe requirements in the Ocean Plan that encompass all circumstances and conditions that could be encountered by all dischargers, nor is it desirable to limit the flexibility of the Regional Water Boards in the monitoring of ocean waters.* This appendix should therefore be considered the basic framework for the design of an ocean discharger monitoring program. The Regional Water Boards are responsible for issuing monitoring and reporting programs (MRPs) that will implement this monitoring guidance. Regional Water Boards can deviate from the procedures required in the appendix only with the approval of the State Water Resources Control Board.

This monitoring guidance utilizes a model monitoring framework. The model monitoring framework has three components that comprise a range of spatial and temporal scales: (1) core monitoring, (2) regional monitoring, and (3) special studies.

1) Core monitoring consists of the basic site-specific monitoring necessary to measure compliance with individual effluent limits and/or impacts to receiving water* quality. Core monitoring is typically conducted in the immediate vicinity of the discharge by examining local scale spatial effects.

2) Regional monitoring provides information necessary to make assessments over large areas and serves to evaluate cumulative effects of all anthropogenic inputs. Regional monitoring data also assists in the interpretation of core monitoring studies. It is recommended that the Regional Water Boards require participation by the discharger in an approved regional monitoring program, if available, for the receiving water*.* In the event that a regional monitoring effort takes place during a permit cycle in which the MRP does not specifically address regional monitoring, a Regional Water Board may allow relief from aspects of core monitoring components in order to encourage participation.

3) Special studies are directed monitoring efforts designed in response to specific management or research questions identified through either core or regional monitoring programs. Often they are used to help understand core or regional monitoring results, where a specific environmental process is not well understood, or to address unique issues of local importance. Regional Water Boards may require special studies as appropriate. Special studies are not addressed further in this guidance because they are beyond its scope.

The Ocean Plan does not address all site-specific monitoring issues and allows the Regional Water Boards to select alternative protocols with the approval of the State Water Board. If no direction is given in this appendix for a specific provision of the Ocean Plan, it is within the

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* See Appendix I for definition of terms.

discretion of the Regional Water Boards to establish the monitoring requirements for that provision.

2. QUALITY ASSURANCE

All receiving* and ambient water monitoring conducted in compliance with MRPs must be comparable with the Quality Assurance requirements of the Surface Water Ambient Monitoring Program (SWAMP).

SWAMP comparable means all sample collection and analyses shall meet or exceed the measurement quality objectives (MQOs) – including all sample types, frequencies, control limits and holding time requirements – as specified in the SWAMP Quality Assurance Project Plan (QAPrP)

The SWAMP QAPrP is located at:
http://www.waterboards.ca.gov/water_issues/programs/swamp/tools.shtml#qa.

For those measurements that do not have SWAMP MQOs available, then MQOs shall be at the discretion of the Regional Water Board. Refer to the USEPA guidance document (EPA QA/G-4) for selecting data quality objectives, located at http://www.epa.gov/quality/qs-docs/g4-final.pdf.

Water Quality data must be reported according to the California Environmental Data Exchange Network (CEDEN) “Data Template” format for all constituents that are monitored in receiving and ambient water. CEDEN Data Template are available at: http://ceden.org.

3. TYPE OF WASTE DISCHARGE SOURCES

Discharges to ocean waters* are highly diverse and variable, exhibiting a wide range of constituents, effluent quality and quantity, location and frequency of discharge. Different types of discharges will require different approaches. This Appendix provides specific direction for three broad types of discharges: (1) Point Sources, (2) Storm Water Point Sources and (3) Non-point Sources.

3.1. Point Sources

Industrial, municipal, marine laboratory and other traditional point sources of pollution that discharge wastewater directly to surface waters and are required to obtain NPDES permits.

3.2. Storm Water Point Sources

Storm Water Point Sources, hereafter referred to as Storm Water Sources, are those NPDES permitted discharges regulated by Construction or Industrial Storm Water General Permits or municipal separate storm sewer system (MS4s) Permits. MS4 Permits are further divided into Phase I and II Permits. A Phase I MS4 Permit is issued by a Regional Water Board for medium (serving between 100,000 and 250,000 people) and large (serving 250,000 or more people) municipalities. A Phase II MS4 General Permit is issued by the State Water Resources Control Board for the discharge of storm water for smaller municipalities, and includes nontraditional Small MS4s, which are governmental facilities such as military bases, public campuses, prison and hospital complexes.

* See Appendix I for definition of terms.

3.3. Non-point Sources

A Non-point Source is any source of pollutants that is not a Point Source described in ~~S~~section 3.1 or a Storm Water Point Source as described in ~~S~~section 3.2. Land use categories contributing to non-point sources include but are not limited to:

a. Agriculture
b. Grazing
c. Forestry/timber harvest
d. Urban not covered under an NPDES permit
e. Marinas and mooring fields
f. Golf Courses not covered under an NPDES Permit

Only agricultural and golf course related non-point source discharge monitoring is addressed in this Appendix, but Regional Water Boards may issue MRPs for other non-point sources at their discretion. Agriculture includes irrigated lands. Irrigated lands are where water is applied for the purpose of producing crops, including, but not limited to, row and field crop, orchards, vineyard, rice production, nurseries, irrigated pastures, and managed wetlands.

4. INDICATOR BACTERIA*

4.1. Point Sources

Primary questions to be addressed:

1. Does the effluent comply with the water quality standards in the receiving water*?
2. Does the sewage effluent reach water contact zones or commercial shellfish* beds?

To answer these questions, core monitoring shall be conducted in receiving water* on the shoreline for the indicator bacteria* at a minimum weekly for any point sources discharging treated sewage effluent:

a. within one nautical mile of shore, or
b. within one nautical mile of a commercial shellfish* bed, or
c. if the discharge is in excess of 10 million gallons per day (MGD).

Alternatively, these requirements may be met through participation in a regional monitoring program to assess the status of marine contact recreation water quality. If the permittee participates in a regional monitoring program, in conjunction with local health organization(s), core monitoring may be suspended for that period at the discretion of the Regional Water Board. Regional monitoring should be used to answer the above questions, and may be used to answer additional questions. These additional questions may include, but are not limited to, questions regarding the extent and magnitude of current or potential receiving water* indicator bacteria* problems, or the sources of indicator bacteria.*

4.2. Storm Water

* See Appendix I for definition of terms.

Primary questions to be addressed:

1. Does the receiving water* comply with water quality standards?
2. Is the condition of the receiving water* protective of contact recreation and shellfish* harvesting beneficial uses?
3. Are the indicator bacteria* levels in receiving water* getting better or worse?
4. What is the relative contribution of indicator bacteria* to the receiving water* from storm water runoff?

To answer these questions, core monitoring for indicator bacteria* shall be required periodically for storm water discharges representative of the area of concern. At a minimum, for municipal storm water discharges, all receiving water* at outfalls greater than 36 inches in diameter or width must be monitored (ankle depth, point zero) at the following frequencies:

a. During wet weather with a minimum of three storms per year, and
b. When non-storm water discharges* occur (flowing during dry weather), and if located at an AB 411 beach, at least weekly. (An AB 411 Beach is defined as a beach visited by more than 50,000 people annually and located on an area adjacent to a storm drain that flows in the summer. (Health & Saf. Code § 115880.)).

Regional Water Boards may waive monitoring once structural best management practices have been installed, evaluated and determined to have successfully controlled indicator bacteria.*

Alternatively, these requirements may be met through participation in a regional monitoring program to assess the status of marine contact recreation water quality. If the permittee participates in a regional monitoring program, in conjunction with local health organization(s), core monitoring may be suspended for that period at the discretion of the Regional Water Board. Regional monitoring should be used to answer the above questions, and may be used to answer additional questions. These additional questions may include, but are not limited to, questions regarding the extent and magnitude of current or potential receiving water* indicator bacteria* problems, or the sources of indicator bacteria*.*

4.3. Non-point Sources

Primary questions to be addressed:

1. Does the receiving water* comply with water quality standards?
2. Do agricultural and golf course non-point source discharges reach water contact or shellfish* harvesting zones?
3. Are the indicator bacteria* levels in receiving water* getting better or worse?
4. What is the relative contribution of indicator bacteria* to the receiving water* from agricultural and golf course non-point sources?

To answer these questions, core monitoring of representative agricultural irrigation tail water and storm water runoff, at a minimum, will be conducted in receiving water* (ankle depth, point zero) for indicator bacteria*:

a. During wet weather, at a minimum of two storm events per year, and
b. When non-storm water discharges* occur (flowing during dry weather), and if located at an AB 411 beach or within one nautical mile of shellfish* bed, at least weekly.

* See Appendix I for definition of terms.

Alternatively, these requirements may be met through participation in a regional monitoring program to assess the status of marine contact recreation water quality. If the discharger participates in a regional monitoring program, in conjunction with local health organization(s), core monitoring may be suspended for that period at the discretion of the Regional Water Board. Regional monitoring should be used to answer the above questions, and may be used to answer additional questions. These additional questions may include, but are not limited to, questions regarding the extent and magnitude of current or potential receiving water* indicator bacteria* problems, or the sources of indicator bacteria*.*

5. CHEMICAL CONSTITUENTS

5.1. Point Sources

Primary questions addressed:

1. Does the effluent meet permit effluent limits thereby ensuring that water quality standards are achieved in the receiving water*?
2. What is the mass of the constituents that are discharged annually?
3. Is the effluent concentration or mass changing over time?

Consistent with Appendix VI, the core monitoring for the substances in Table 1 and Table 2 shall be required periodically. For discharges less than 10 MGD, the monitoring frequency shall be at least one complete scan of the Table 1 substances annually. Discharges greater than 10 MGD shall be required to monitor at least semiannually.

5.2. Storm Water

Primary questions addressed:

1. Does the receiving water* meet the water quality standards?
2. Are the conditions in receiving water* getting better or worse?
3. What is the relative runoff contribution to pollution in the receiving water*?

For Phase I and Phase II MS4 dischargers, core receiving water* monitoring will be required at a minimum for 10 percent of all outfalls greater than 36 inches in diameter or width once per year. If a discharger has less than five outfalls exceeding 36 inches in diameter or width, they shall conduct monitoring at a minimum of only once per outfall during a five year period. Monitoring shall be for total suspended solids, oil & grease, total organic carbon, pH, temperature, biochemical oxygen demand, turbidity, Table 1 metals, PAHs,*, and pesticides determined by the Regional Water Boards. Regional Water Boards may waive monitoring once structural best management practices have been installed, evaluated and determined to have successfully controlled pollutants.

For industrial storm water discharges, runoff monitoring must be conducted at all outfalls at least two storm events per year. In addition, at least one representative receiving water* sample must be collected per industrial storm water permittee during two storm events per year. Monitoring shall be conducted for total suspended solids, oil & grease, total organic carbon, pH, temperature, biochemical oxygen demand, turbidity, and Table 1 metals and PAHs*.*

* See Appendix I for definition of terms.

The requirements for individual core monitoring for Table 1 metals, PAHs* and pesticides may be waived at the discretion of the Regional Water Board, if the permittee participates in a regional program for monitoring runoff and/or receiving water* to answer the above questions as well as additional questions. Additional questions may include, but are not limited to, questions regarding the extent and magnitude of current or potential receiving water* problems from storm water runoff, or sources of any runoff pollutants.

5.3. Non-point Sources

The primary questions are:

1. Does the agricultural or golf course runoff meet water quality standards in the receiving water*?
2. Are nutrients present that would contribute to objectionable aquatic algal blooms or degrade* indigenous biota?
3. Are the conditions in receiving water* getting better or worse?
4. What is the relative agricultural runoff or golf course contribution to pollution in the receiving water*?

To answer these questions, a statistically representative sample (determined by the Regional Water Board) of receiving water* at the sites of agricultural irrigation tail water and storm water runoff, and golf course runoff in each watershed will be monitored for Ocean Plan Table 1 metals, ammonia as N, nitrate as N, phosphate as P, and pesticides determined by the Regional Board:

a. During wet weather, at a minimum of two storm events per year, and
b. During dry weather, when flowing, at a frequency determined by the Regional Boards.

This requirement may be satisfied by core monitoring individually, or through participation in a regional program for monitoring runoff and receiving water* at the discretion of the Regional Water Board to answer the above questions as well as additional questions. Additional questions may include, but are not limited to, questions regarding the sources of agricultural pollutants.

6. SEDIMENT MONITORING

All Sources:

1. Is the dissolved sulfide concentration of waters in sediments significantly* increased above that present under natural conditions?
2. Is the concentration of substances set forth in Table 1, for protection of marine aquatic life, in marine sediments at levels which would degrade* the benthic community?
3. Is the concentration of organic pollutants in marine sediments at levels that would degrade* the benthic community?

6.1. Point Sources

For discharges greater than 10 MGD, acid volatile sulfides, OP Pesticides, Table 1 metals, ammonia N, PAHs,*, and chlorinated hydrocarbons will be measured in sediments annually in a core monitoring program approved by the Regional Water Board. Sediment sample locations will be determined by the Regional Water Board. If sufficient data exists from previous water

* See Appendix I for definition of terms.

column monitoring for these parameters, the Regional Water Board at its discretion may reduce the frequency of monitoring, or may allow this requirement to be satisfied through participation in a regional monitoring program.

6.2. Storm Water

For Phase I MS4 permittees, discharges greater than 72 inches in diameter or width discharging to low energy coastal environments with the likelihood of sediment deposition, acid volatile sulfides, OP Pesticides, Ocean Plan Table 1 metals, ammonia N, PAHs,*~~,~~ and chlorinated hydrocarbons will be measured in sediments once per permit cycle.

Regional Water Boards may waive monitoring once structural best management practices have been installed, evaluated and determined to have successfully controlled pollutants.

This requirement may be satisfied by core monitoring individually or through participation in a regional monitoring program at the discretion of the Regional Water Board. Sediment sample locations will be determined by the Regional Water Board.

7. AQUATIC LIFE TOXICITY

Toxicity tests are another method used to assess risk to aquatic life. These tests assess the overall toxicity of the effluent, including the toxicity of unmeasured constituents and/or synergistic effects of multiple constituents.

7.1. Point Sources

1. Does the effluent meet permit effluent limits for toxicity thereby ensuring that water quality standards are achieved in the receiving water*?
2. If not:
   a. Are unmeasured pollutants causing risk to aquatic life?
   b. Are pollutants in combinations causing risk to aquatic life?

Core monitoring for Table 1 effluent toxicity shall be required periodically. For discharges less than 0.1 MGD the monitoring frequency for acute and/or chronic toxicity* shall be twice per permit cycle. For discharges between 0.1 and 10 MGD, the monitoring frequency for acute and/or chronic toxicity* of the effluent should be at least annually. For discharges greater than 10 MGD, the monitoring frequency for acute and/or chronic toxicity* of the effluent should be at least semiannually.

For discharges greater than 10 MGD in a low energy coastal environment with the likelihood of sediment deposition, Core monitoring for acute sediment toxicity is required and will utilize alternative amphipod species (*Eohaustorius estuarius, Leptocheirus plumulosus, Rhepoxynius abronius*).

If an exceedance is detected, six additional toxicity tests are required within a 12-week period. If an additional exceedance is detected within the 12-week period, a toxicity reduction evaluation (TRE) is required, consistent with chapter ~~Section~~ III.C.10~~. which~~ that requires a TRE if a discharge consistently exceeds an effluent limitation based on a toxicity objective in Table 1.

* See Appendix I for definition of terms.

7.2. Storm Water

1. Does the runoff meet objectives for toxicity in the receiving water*?
2. Are the conditions in receiving water* getting better or worse with regard to toxicity?
3. What is the relative runoff contribution to the receiving water* toxicity?
4. What are the causes of the toxicity and the sources of the constituents responsible?

For Phase I MS4, Phase II MS4, and industrial storm water discharges, core toxicity monitoring will be required at a minimum for 10 percent of all outfalls greater than 36 inches in diameter or width at a minimum of once per year. Receiving water* monitoring shall be for Table 1 critical life stage chronic toxicity* for a minimum of one invertebrate species.

For storm water discharges greater than 72 inches in diameter or width in a low energy coastal environment with the likelihood of sediment deposition, core sediment monitoring for acute sediment toxicity is required and will utilize alternative amphipod species (*Eohaustorius estuarius, Leptocheirus plumulosus, Rhepoxynius abronius*).

Regional Water Boards may waive monitoring once structural best management practices have been installed, evaluated and determined to have successfully controlled toxicity.

If an exceedence is detected, an additional toxicity test is required during the subsequent storm event. If an additional exceedance is detected at that time, a TRE is required, consistent with chapter ~~Section~~ III.C.10~~.~~ ~~which~~ that requires a TRE if a discharge consistently exceeds an effluent limitation based on a toxicity objective in Table 1. A sufficient volume must be collected to conduct a TIE, if necessary, as a part of a TRE.

The requirement for core toxicity monitoring may be waived at the discretion of the Regional Water Board, if the permittee participates in a regional monitoring program to answer the above questions, as well as any other additional questions that may be developed by the regional monitoring program.

7.3. Non-point Sources

1. Does the agricultural and golf course runoff meet water quality standards for toxicity in the receiving water*?
2. Are the conditions in receiving water* getting better or worse with regard to toxicity?
3. What is the relative agricultural and golf course runoff contribution to receiving water* toxicity?
4. What are the causes of the toxicity, and the sources of the constituents responsible?

To answer these questions, a statistically representative sample (determined by the Regional Water Board) of receiving water* at the sites of agricultural irrigation tail water and storm water runoff, and golf course runoff, in each watershed will be monitored:

a. During wet weather, at a minimum of two storm events per year, and
b. During dry weather, when flowing, at a frequency determined by the Regional Boards.

Core receiving water* monitoring shall include Table 1 critical life stage chronic toxicity* for a minimum of one invertebrate species.

* See Appendix I for definition of terms.

For runoff in a low energy coastal environment with the likelihood of sediment deposition, core sediment monitoring shall include acute sediment toxicity utilizing alternative amphipod species (*Eohaustorius estuarius, Leptocheirus plumulosus, Rhepoxynius abronius*) at a minimum once per year.

If an exceedence is detected, an additional toxicity test is required during the subsequent storm event. If an additional exceedance is detected, a TRE is required, consistent with chapter ~~Section~~ III.C.10~~.which~~ that requires a TRE if a discharge consistently exceeds an effluent limitation based on a toxicity objective in Table 1. A sufficient volume must be collected to conduct a TIE, if necessary, as a part of a TRE.

The requirement for core monitoring may be waived at the discretion of the Regional Water Board, if the permittee participates in a regional monitoring program to answer the above questions, as well as any other additional questions that may be developed by the regional monitoring program.

8. BENTHIC COMMUNITY HEALTH

8.1. Point Sources

1. Are benthic communities degraded* as a result of the discharge?

To answer this question, benthic community monitoring shall be conducted
   a. for all discharges greater than 10 MGD, or
   b. those discharges greater than 0.1 MGD and one nautical mile or less from shore, or
   c. discharges greater than 0.1 MGD and one nautical mile or less from a State Water Quality Protection Area* or a State Marine Reserve.

The minimum frequency shall be once per permit cycle, except for discharges greater than 100 MGD the minimum frequency shall be at least twice per permit cycle.

This requirement may be satisfied by core monitoring individually or through participation in a regional monitoring program at the discretion of the Regional Board.

9. BIOACCUMULATION

9.1. Point Sources

1. Does the concentration of pollutants in fish, shellfish,*~~,~~ or other marine resources used for human consumption bioaccumulate to levels that are harmful to human health?
2. Does the concentration of pollutants in marine life bioaccumulate to levels that degrade* marine communities?

To answer these questions, bioaccumulation monitoring shall be conducted, at a minimum, once per permit cycle for:

   a. discharges greater than 10 MGD, or
   b. those discharges greater than 0.1 MGD and one nautical mile or less from shore, or
   c. discharges greater than 0.1 MGD and one nautical mile or less from a State Water Quality Protection Area* or a State Marine Reserve, Park or Conservation Area.

* See Appendix I for definition of terms.

Constituents to be monitored must include pesticides (at the discretion of the Regional Board), Table 1 metals, and PAHs*.* Bioaccumulation may be monitored by a mussel watch program or a fish tissue program. Resident mussels are preferred over transplanted mussels. Sand crabs and/or fish may be added or substituted for mussels at the discretion of the Regional Water Board.

This requirement may be satisfied individually as core monitoring or through participation in a regional monitoring program at the discretion of the Regional Water Board.

9.2. Storm Water

1. Does the concentration of pollutants in fish, shellfish,*, or other marine resources used for human consumption bioaccumulate to levels that are harmful to human health?
2. Does the concentration of pollutants in marine life bioaccumulate to levels that degrade* marine communities?

For Phase I MS4 dischargers, bioaccumulation monitoring shall be conducted, at a minimum, once per permit cycle. Constituents to be monitored must include OP Pesticides, Ocean Plan Table 1 metals, Table 1 PAHs,*, Table 1 chlorinated hydrocarbons, and pyrethroids. Bioaccumulation may be monitored by a mussel watch program or a fish tissue program. Sand crabs, fish, and/or Solid Phase Microextraction may be added or substituted for mussels at the discretion of the Regional Water Board.

This requirement may be satisfied individually as core monitoring or through participation in a regional monitoring program at the discretion of the Regional Water Board.

10. RECEIVING WATER* CHARACTERISTICS

All Sources:

1. Is natural light* significantly* reduced at any point outside the zone of initial dilution* as the result of the discharge of waste*?
2. Does the discharge of waste* cause a discoloration of the ocean surface?
3. Does the discharge of oxygen demanding waste* cause the dissolved oxygen concentration to be depressed at any time more than 10 percent from that which occurs naturally, as the result of the discharge of oxygen demanding* waste* materials*?
4. Does the discharge of waste* cause the pH to change at any time more than 0.2 units from that which occurs naturally?
5. Does the discharge of waste* cause the salinity* to become elevated in the receiving water*?
6. Do nutrients cause objectionable aquatic growth or degrade* indigenous biota?

10.1. Point Sources

For discharges greater than 10 MGD, turbidity (alternatively light transmissivity or surface water transparency), color [Chlorophyll-A and/or color dissolved organic matter (CDOM)], dissolved oxygen and pH shall be measured in the receiving water* seasonally, at a minimum, in a core monitoring program approved by the Regional Water Board. If sufficient data exists from previous water column monitoring for these parameters, the Regional Water Board, at its

* See Appendix I for definition of terms.

discretion, may reduce the frequency of water column monitoring, or may allow this requirement to be satisfied through participation in a regional monitoring program. Use of regional ocean observing programs, such as the Southern California Coastal Ocean Observing System (SCCOOS) and the Central and Northern California Ocean Observing System (CeNCCOOS) is encouraged.

Salinity* must also be monitored by all point sources discharging ~~desalination~~ brine* as part of their core monitoring program. Desalination facilities* discharging brine* into ocean waters* shall monitor salinity as described in chapter III.L.4.

10.2. Storm Water

At a minimum, at 10 percent of Phase I MS4 discharges greater than 36 inches in diameter or width, receiving water* turbidity, color, dissolved oxygen, pH, nitrate, phosphate, and ammonia shall be measured annually in a core monitoring program approved by the Regional Water Board.

Regional Water Boards may waive monitoring once structural best management practices have been installed, evaluated and determined to have successfully controlled pollutants. The Regional Water Board, at its discretion, may also allow this requirement to be satisfied through participation in a regional monitoring program.

10.3. Non-point Sources

Representative agricultural and golf course discharges shall be measured, at a minimum twice annually (during the storm season and irrigation season) for receiving water* turbidity, color, dissolved oxygen, pH, nitrate, phosphate, ammonia in a core monitoring program approved by the Regional Water Board. The Regional Water Board, at its discretion, may allow this requirement to be satisfied through participation in a regional monitoring program.

11. ANALYTICAL REQUIREMENTS

Procedures, calibration techniques, and instrument/reagent specifications shall conform to the requirements of 40 CFR PART 136. Compliance monitoring shall be determined using an U.S. EPA approved protocol as provided in 40 CFR PART 136. All methods shall be specified in the monitoring requirement section of waste* discharge requirements.

Where methods are not available in 40 CFR PART 136, the Regional Water Boards shall specify suitable analytical test methods in waste* discharge requirements. Acceptance of data should be predicated on demonstrated laboratory performance.

Laboratories analyzing monitoring data shall be certified by the California Department of Public Health, in accordance with the provisions of Water Code section 13176, and must include quality assurance quality control data with their reports.

Sample dilutions for total and fecal coliform bacterial analyses shall range from 2 to 16,000. Sample dilutions for enterococcus bacterial analyses shall range from 1 to 10,000 per 100 mL. Each test method number or name (e.g., EPA 600/4-85/076, Test Methods for *Escherichia coli* and *Enterococci* in Water by Membrane Filter Procedure) used for each analysis shall be specified and reported with the results.

* See Appendix I for definition of terms.

Test methods used for coliforms (total and fecal) shall be those presented in Table 1A of 40 CFR PART 136, unless alternate test methods have been approved in advance by U.S. EPA pursuant to 40 CFR PART 136.

Test methods used for enterococcus shall be those presented in U.S. EPA publication EPA 600/4-85/076, Test Methods for *Escherichia coli* and *Enterococci* in Water by Membrane Filter Procedure or any improved test method determined by the Regional Board to be appropriate. The Regional Water Board may allow analysis for *Escherichia coli* (*E. coli)* by approved test methods to be substituted for fecal coliforms if sufficient information exists to support comparability with approved test methods and substitute the existing test methods.

The State or Regional Water Board may, subject to U.S. EPA approval, specify test methods which are more sensitive than those specified in 40 CFR PART 136. Because storm water and non-point sources are not assigned a dilution factor, sufficient sampling and analysis shall be required to determine compliance with Table 1 Water Quality Objectives. Total chlorine residual is likely to be a test method detection limit effluent limitation in many cases. The limit of detection of total chlorine residual in standard test methods is less than or equal to 20 µg/L.

Toxicity monitoring requirements in permits prepared by the Regional Water Boards shall use marine test species instead of freshwater species when measuring compliance. The Regional Water Board shall require the use of critical life stage toxicity tests specified in this Appendix to measure TUc. For Point Sources, a minimum of three test species with approved test protocols shall be used to measure compliance with the toxicity objective. If possible, the test species shall include a fish, an invertebrate, and an aquatic plant. After a screening period, monitoring can be reduced to the most sensitive species.

Dilution and control water should be obtained from an unaffected area of the receiving waters*.* The sensitivity of the test organisms to a reference toxicant shall be determined concurrently with each bioassay test and reported with the test results.

Use of critical life stage bioassay testing shall be included in waste* discharge requirements as a monitoring requirement for all Point Source discharges greater than 100 MGD.

Procedures and test methods used to determine compliance with benthic monitoring should use the following federal guidelines when applicable: Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters (1990) -- EPA/600/4-90/030 (PB91-171363). This manual describes guidelines and standardized procedures for the use of macroinvertebrates in evaluating the biological integrity of surface waters.

Procedures used to determine compliance with bioaccumulation monitoring should use the U.S. EPA. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (November 2000, EPA 823-B-00-007), NOAA Technical Memorandum NOS ORCA 130, Sampling and Analytical Methods of the National Status and Trends Program Mussel Watch Project (1998 update), and/or State Mussel Watch Program, 1987-1993 Data Report, State Water Resources Control Board 94-1WQ.

* See Appendix I for definition of terms.

TABLE III-1
APPROVED TESTS – CHRONIC TOXICITY* (TUc)

Species	Effect	Tier	Reference
giant kelp, *Macrocystis pyrifera*	percent germination; germ tube length	1	1,3
red abalone, *Haliotis rufescens*	Abnormal shell development	1	1,3
oyster, *Crassostrea gigas*; mussels, *Mytilus spp.*	Abnormal shell development; percent survival	1	1,3
urchin, *Strongylocentrotus purpuratus*; sand dollar, *Dendraster excentricus*	Percent normal development	1	1,3
urchin, *Strongylocentrotus purpuratus*; sand dollar, *Dendraster excentricus*	Percent fertilization	1	1,3
shrimp, *Holmesimysis costata*	Percent survival; growth	1	1,3
shrimp, *Mysidopsis bahia*	Percent survival; growth; fecundity	2	2,4
topsmelt, *Atherinops affinis*	Larval growth rate; percent survival	1	1,3
Silversides, *Menidia beryllina*	Larval growth rate; percent survival	2	2,4

Table III-1 Notes

The first tier test methods are the preferred toxicity tests for compliance monitoring. A Regional Water Board can approve the use of a second tier test method for waste* discharges if first tier organisms are not available.

* See Appendix I for definition of terms.

Protocol References

1. Chapman, G.A., D.L. Denton, and J.M. Lazorchak. 1995. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to west coast marine and estuarine organisms. U.S. EPA Report No. EPA/600/R-95/136.

2. Klemm, D.J., G.E. Morrison, T.J. Norberg-King, W.J. Peltier, and M.A. Heber. 1994. Short-term methods for estimating the chronic toxicity of effluents and receiving water to marine and estuarine organisms. U.S. EPA Report No. EPA-600-4-91-003.

3. SWRCB 1996. Procedures Manual for Conducting Toxicity Tests Developed by the Marine Bioassay Project. 96-1WQ.

4. Weber, C.I., W.B. Horning, I.I., D.J. Klemm, T.W. Nieheisel, P.A. Lewis, E.L. Robinson, J. Menkedick and F. Kessler (eds). 1988. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms. EPA/600/4-87/028. National Information Service, Springfield, VA.

* See Appendix I for definition of terms.

APPENDIX IV
PROCEDURES FOR THE NOMINATION AND DESIGNATION OF STATE WATER QUALITY PROTECTION AREAS*.*

1. Any person may nominate areas of ocean waters* for designation as SWQPA-ASBS or SWQPA-GP by the State Water Board. Nominations shall be made to the appropriate Regional Water Board and shall include:

   (a) Information such as maps, reports, data, statements, and photographs to show that:

      (1) Candidate areas are located in ocean waters* as defined in the “Ocean Plan”.

      (2) Candidate areas are intrinsically valuable or have recognized value to man for scientific study, commercial use, recreational use, or esthetic reasons.

      (3) Candidate areas need protection beyond that offered by waste* discharge restrictions or other administrative and statutory mechanisms.

   (b) Data and information to indicate whether the proposed designation may have a significant* effect on the environment.

      (1) If the data or information indicate that the proposed designation will have a significant* effect on the environment, the nominee must submit sufficient information and data to identify feasible changes in the designation that will mitigate or avoid the significant* environmental effects.

2. The State Water Board or a Regional Water Board may also nominate areas for designation as SWQPA-ASBS or SWQPA-GP on their own motion.

3. A Regional Water Board may decide to (a) consider individual SWQPA-ASBS or SWQPA-GP nominations upon receipt, (b) consider several nominations in a consolidated proceeding, or (c) consider nominations in the triennial review of its water quality control plan (basin plan). A nomination that meets the requirements of 1. above may be considered at any time but not later than the next scheduled triennial review of the appropriate basin plan or Ocean Plan.

4. After determining that a nomination meets the requirements of paragraph 1. above, the Executive Officer of the affected Regional Water Board shall prepare a Draft Nomination Report containing the following:

   (a) The area or areas nominated for designation as SWQPA-ASBS or SWQPA-GP.

   (b) A description of each area including a map delineating the boundaries of each proposed area.

   (c) A recommendation for action on the nomination(s) and the rationale for the recommendation. If the Draft Nomination Report recommends approval of the proposed designation, the Draft Nomination Report shall comply with the CEQA documentation requirements for a water quality control plan amendment in Ssection 3777, Ttitle 23, California Code of Regulations.

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* See Appendix I for definition of terms.

5. The Executive Officer shall, at a minimum, seek informal comment on the Draft Nomination Report from the State Water Board, Department of Fish and Game, other interested state and federal agencies, conservation groups, affected waste dischargers, and other interested parties. Upon incorporation of responses from the consulted agencies, the Draft Nomination Report shall become the Final Nomination Report.

6. (a) If the Final Nomination Report recommends approval of the proposed designation, the Executive Officer shall ensure that processing of the nomination complies with the CEQA consultation requirements in ~~S~~section 3778, Title 23, California Code of Regulations and proceed to step 7 below.

   (b) If the Final Nomination Report recommends against approval of the proposed designation, the Executive Officer shall notify interested parties of the decision. No further action need be taken. The nominating party may seek reconsideration of the decision by the Regional Water Board itself.

7. The Regional Water Board shall conduct a public hearing to receive testimony on the proposed designation. Notice of the hearing shall be published three times in a newspaper of general circulation in the vicinity of the proposed area or areas and shall be distributed to all known interested parties 45 days in advance of the hearing. The notice shall describe the location, boundaries, and extent of the area or areas under consideration, as well as proposed restrictions on waste* discharges within the area.

8. The Regional Water Board shall respond to comments as required in ~~S~~section 3779, Title 23, California Code of Regulations, and 40 C.F.R. Part 25 (July 1, 1999).

9. The Regional Water Board shall consider the nomination after completing the required public review processes required by CEQA.

   (a) If the Regional Water Board supports the recommendation for designation, the board shall forward to the State Water Board its recommendation for approving designation of the proposed area or areas and the supporting rationale. The Regional Water Board submittal shall include a copy of the staff report, hearing transcript, comments, and responses to comments.

   (b) If the Regional Water Board does not support the recommendation for designation, the Executive Officer shall notify interested parties of the decision, and no further action need be taken.

10. After considering the Regional Water Board recommendation and hearing record, the State Water Board may approve or deny the recommendation, refer the matter to the Regional Water Board for appropriate action, or conduct further hearing itself. If the State Water Board acts to approve a recommended designation, the State Water Board shall amend Appendix V, Table V-1, of this Plan. The amendment will go into effect after approval by the Office of Administrative Law and US EPA. In addition, after the effective date of a designation, the affected Regional Water Board shall revise its water quality control plan in the next triennial review to include the designation.

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* See Appendix I for definition of terms.

12. The State Water Board Executive Director shall advise other agencies to whom the list of designated areas is to be provided that the basis for an SWQPA-ASBS or SWQPA-GP designation is limited to protection of marine life from waste* discharges.

* See Appendix I for definition of terms.

APPENDIX V
STATE WATER QUALITY PROTECTION AREAS*
AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE*

TABLE V-1
STATE WATER QUALITY PROTECTION AREAS*
AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE*
(DESIGNATED OR APPROVED BY THE STATE WATER RESOURCES CONTROL BOARD)

No.	ASBS Name	Date Designated	State Water Board Resolution No.	Region No.
1.	Jughandle Cove	March 21, 1974,	74-28	1
2.	Del Mar Landing	March 21, 1974,	74-28	1
3.	Gerstle Cove	March 21, 1974,	74-28	1
4.	Bodega	March 21, 1974,	74-28	1
5.	Saunders Reef	March 21, 1974,	74-28	1
6.	Trinidad Head	March 21, 1974,	74-28	1
7.	King Range	March 21, 1974,	74-28	1
8.	Redwoods National Park	March 21, 1974,	74-28	1
9.	James V. Fitzgerald	March 21, 1974,	74-28	2
10.	Farallon Islands	March 21, 1974,	74-28	2
11.	Duxbury Reef	March 21, 1974,	74-28	2
12.	Point Reyes Headlands	March 21, 1974,	74-28	2
13.	Double Point	March 21, 1974,	74-28	2
14.	Bird Rock	March 21, 1974,	74-28	2
15.	Año Nuevo	March 21, 1974,	74-28	3
16.	Point Lobos	March 21, 1974,	74-28	3
17.	San Miguel, Santa Rosa, and Santa Cruz Islands	March 21, 1974,	74-28	3
18.	Julia Pfeiffer Burns	March 21, 1974,	74-28	3
19.	Pacific Grove	March 21, 1974,	74-28	3
20.	Salmon Creek Coast	March 21, 1974,	74-28	3
21.	San Nicolas Island and Begg Rock	March 21, 1974,	74-28	4
22.	Santa Barbara and Anacapa Islands	March 21, 1974,	74-28	4
23.	San Clemente Island	March 21, 1974,	74-28	4

Table V-1 Continued on next page…

* See Appendix I for definition of terms.

Table V-1 (Continued)

Areas of Special Biological Significance*
(Designated or Approved by the State Water Resources Control Board)

No.	ASBS Name	Date Designated	State Water Board Resolution No.	Regio n No.
24.	Laguna Point to Latigo Point	March 21, 1974,	74-28	4
25.	Northwest Santa Catalina Island	March 21, 1974,	74-28	4
26.	Western Santa Catalina Island	March 21, 1974,	74-28	4
27.	Farnsworth Bank	March 21, 1974,	74-28	4
28.	Southeast Santa Catalina	March 21, 1974,	74-28	4
29.	La Jolla	March 21, 1974,	74-28	9
30.	Heisler Park	March 21, 1974,	74-28	9
31.	San Diego-Scripps	March 21, 1974,	74-28	9
32.	Robert E. Badham	April 18, 1974	74-32	8
33.	Irvine Coast	April 18, 1974	74-32	8,9
34.	Carmel Bay	June 19, 1975	75-61	3

* See Appendix I for definition of terms.

APPENDIX VI

REASONABLE POTENTIAL ANALYSIS PROCEDURE FOR DETERMINING WHICH TABLE 1 OBJECTIVES REQUIRE EFFLUENT LIMITATIONS

In determining the need for an effluent limitation, the Regional Water Board shall use all representative information to characterize the pollutant discharge using a scientifically defensible statistical method that accounts for the averaging period of the water quality objective, accounts for and captures the long-term variability of the pollutant in the effluent, accounts for limitations associated with sparse data sets, accounts for uncertainty associated with censored data sets, and (unless otherwise demonstrated) assumes a lognormal distribution of the facility-specific effluent data.

The purpose of the following procedure (see also Figure VI-1) is to provide direction to the Regional Water Boards for determining if a pollutant discharge causes, has the reasonable potential to cause, or contributes to an excursion above Table 1 water quality objectives in accordance with 40 CFR 122.44 (d)(1)(iii). The Regional Water Board may use an alternative approach for assessing reasonable potential such as an appropriate stochastic dilution model that incorporates both ambient and effluent variability. The permit fact sheet or statement of basis will document the justification or basis for the conclusions of the reasonable potential assessment. This appendix does not apply to permits or any portion of a permit where the discharge is regulated through best management practices (BMP) unless such discharge is also subject to numeric effluent limitations.

<u>Step 1</u>: Identify C_o, the applicable water quality objective from Table 1 for the pollutant.

<u>Step 2</u>: Does information about the receiving water* body or the discharge support a reasonable potential assessment (RPA) without characterizing facility-specific effluent monitoring data? If yes, go to *Step 13* to conduct an RPA based on best professional judgment (BPJ). Otherwise, proceed to *Step 3*.

<u>Step 3</u>: Is facility-specific effluent monitoring data available? If yes, proceed to *Step 4.* Otherwise, go to *Step 13.*

<u>Step 4</u>: Adjust all effluent monitoring data C_e, including censored (ND or DNQ) values to the concentration *X* expected after complete mixing. For Table 1 pollutants use $X = (C_e + D_m C_s) / (D_m + 1)$; for acute toxicity* use $X = C_e / (0.1 D_m + 1)$; where D_m is the minimum probable initial dilution* expressed as parts seawater* per part wastewater and C_s is the background seawater* concentration from Table ~~C~~3. For ND values, C_e is replaced with "<MDL*;" for DNQ values C_e is replaced with "<ML.*" Go to *Step 5*.

<u>Step 5</u>: Count the total number of samples *n*, the number of censored (ND or DNQ) values, *c* and the number of detected values, *d, such that* $n = c + d$.

Is any *detected* pollutant concentration after complete mixing greater than C_o? If yes, the discharge causes an excursion of C_o; go to *Endpoint 1*. Otherwise, proceed to *Step 6*.

* See Appendix I for definition of terms.

Step 6: Does the effluent monitoring data contain three or more detected observations ($d \geq 3$)? If yes, proceed to *Step 7* to conduct a parametric RPA. Otherwise, go to *Step11* to conduct a nonparametric RPA.

Step 7: Conduct a parametric RPA. Assume data are lognormally distributed, unless otherwise demonstrated. Does the data consist entirely of detected values ($c/n = 0$)? If yes,

- calculate summary statistics M_L and S_L, the mean and standard deviation of the natural logarithm transformed effluent data expected after complete mixing, ln(X),
- go to *Step 9*.

Otherwise, proceed to *Step 8*.

Step 8: Is the data censored by 80% or less ($c/n \leq 0.8$)? If yes,

- calculate summary statistics M_L and S_L using the censored data analysis method of Helsel and Cohn (1988),
- go to *Step 9*.

Otherwise, go to Step 11.

Step 9: Calculate the UCB i.e., the one-sided, upper 95 percent confidence bound for the 95th percentile of the effluent distribution after complete mixing. For lognormal distributions, use $UCBL_{(.95,.95)} = \exp(M_L + S_L\, g'_{(.95,.95,n)})$, where g' is a normal tolerance factor obtained from the table below (Table VI-1). Proceed to *Step 10*.

Step 10: Is the UCB greater than C_o? If yes, the discharge has a reasonable potential to cause an excursion of C_o; go to *Endpoint 1*. Otherwise, the discharge has no reasonable potential to cause an excursion of C_o; go to *Endpoint 2*.

Step 11: Conduct a non-parametric RPA. Compare each data value X to C_o. Reduce the sample size n by 1 for each tie (i.e., inconclusive censored value result) present. An adjusted ND value having C_o < MDL* is a tie. An adjusted DNQ value having C_o < ML* is also a tie.

Step 12: Is the adjusted n > 15? If yes, the discharge has no reasonable potential to cause an excursion of C_o; go to *Endpoint 2*. Otherwise, go to *Endpoint 3*.

Step 13: Conduct an RPA based on BPJ. Review all available information to determine if a water quality-based effluent limitation is required, notwithstanding the above analysis in *Steps 1* through *12*, to protect beneficial uses. Information that may be used includes: the facility type, the discharge type, solids loading analysis, lack of dilution, history of compliance problems, potential toxic impact of discharge, fish tissue residue data, water quality and beneficial uses of the receiving water*,* CWA 303(d) listing for the pollutant, the presence of endangered or threatened species or critical habitat, and other information.

Is data or other information unavailable or insufficient to determine if a water quality-based effluent limitation is required? If yes, go to *Endpoint 3.* Otherwise, go to either *Endpoint 1* or *Endpoint 2* based on BPJ.

Endpoint 1: An effluent limitation must be developed for the pollutant. Effluent monitoring for the pollutant, consistent with the monitoring frequency in Appendix III, is required.

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* See Appendix I for definition of terms.

Endpoint 2: An effluent limitation is not required for the pollutant. Appendix III effluent monitoring is not required for the pollutant; the Regional Board, however, may require occasional monitoring for the pollutant or for whole effluent toxicity as appropriate.

Endpoint 3: The RPA is inconclusive. Monitoring for the pollutant or whole effluent toxicity testing, consistent with the monitoring frequency in Appendix III, is required. An existing effluent limitation for the pollutant shall remain in the permit, otherwise the permit shall include a reopener clause to allow for subsequent modification of the permit to include an effluent limitation if the monitoring establishes that the discharge causes, has the reasonable potential to cause, or contributes to an excursion above a Table 1 water quality objective.

Appendix VI References:

Helsel D. R. and T. A. Cohn. 1988. Estimation of descriptive statistics for multiply censored water quality data. Water Resources Research, Vol 24(12):1977-2004.

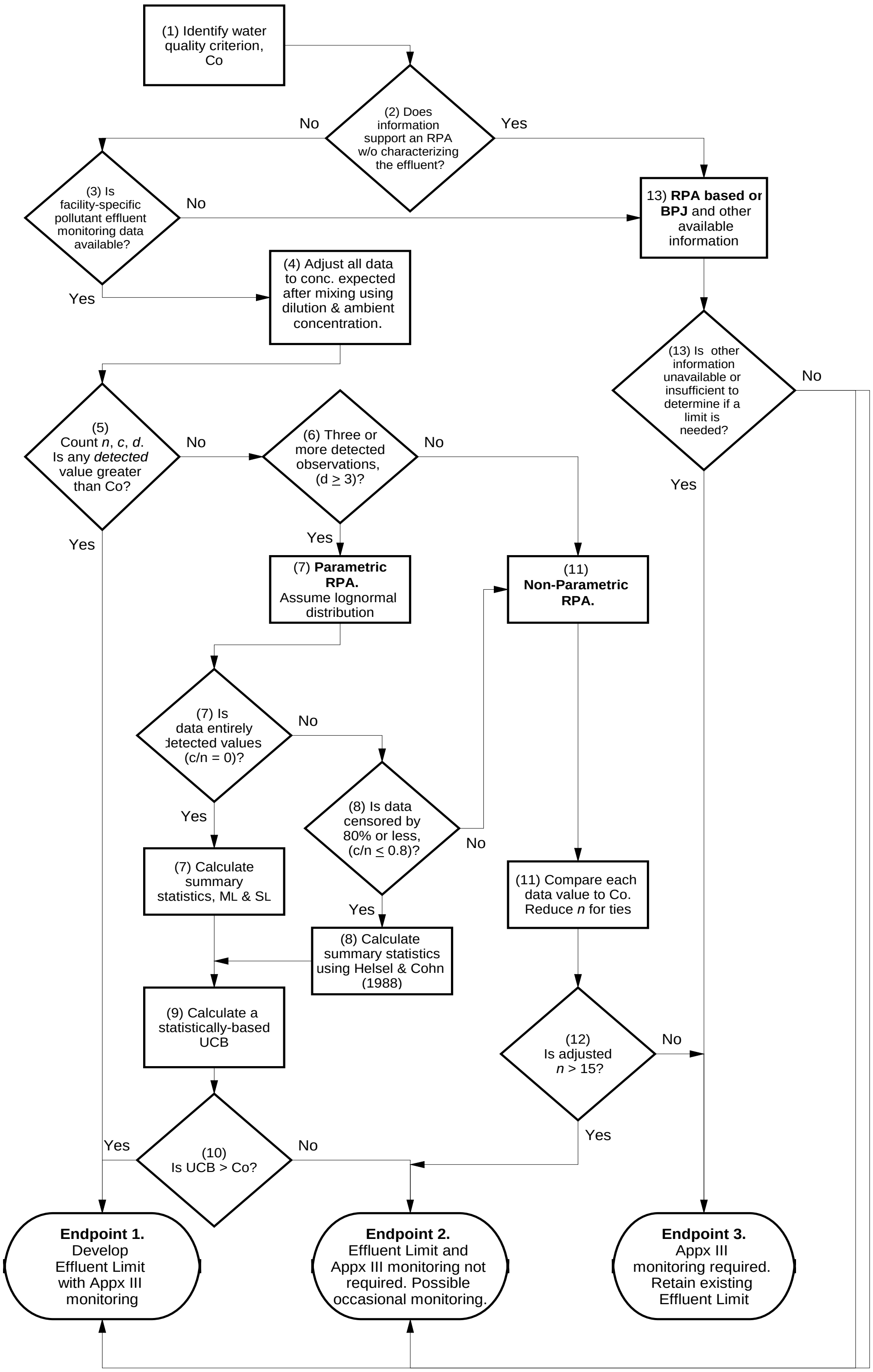
Hahn J. H. and W. Q. Meeker. 1991. Statistical Intervals, A guide for practitioners. J. Wiley & Sons, NY.

TABLE VI-1: Tolerance factors $g'_{(.95,.95,n)}$ for calculating normal distribution one-sided upper 95 percent tolerance bounds for the 95th percentile (Hahn & Meeker 1991)

n	$g'_{(.95,.95,n)}$	***n***	$g'_{(.95,.95,n)}$
2	26.260	21	2.371
3	7.656	22	2.349
4	5.144	23	2.328
5	4.203	24	2.309
6	3.708	25	2.292
7	3.399	26	2.275
8	3.187	27	2.260
9	3.031	28	2.246
10	2.911	29	2.232
11	2.815	30	2.220
12	2.736	35	2.167
13	2.671	40	2.125
14	2.614	50	2.065
15	2.566	60	2.022
16	2.524	120	1.899
17	2.486	240	1.819
18	2.453	480	1.766
19	2.423	∞	1.645
20	2.396		

* See Appendix I for definition of terms.

Figure VI-1. Reasonable potential analysis flow chart



* See Appendix I for definition of terms.

APPENDIX VII

EXCEPTIONS TO THE CALIFORNIA OCEAN PLAN

TABLE VII-1
EXCEPTIONS TO THE OCEAN PLAN

(GRANTED BY THE STATE WATER RESOURCES CONTROL BOARD)

Year	Resolution	Applicable Provision	Discharger
1977	77-11	Discharge Prohibition, ASBS #23	US Navy San Clemente Island
1979	79-16	Discharge Prohibition for wet weather discharges from combined storm and wastewater collection system.	The City and County of San Francisco
1983	83-78	Discharge Prohibition, ASBS #7	Humboldt County Resort Improvement District No.1
1984	84-78	Discharge Prohibition, ASBS #34	Carmel Sanitary District
1988	88-80	Total Chlorine Residual Limitation	Haynes Power Plant Harbor Power Plant Scattergood Power Plant Alamitos Power Plant El Segundo Power Plant Long Beach Power Plant Mandalay Power Plant Ormond Beach Power Plant Redondo Power Plant
1990	90-105	Discharge Prohibition, ASBS #21	US Navy San Nicolas Island
2004	2004-0052	Discharge Prohibition, ASBS #31	UC Scripps Institution of Oceanography
2006	2006-0013	Discharge Prohibition, ASBS #25	USC Wrigley Marine Science Center
2007	2007-0058	Discharge Prohibition, ASBS #4	UC Davis Bodega Marine Laboratory
2011	2011-0049	Discharge Prohibition, ASBS #6	HSU Telonicher Marine lab
2011	2011-0050	Discharge Prohibition, ASBS #19	Monterey Bay Aquarium
2011	2011-0051	Discharge Prohibition, ASBS #19	Stanford Hopkins Marine Station
2012	2012-0012, as amended on June 19	ASBS Discharge Prohibition, General Exception for Storm Water and Nonpoint Sources	27 applicants for the General Exception

* See Appendix I for definition of terms.

	2012; in 2012-0031		

* See Appendix I for definition of terms.

APPENDIX VIII
MAPS OF THE OCEAN, COAST, AND ISLANDS

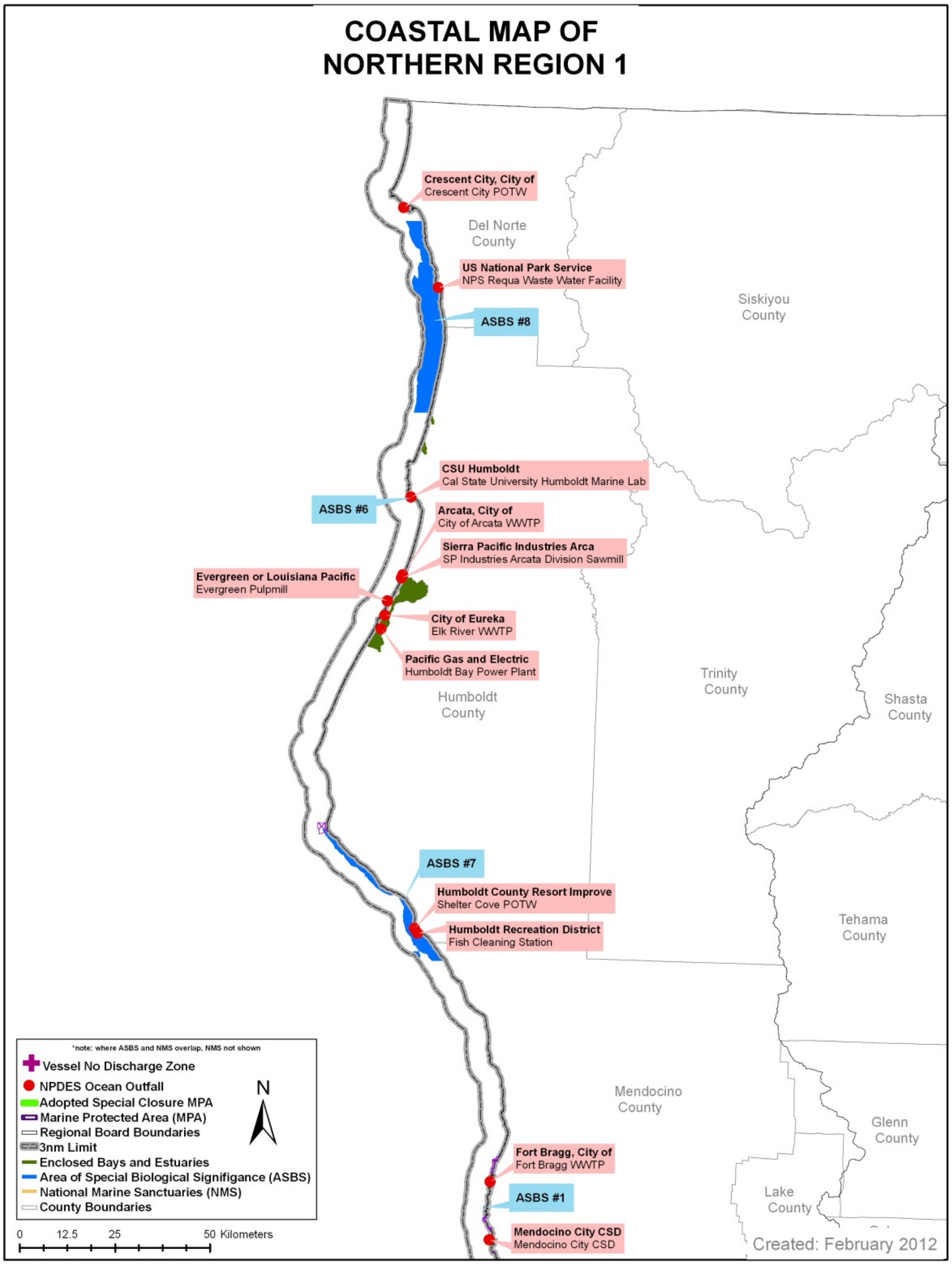


Figure VIII-1. ASBS Boundaries, MPA Boundaries, Wastewater Outfall Points, Marine Sanctuary Boundaries, and Enclosed Bays in northern Region 1.

* See Appendix I for definition of terms.

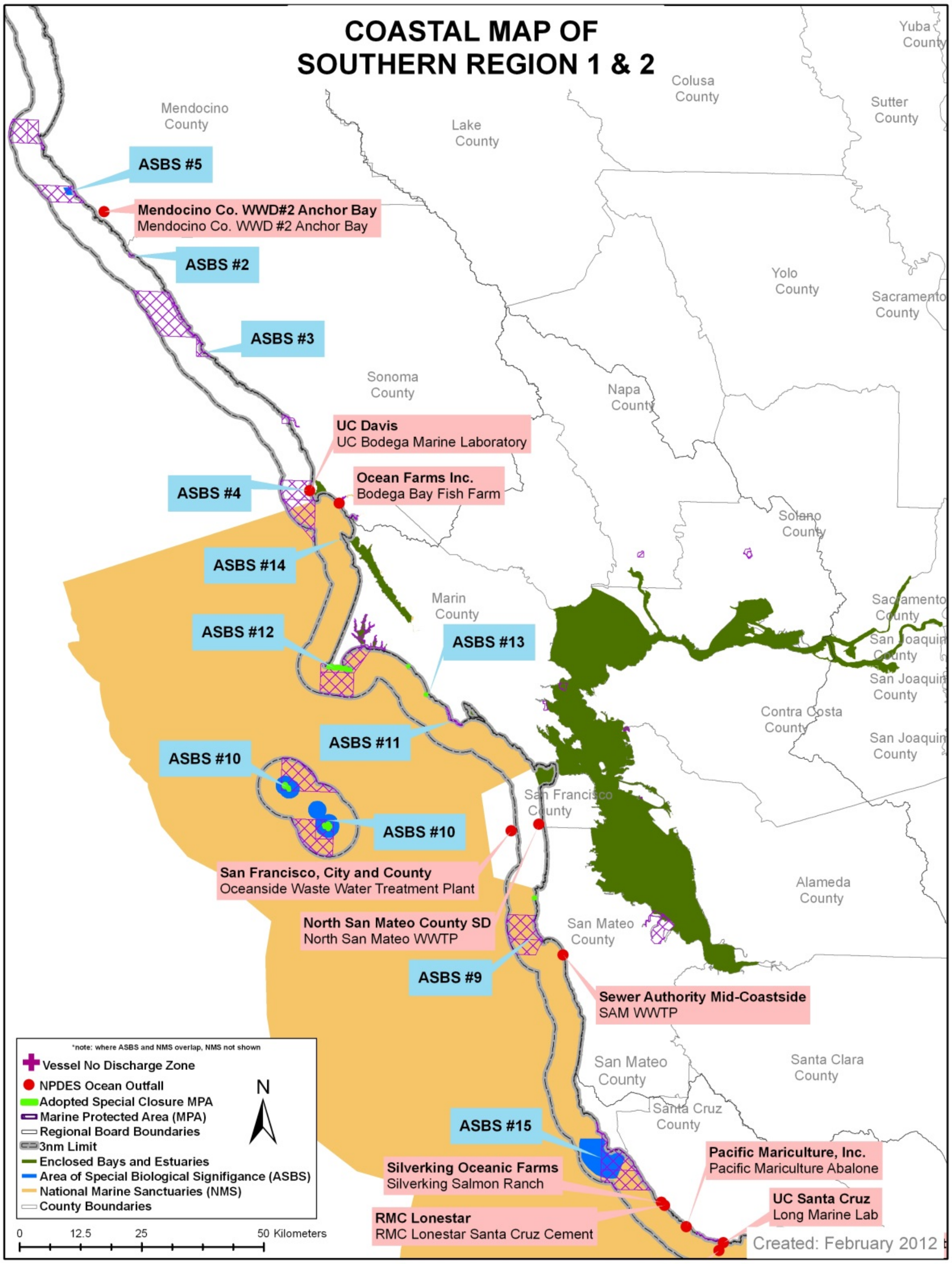


Figure VIII-2. ASBS Boundaries, MPA Boundaries, Wastewater Outfall Points, Marine Sanctuary Boundaries, and Enclosed Bays in southern Region 1 and Region 2.

* See Appendix I for definition of terms.

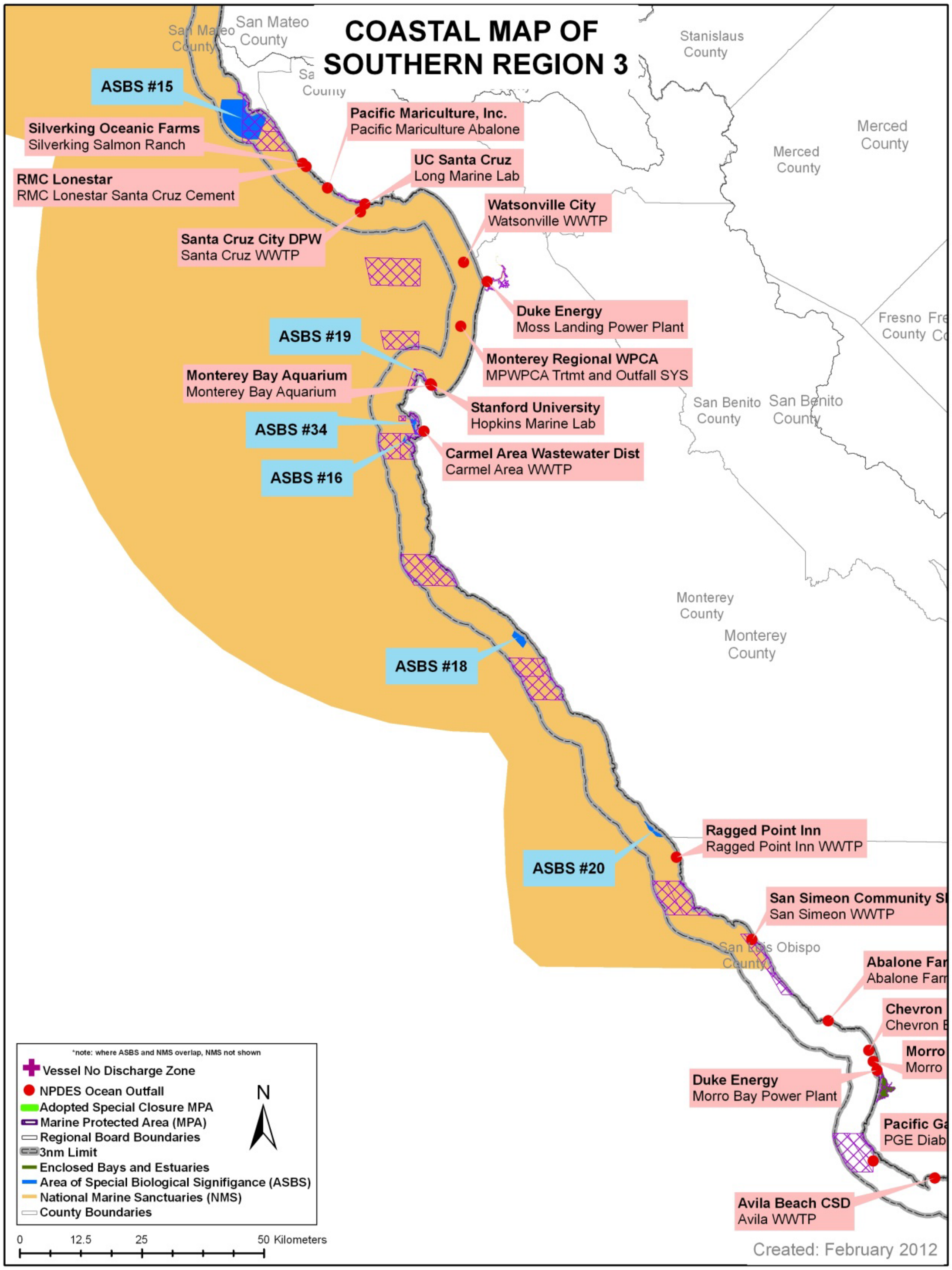


Figure VIII-3. ASBS Boundaries, MPA Boundaries, Wastewater Outfall Points, Marine Sanctuary Boundaries, and Enclosed Bays in northern Region 3.

* See Appendix I for definition of terms.

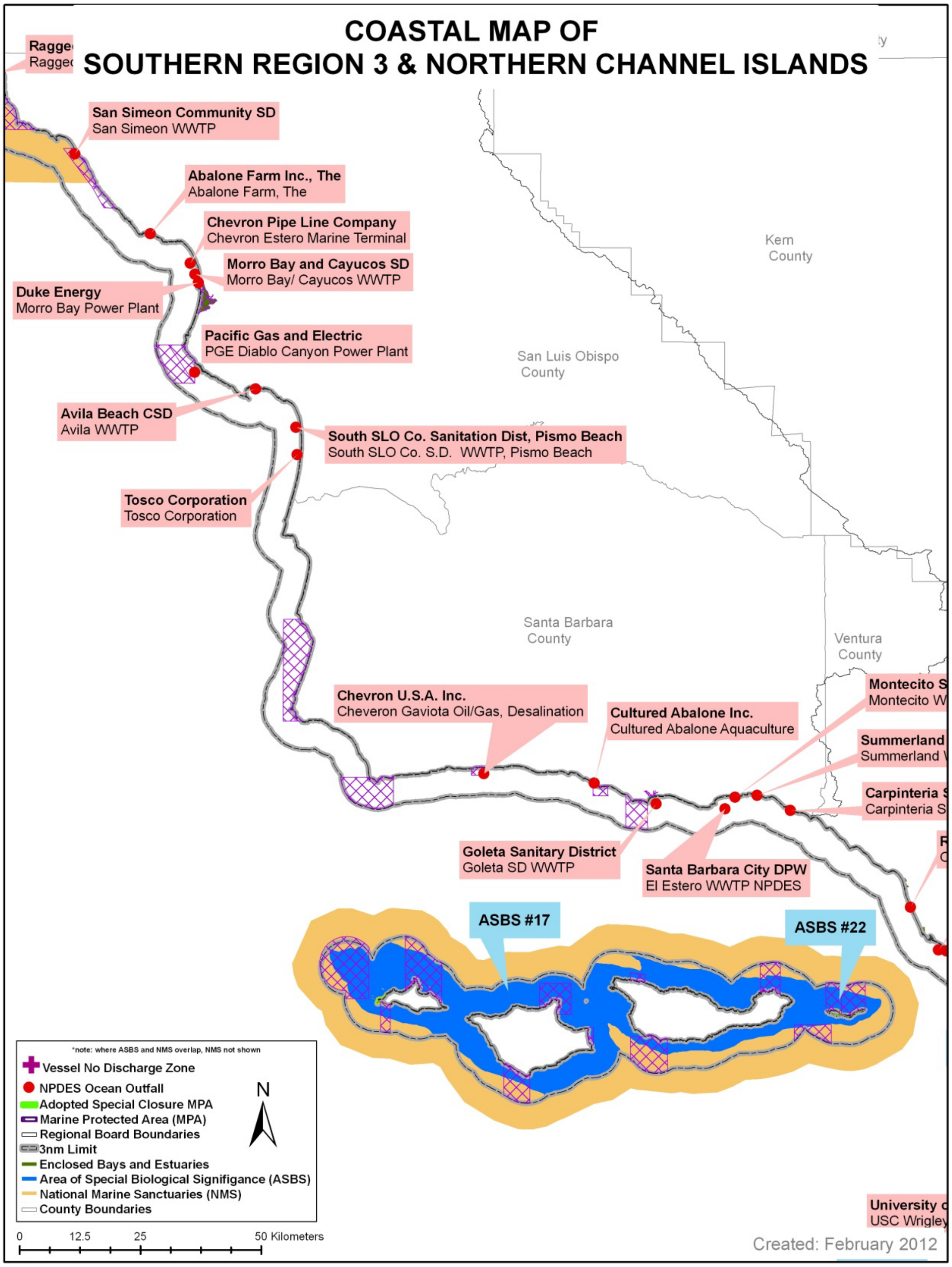


Figure VIII-4. ASBS Boundaries, MPA Boundaries, Wastewater Outfall Points, Marine Sanctuary Boundaries, and Enclosed Bays in southern Region 3 and northern Channel Islands.

* See Appendix I for definition of terms.

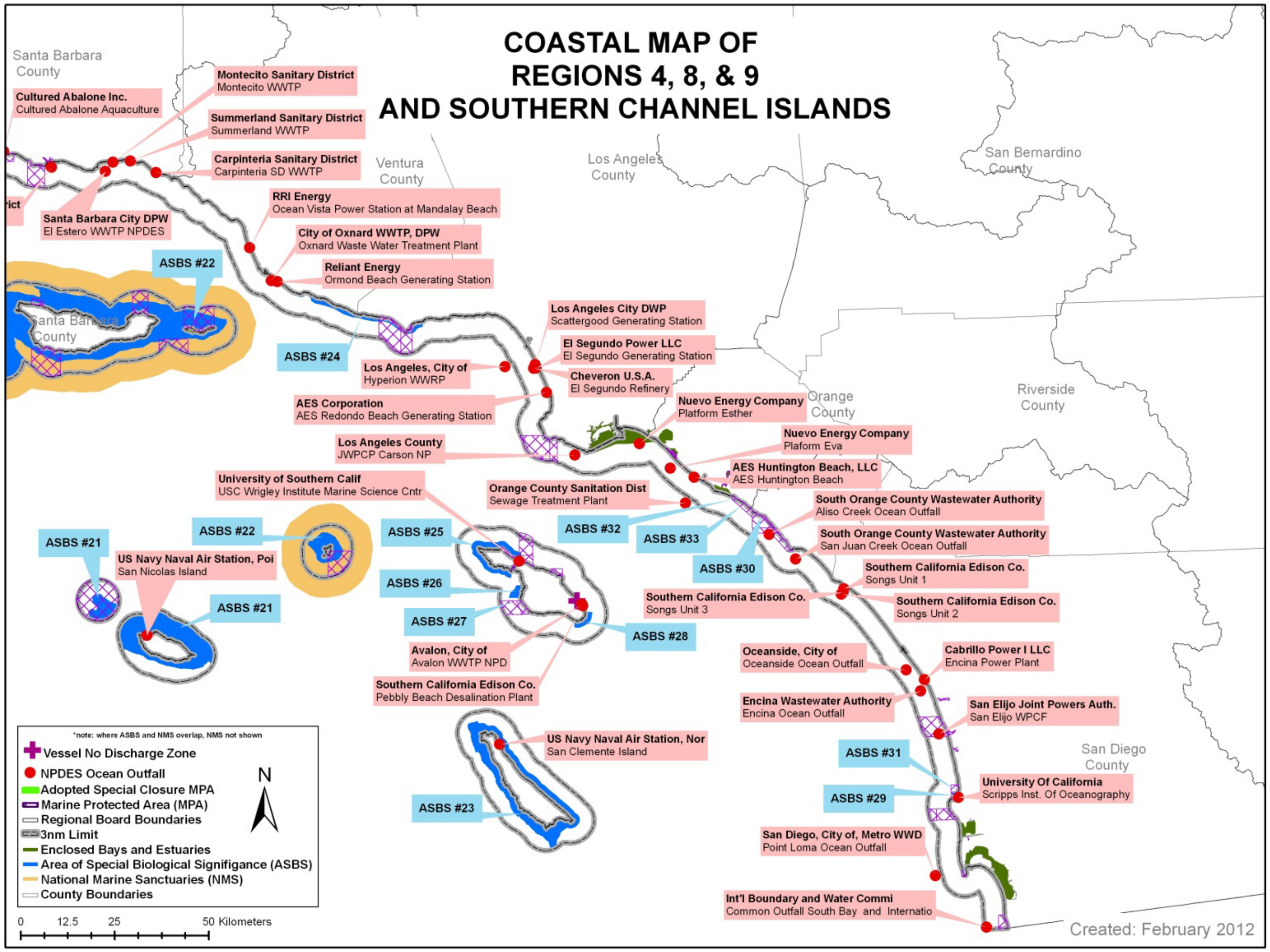


Figure VIII-5. ASBS Boundaries, MPA Boundaries, Wastewater Outfall Points, Marine Sanctuary Boundaries, and Enclosed Bays in southern Channel Islands and Regions 4, 8 and 9.

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* See Appendix I for definition of terms.

Appendix B- CEQA Checklist

THE PROJECT

1. **PROJECT TITLE**: Amendment of the Water Quality Control Plan for Ocean Waters of California for Desalination Facility Intakes and Brine Discharges, and Other Non-substantive Changes.

2. **LEAD AGENCY NAME AND ADDRESS:**

   State Water Resources Control Board – Division of Water Quality

   1001 I Street Sacramento California 95814

3. **CONTACT PERSON AND PHONE NUMBER:**

   <u>Contacts:</u>

   Ms. Claire Waggoner, Environmental Scientist

   Email Claire.Waggoner@Waterboards.ca.gov

   Phone (916) 341-5582

   <u>Or Contact:</u>

   Maria de la Paz Carpio-Obeso, Ocean Standards Unit Chief

   Office Phone: (916) 341-5858

   Email: MarielaPaz.Carpio-Obeso@waterboards.ca.gov

4. **PROJECT LOCATION:**

   Ocean Waters of California

5. **DESCRIPTION OF PROJECT**:

   The proposed Desalination Amendment, if adopted, would establish a uniform approach for protecting beneficial uses of ocean waters from degradation due to seawater intake and discharge of brine wastes from desalination facilities. The proposed Desalination Amendment will protect and maintain the highest reasonable water quality possible for the use and enjoyment of the people of the state. The proposed Desalination Amendment contains four primary components intended to control potential adverse impacts to marine life associated with desalination facility intakes and brine discharges as described below.

   - Implementation procedures for evaluating the best site, design, technology, and mitigation measures to minimize the intake and mortality of marine life at new or expanded desalination facilities.
   - A receiving water limit for salinity applicable to all desalination facilities to ensure that brine discharges to marine waters do not cause adverse effects to marine species and communities.
   - Alternative implementation procedures for discharges of waste brine to minimize

marine life mortality at desalination discharges.

- Provisions protecting sensitive habitats, sensitive species, MPAs, and SWQPAs from degradation of water quality associated with desalination facility intakes and discharges.

The Desalination Amendment, if adopted, would apply intake-related provisions to all new and expanded desalination facilities that intake state ocean waters. Discharge requirements would apply to all desalination facilities. The proposed Desalination Amendment would be implemented through NPDES permits or WDRs issued by the applicable regional water board in consultation with the State Water Board. The goals of the proposed Desalination Amendment are to accomplish the following:

1. Provide a consistent statewide approach for minimizing intake and mortality of marine life, protecting water quality, and related beneficial uses of ocean waters. Meeting this goal will address the need for a uniform statewide approach for controlling adverse effects of desalination facilities that are not currently addressed in the Ocean Plan or the Statewide Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling (OTC Policy).
2. Support environmentally responsible desalination in California and to use ocean water as a reliable alternative to traditional water supplies.
3. Promote interagency collaboration for siting, design, and permitting of desalination facilities and to help define the roles of the Water Boards in regulating such facilities.

EVALUATION OF THE ENVIRONMENTAL IMPACTS IN THE CHECKLIST

1. The board must complete an environmental checklist prior to the adoption of plans or policies for the Basin/208 Planning program as certified by the Secretary for Natural Resources. The checklist becomes a part of the SED.
2. For each environmental category in the checklist, the board must determine whether the project will cause any adverse impact. If there are potential impacts that are not included in the sample checklist, those impacts should be added to the checklist.
3. If the board determines that a particular adverse impact may occur as a result of the project, then the checklist boxes must indicate whether the impact is “Potentially Significant,” “Less than Significant with Mitigation Incorporated,” or “Less than Significant.”
    a. “Potentially Significant Impact” applies if there is substantial evidence that an impact may be significant. If there are one or more “Potentially Significant Impact” entries on the checklist, the SED must include an examination of feasible alternatives and mitigation measures for each such impact, similar to the requirements for preparing an EIR.
    b. “Less than Significant with Mitigation Incorporated” applies if the board or another agency incorporates mitigation measures into the SED that will reduce an impact that is “Potentially Significant” to a “Less than Significant Impact.” If the board does not require the specific mitigation measures itself, then the board must be certain that the other agency will in fact incorporate those measures.

   c. “Less than Significant” applies if the impact will not be significant, and mitigation is therefore not required.

   d. If there will be no impact, check the box under “No Impact.”

4. The board must provide a brief explanation for each “Potentially Significant,” “Less than Significant with Mitigation Incorporated,” “Less than Significant,” or “No Impact” determination in the checklist. The explanation may be included in the written report described in section 3777, subdivision (a)(1) or in the checklist itself. The explanation of each issue should identify: (a) the significance criteria or threshold, if any, used to evaluate each question; and (b) the specific mitigation measure(s) identified, if any, to reduce the impact to less than significant. The board may determine the significance of the impact by considering factual evidence, agency standards, or thresholds. If the “No Impact” box is checked, the board should briefly provide the basis for that answer. If there are types of impacts that are not listed in the checklist, those impacts should be added to the checklist.

5. The board must include mandatory findings of significance if required by CEQA Guidelines section 15065.

6. The board should provide references used to identify potential impacts, including a list of information sources and individuals contacted.

EXPLANATION OF CHECKLIST

The checklist identifies those impacts representing the Desalination Amendment project and alternatives and does not provide a detailed evaluation of a particular desalination facility (presented in Section 12.1). A detailed discussion of the impacts and associated findings of the Desalination Amendment project and alternatives are presented in section 8 and 12.4 of this document.

CEQA Checklist

Amendment of the Water Quality Control Plan for Ocean Waters of California for Desalination Facility Intakes and Brine Discharges, and Other Non-substantive Changes

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
I. AESTHETICS				
Would the project:				
a) Have a substantial adverse effect on a scenic vista?	☑	☐	☐	☐
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☑	☐
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☑	☐	☐	☐
d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area?	☐	☐	☑	☐

The proposed Desalination Amendment could impact aesthetics; however some of these impacts can be reduced to less than significant with mitigation as described in section 12.1.1 and 12.4.1. In addition, construction and operation of desalination facilities in general would require actions outside of the jurisdiction of the water boards to implement and enforce. Some of those impacts are considered significant and unavoidable.

II. AGRICULTURE AND FOREST RESOURCES

In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Dept. of Conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment Project; and forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Boards. Would the project:				
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland),	☐	☐	☐	☑

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?				
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?	☐	☐	☐	☑
c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)), timberland (as defined by Public Resources Code section 4526), or timberland zoned Timberland Production (as defined by Government Code section 51104(g))?	☐	☐	☐	☑
d) Result in the loss of forest land or conversion of forest land to non-forest use?	☐	☐	☐	☑
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use or conversion of forest land to non-forest use?	☐	☐	☐	☑

The proposed Desalination Amendment would not result in the loss or conversion of farmland or conflict with existing timber or forest zoning because the scope of the water board action relates to intake of seawater and discharge of brine at ocean locations only. As determined on a case-by-case basis, desalination facilities in general may adversely impact agriculture or forest resources, however, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, the construction and operation of desalination facilities could cause impacts to agriculture or forest resources that are unrelated to the State Water Board's project. Those impacts that may occur from approval of a particular desalination facility are described in section 12.1.2.

III. AIR QUALITY

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:				
a) Conflict with or obstruct implementation of the applicable air quality plan?	☑	☐	☐	☐
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☐	☑
c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality	☐	☑	☐	☐

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?				
d) Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☐	☑
e) Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☑

The proposed Desalination Amendment could potentially result in significant and unavoidable impacts if additional power is needed to implement these alternatives and fossil fuel power plants are relied upon to provide the power. These potential impacts are described in section 12.4.2. In the interest of full disclosure, the potential site specific impacts to air quality that may occur from approval of a particular desalination facility and unrelated to the proposed Desalination Amendment are discussed in section 12.1.3 of the Staff Report.

IV. BIOLOGICAL RESOURCES

Would the project:

a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☑	☐	☐	☐
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☑	☐	☐	☐
c) Have a substantial adverse effect on federally protected wetlands as defined by section 404 of the CWA (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?	☑	☐	☐	☐
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?	☑	☐	☐	☐
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	☐	☑
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	☐	☑

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact

The proposed Desalination Amendment could potentially result in significant impacts to biological resources as described in section 12.4.3, however, some of these impacts can be mitigated to result in less than significant impacts. In the interest of full disclosure, the potential site specific impacts to biological resources that may occur from approval of a particular desalination facility are discussed in section 12.1.4 of the Staff Report.

V. CULTURAL RESOURCES

Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in § 15064.5?	☐	☐	☐	☑
b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to § 15064.5?	☐	☐	☐	☑
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☐	☑
d) Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☐	☑

The proposed Desalination Amendment would not affect historical, archeological, or paleontological, geologic features or human remains because the scope of the water board action relates to intake of seawater and discharge of brine that would occur or be located in the coastal ocean environment. As determined on a case-by-case basis, desalination facilities may adversely impact cultural resources. However, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, these potential site specific impacts to cultural resources that may occur from approval of a particular desalination facility are discussed in section 12.1.5 of the Staff Report.

VI. GEOLOGY AND SOILS

Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:	☐	☐	☐	☑
i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.	☐	☐	☐	☑
ii) Strong seismic ground shaking?	☐	☐	☐	☑

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☐	☑
iv) Landslides?	☐	☐	☐	☑
b) Result in substantial soil erosion or the loss of topsoil?	☐	☐	☐	☑
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?	☐	☐	☐	☑
d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	☐	☐	☐	☑
e) Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water?	☐	☐	☐	☑

The proposed Desalination Amendment would not result in increased risk associated with geologic hazards such as ground shaking, ground failure or increased potential for soil erosion because the scope of the water board action relates only to the intake of seawater and discharge of brine that would occur or be located in the coastal ocean environment. As determined on a case-by-case basis, the siting, design and location of individual desalination facilities will need to consider these factors to address and minimize the potential risks associated with soils and geologic conditions onsite. However, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, these potential site specific impacts associated with soils and geology that may occur from approval of a particular desalination facility are discussed in section 12.1.6 of the Staff Report.

VII. GREENHOUSE GAS EMISSIONS

Would the project:

a) Generate Greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?	☑	☐	☐	☐
b) Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases?	☐	☐	☐	☑

The proposed Desalination Amendment could potentially result in significant greenhouse gas emissions as a result of construction activities described in 12.4.4. .

VIII. HAZARDS AND HAZARDOUS MATERIALS

Issue Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☑
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☐	☑
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?	☐	☐	☐	☑
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?	☐	☐	☐	☑
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☑
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☑
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☑
h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	☑

The proposed Desalination Amendment would not directly or indirectly create a significant hazard to the public, result in increased emissions or cause a project to be located on a hazardous waste site because the scope of the water board action relates only to the intake of seawater and discharge of brine that would occur or be located in the coastal ocean environment. As determined on a case-by-case basis, the siting, design and location of individual desalination facilities will need to consider these factors to address and minimize the potential hazards and the use of, or exposure to hazardous materials by onsite workers and the public working and residing in the area. However, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, potential hazards that may occur from approval of a particular desalination facility are discussed in section 12.1.8 of the Staff Report.

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
IX. HYDROLOGY AND WATER QUALITY				
Would the project:				
a) Violate any water quality standards or waste discharge requirements?	☐	☐	☐	☑
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☑	☐
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site?	☐	☐	☐	☑
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?	☐	☐	☐	☑
e) Create or contribute runoff water which would exceed the capacity of existing or planned storm water drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	☑
f) Otherwise substantially degrade water quality?	☐	☑	☐	☐
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	☑
h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	☐	☐	☐	☑
i) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	☐	☑
j) Inundation by seiche, tsunami, or mudflow?	☐	☐	☐	☑

The State Water Boards adoption of the proposed Desalination Amendment could result in less than significant impacts to Hydrology and Water Quality as described in section 12.4.5. In the interest of full disclosure, impacts associated with the construction and operation of desalination facilities in general are described in section 12.1.9

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
X. LAND USE AND PLANNING				
Would the project:				
a) Physically divide an established community?	☐	☐	☐	☑
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☑
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☑

The proposed Desalination Amendment would not physically divide a community, or conflict with land use plans policies or habitat conservation plans because the scope of the State Water Board action relates only to the intake of seawater and discharge of brine that would occur or be located in the coastal ocean environment. As determined on a case-by-case basis, the siting, design and location of desalination facilities in general could impact land use and planning; however, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. The siting, location and design of each individual facility would need to consider local land use plans policies and conservation plans. In the interest of full disclosure, potential site specific impacts to land use and planning that may occur from approval of a particular desalination facility are discussed in Section 12.1.10 of the Staff Report.

XI. MINERAL RESOURCES

Would the project:

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?	☐	☐	☐	☑
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?	☐	☐	☐	☑

The proposed Desalination Amendment would not affect mineral resources. The scope of the water board action relates only to the intake of seawater and discharge of brine that would occur during the operation of a desalination facility in the coastal ocean environment where few mineral resources have been identified as described in section 12.1.11 of the Staff Report.

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact

XII. NOISE

Would the project result in:

a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☑
b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?	☐	☐	☐	☑
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☑
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☑
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	☑
f) For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	☑

The proposed Desalination Amendment would not cause directly or indirectly exposure to harmful noise, excessive groundborne vibration or increase ambient noise above existing levels because the scope of the water board action relates only to the intake of seawater and discharge of brine in the coastal ocean environment. As determined on a case-by-case basis, the construction and operation of individual desalination facilities will need to address and minimize noise impacts; however, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment because the infrastructure required by the proposed Desalination Amendment would be, from the perspective of noise generation, equivalent to infrastructure that would be needed for any desalination facility. In the interest of full disclosure, potential noise related impacts that may occur from approval of a particular desalination facility are discussed in section 12.1.12 of the Staff Report.

XIII. POPULATION AND HOUSING

Would the project:

a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?	☐	☐	☐	☑

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☑
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☑

The proposed Desalination Amendment would not cause directly or indirectly population growth, displace housing or residents because the scope of the water board action relates only to the intake of seawater and discharge of brine in the coastal ocean environment. As determined on a case-by-case basis, the siting, construction and operation of individual desalination facilities will need to address population, growth and housing; however, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, potential impacts that may occur from approval of a particular desalination facility and the potential for growth associated with more reliable water supplies are discussed in section 12.1.13 of the Staff Report.

XIV. PUBLIC SERVICES

a) Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the public services:	☐	☐	☐	☑
i) Fire protection?	☐	☐	☐	☑
ii) Police protection?	☐	☐	☐	☑
iii) Schools?	☐	☐	☐	☑
iv) Parks?	☐	☐	☐	☑
v) Fire protection?	☐	☐	☐	☑
vi) Other public facilities?	☐	☐	☐	☑

The proposed Desalination Amendment would not cause directly or indirectly impacts to fire services, police protection or the need for new schools parks or other public facilities because the scope of the Water Board's action relates only to the intake of seawater and discharge of brine in the coastal ocean environment. As determined on a case-by-case basis, the siting, construction and operation of individual desalination facilities will need to take into account any potential impacts to public services. However, these impacts would not

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact

be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, potential impacts that may occur from approval of a particular desalination facility and the potential for growth associated with more reliable water supply are discussed in section 12.1.14 of the Staff Report.

XV. RECREATION

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	☐	☑
b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?	☐	☐	☐	☑

The proposed Desalination Amendment would not directly or indirectly cause increased use of regional parks or recreational facilities or require construction or expansion of new facilities because the scope of the Water Board's action relates only to the intake of seawater and discharge of brine in the coastal ocean environment. As determined on a case-by-case basis, the siting, construction and operation of individual desalination facilities will need to consider any potential impacts to recreation; however, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, potential impacts that may occur from approval of a particular desalination facility and the potential impacts to recreation are discussed in section 12.1.15 of the Staff Report.

XVI. TRANSPORTATION/TRAFFIC

Would the project:

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Conflict with an applicable plan, ordinance or policy establishing measures of effectiveness for the performance of the circulation system, taking into account all modes of transportation including mass transit and non-motorized travel and relevant components of the circulation system, including, but not limited to intersections, streets, highways and freeways, pedestrian and bicycle paths, and mass transit?	☐	☐	☐	☑
b) Conflict with an applicable congestion management program, including, but not limited to level of service standards and travel demand measures, or other standards established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☑
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that result in substantial safety risks?	☐	☐	☐	☑

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☑
e) Result in inadequate emergency access?	☐	☐	☐	☑
f) Conflict with adopted policies, plans, or programs regarding public transit, bicycle, or pedestrian facilities, or otherwise decrease the performance or safety of such facilities?	☐	☐	☐	☑

The proposed Desalination Amendment would not cause directly or indirectly conflicts with applicable traffic plans, policies, or ordinances nor would it conflict with traffic management plans, or increase traffic and associated hazards because the scope of the Water Board's action relates only to the intake of seawater and discharge of brine in the coastal ocean environment. As determined on a case-by-case basis, the siting, construction and operation of individual desalination facilities will need to take into account for potential impacts to traffic; however, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, potential impacts that may occur from approval of a particular desalination facility during construction and operation are discussed in section 12.1.16 of the Staff Report.

XVII. UTILITIES AND SERVICE SYSTEMS

Would the project:

a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?	☐	☐	☐	☑
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☑
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☑
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?	☐	☐	☐	☑
e) Result in a determination by the wastewater treatment provider which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☑
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☑

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
g) Comply with federal, state, and local statutes and regulations related to solid waste?	☐	☐	☐	☑

The proposed Desalination Amendment would not cause directly or indirectly impacts to wastewater treatment, require construction of new wastewater facilities, expansion of existing facilities or construction or expansion of stormwater retention systems or landfills because the scope of the Water Board's action relates only to the intake of seawater and discharge of brine in the coastal ocean environment. As determined on a case-by-case basis, the siting, construction and operation of individual desalination facilities will need to take into account the potential impacts to utilities and service systems; however, these impacts would not be caused directly or indirectly by the State Water Board's proposed Desalination Amendment. In the interest of full disclosure, potential impacts that may occur from approval of a particular desalination facility are discussed in section 12.1.17 of the Staff Report.

XVIII. MANDATORY FINDINGS OF SIGNIFICANCE

Issue	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?	☑	☐	☐	☐
b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?	☐	☐	☐	☑
c) Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	☐	☑

As discussed in section 12.4.3, the proposed Desalination Amendment has the potential to impact biological resources through the construction of facilities that are similar to, but potentially of greater complexity than would occur in absence of the amendment. Given desalination facilities could potentially be located throughout the state, it is reasonably foreseeable that facilities will be situated within designated habitat for special status species. While suitable mitigation measures are available to reduce these impacts to less than significant, many of these mitigation measures are not within the jurisdiction of the water boards to enforce. Therefore, there is a potential for significant impact to wildlife including special status species and their habitat.

PRELIMINARY DETERMINATION

☐ The proposed Desalination Amendment COULD NOT have a significant effect on the environment, and, therefore, no alternatives or mitigation measures are proposed.

☑ The proposed Desalination Amendment MAY have a significant or potentially significant effect on the environment, and therefore alternatives and mitigation measures have been evaluated.

Appendix C Life History Information for Selected California Marine Organisms

Associated with the Draft Staff Report Including the Draft Substitute Environmental Documentation For the Proposed Desalination Amendment

Table C-1. Life History Information for Selected California Marine Algae (http://www.dfg.ca.gov/marine/table_inv.asp)

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
***Gelidium* spp.**	Intertidal, to 100	All regions, including islands	rocky reefs	rocky reefs	may forms mats of algal turf	not applicable
***Gracilaria* spp.**	Intertidal to 50	All regions, including islands	soft bottoms	soft bottoms	used as spawning substrate by herring in SF Bay	not applicable
***Porphyra* spp.**	Intertidal to 100	All regions, including islands	rocky reefs	rocky reefs	may be common in high-energy surf zones	not applicable
Sea palm	Intertidal	N,NC,SC	exposed rocky reefs	exposed rocky reefs	individuals can regenerate blades but not stipe	not applicable
Kelp, giant	20-120	NC,SC,S	on sand and rock substrate	on sand and rock substrate	fronds may grow up to 24 inches per day	not applicable
Kelp, bull	10-70	N,NC,SC	on rock or cobble substrate	on rock or cobble substrate	found where water temp is less than 60°F	not applicable

Table C-2. Life History Information for Selected California Marine Invertebrates. (http://www.dfg.ca.gov/marine/table_inv.asp)

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Crab, box	0-1800	All regions, including islands	rocky reef, submarine canyons	rocky reef, submarine canyons	unknown	unknown
Crab, brown rock	0-300	All regions, including islands	rocky reefs, kelp beds	rocky reefs, kelp beds	rock crabs may live 5-6 years	3-4 months
Crab, Dungeness	0-750	N,NC,SC	sand, sand-mud, estuaries	sand, sand-mud	larvae may be transported more than 50 miles offshore	105-125 days
Crab, spider (sheep crab)	20-410	South	rocky reefs, kelp beds	rocky reefs, kelp beds	cease molting after reaching maturity	unknown
Crab, yellow rock	0-300	South	sand, soft bottom	sand, soft bottom	egg-bearing females may congregate in rock-sand interface habitat	3-4 months
Lobster, California	0-240	South, mainland and islands	surf grass beds	rocky reef, kelp beds, eel grass beds	egg-bearing females generally found in shallow water	5-9 months
Prawn, spot	150-1,600	All regions, including islands	shallower mud, mud-sand, sand/rock. rocky reef, submarine canyons	mud, mud-sand, sand/rock. rocky reef, submarine canyons	change sex from male to female during year 4	unknown

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Prawn, ridgeback	145-525	South; mainland and islands	sand, shell, green mud	sand, shell, green mud	positive response to El Niño conditions	unknown
Shrimp, bay (several species)	0-575	All regions	soft bottom, estuaries	soft bottom, estuaries	major prey item for fishes	30-40 days
Shrimp, ghost and mud shrimp (several species)	Intertidal	All regions	sand, sand/mud, sand/gravel	sand, sand/mud, sand/gravel	form permanent burrows or impermanent tunnels	unknown
Shrimp, ocean	150-1200	N,NC,SC: Oregon border to Pt. Arguello	green mud, mud-sand	green mud, mud-sand	change sex from male to female during year 2	2.5 to 3 months
Cucumber, sea (several species)	0-300	All regions, including islands	rocky reefs, sand/mud	rocky reefs, sand/mud	do not form spawning aggregations	51-91 days
Urchin, purple	0-300	All regions, including islands	rocky reefs, kelp beds, under canopy of adults	rocky reefs, kelp beds	require high densities for successful spawning	6-8 weeks
Urchin, red	Intertidal to 500	All regions, including islands	rocky reefs, kelp beds, under canopy of adults	rocky reefs, kelp beds	require high densities for successful spawning	6-8 weeks

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Urchin, white	0-990	South, including islands	sand, eel grass beds	sand, eel grass beds	extremely efficient grazers on smaller algae	30-60 days
Abalone, black	Intertidal, 0-20	NC,SC,S	crevices in rocky reefs, kelp beds	rocky reefs, kelp beds	susceptible to withering syndrome disease	4-7 days
Abalone, green	Intertidal, 0-30	South, mainland and islands	crevices in rocky reefs, kelp beds	rocky reefs, kelp beds	feed on drift algae	4-7 days
Abalone, pink	Intertidal, 20-120	South, mainland and islands	crevices in rocky reefs, kelp beds, rock outcrops	rocky reefs, kelp beds, rock outcrops	generally occurs where water temp is above 14 C	4-7 days
Abalone, red	Intertidal to 100	All regions, including islands	crevices in rocky reefs, kelp beds, boulder outcrops, under canopy of red urchins	rocky reefs, kelp beds, boulder outcrops	largest abalone species in the world	4-7 days
Abalone, white	80-200	South, mainland and islands	exposed rocky areas	exposed rocky areas	maximum age estimated at 40 years	4-7 days
Squid, market	0 to at least 600	NC,SC,S	over soft bottom	over soft bottom	short-lived; average squid in commercial fishery is year old.	unknown
Clam, chione (several species)	Intertidal to 165	South, mainland and islands	sandy mud, estuaries	sandy mud, estuaries	smooth chione subject to habitat loss due to harbor development	unknown

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Clam, littleneck (several species)	Intertidal	All regions, including islands	cobble beds	cobble beds	prized food item	unknown
Clam, geoduck	0-360	All regions	sand, sand/mud, estuaries	sand, sand/mud, estuaries	individuals may exceed 10 pounds	2 weeks
Clam, Manila	Intertidal	All regions	sand, sand/mud, estuaries	sand, sand/mud, estuaries	introduced from Japan; important recreational species	3 weeks
Cockles	Intertidal to 660	All regions, including islands	sand, sand/mud, mud, estuaries	sand, sand/mud, mud, estuaries	one species may live to 16 years	unknown
Limpets	Intertidal to 100	All regions, including islands	rocky reefs	rocky reefs	some species may live 15 years	less than 1 week
Mussels (several species)	Intertidal to 130	All regions, including islands	rocky reefs, pilings	rocky reefs, pilings	bio-accumulator of toxins	1 month
Octopus (several species)	Intertidal to 660	All regions, including islands	rocky reefs, kelp beds, soft bottom	rocky reefs, kelp beds, soft bottom	eggs are attached to substrate and brooded by females	1 month or less

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Scallop, rock	Intertidal to 100	All regions, including islands	rocky reefs, pier pilings, rock jetties	rocky reefs, pier pilings, rock jetties	intolerant of salinity less than 25 ppt	5 weeks
Sea hare (two species)	0-60	NC,SC,S	hard and soft bottom, kelp beds	hard and soft bottom, kelp beds	large nerve ganglia make them useful for research	4-5 weeks
Sea stars (many species)	Intertidal to deepest canyons	All regions, including islands	rocky reefs, hard bottom, sand	rocky reefs, hard bottom, sand	some species adapted to exposure at low tides	unknown
Snail, moon	Intertidal to 500	All regions, including islands	soft bottom	soft bottom	has aquiferous system of spongy sinuses in foot	2 weeks
Snail, top (several species)	0-100	S	rocky reefs, kelp beds, including canopy	rocky reefs, kelp beds, including canopy	common in upper kelp canopy	unknown
Snail, turban (several species)	Intertidal to 250	All regions, including islands	shallower rocky reefs, kelp beds, including canopy	rocky reefs, kelp beds, including canopy	feeds primarily on kelp and coralline algae	unknown
Whelk, Kellet's	0-230	South, including islands	rocky reefs, kelp beds, gravel, sand	rocky reefs, kelp beds, gravel, sand	spawning aggregations of up to 20 individuals occur in spring	unknown

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Worms (polychaetes)	Intertidal to deepest canyons	All	rocky reefs in mussel beds, cobble beds, soft bottom	rocky reefs in mussel beds, cobble beds, soft bottom	several species have toothed proboscis	variable

Table C-3. Life History Information for Selected California Marine Fishes. (https://www.dfg.ca.gov/marine/table_fish.asp)

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Crab, box	0-1800	All regions, including islands	rocky reef, submarine canyons	rocky reef, submarine canyons	unknown	unknown
Crab, brown rock	0-300	All regions, including islands	rocky reefs, kelp beds	rocky reefs, kelp beds	rock crabs may live 5-6 years	3-4 months
Crab, Dungeness	0-750	N,NC,SC	sand, sand-mud, estuaries	sand, sand-mud	larvae may be transported more than 50 miles offshore	105-125 days
Crab, spider (sheep crab)	20-410	South	rocky reefs, kelp beds	rocky reefs, kelp beds	cease molting after reaching maturity	unknown
Crab, yellow rock	0-300	South	sand, soft bottom	sand, soft bottom	egg-bearing females may congregate in rock-sand interface habitat	3-4 months
Lobster, California	0-240	South, mainland and islands	surf grass beds	rocky reef, kelp beds, eel grass beds	egg-bearing females generally found in shallow water	5-9 months
Prawn, spot	150-1,600	All regions, including islands	shallower mud, mud-sand, sand/rock. rocky reef, submarine canyons	mud, mud-sand, sand/rock. rocky reef, submarine canyons	change sex from male to female during year 4	unknown

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Prawn, ridgeback	145-525	South; mainland and islands	sand, shell, green mud	sand, shell, green mud	positive response to El Niño conditions	unknown
Shrimp, bay (several species)	0-575	All regions	soft bottom, estuaries	soft bottom, estuaries	major prey item for fishes	30-40 days
Shrimp, ghost and mud shrimp (several species)	Intertidal	All regions	sand, sand/mud, sand/gravel	sand, sand/mud, sand/gravel	form permanent burrows or impermanent tunnels	unknown
Shrimp, ocean	150-1200	N,NC,SC: Oregon border to Pt. Arguello	green mud, mud-sand	green mud, mud-sand	change sex from male to female during year 2	2.5 to 3 months
Cucumber, sea (several species)	0-300	All regions, including islands	rocky reefs, sand/mud	rocky reefs, sand/mud	do not form spawning aggregations	51-91 days
Urchin, purple	0-300	All regions, including islands	rocky reefs, kelp beds, under canopy of adults	rocky reefs, kelp beds	require high densities for successful spawning	6-8 weeks
Urchin, red	Intertidal to 500	All regions, including islands	rocky reefs, kelp beds, under canopy of adults	rocky reefs, kelp beds	require high densities for successful spawning	6-8 weeks
Urchin, white	0-990	South, including	sand, eel grass	sand, eel	extremely efficient	30-60 days

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
		islands	beds	grass beds	grazers on smaller algae	
Abalone, black	Intertidal, 0-20	NC,SC,S	crevices in rocky reefs, kelp beds	rocky reefs, kelp beds	susceptible to withering syndrome disease	4-7 days
Abalone, green	Intertidal, 0-30	South, mainland and islands	crevices in rocky reefs, kelp beds	rocky reefs, kelp beds	feed on drift algae	4-7 days
Abalone, pink	Intertidal, 20-120	South, mainland and islands	crevices in rocky reefs, kelp beds, rock outcrops	rocky reefs, kelp beds, rock outcrops	generally occurs where water temp is above 14 C	4-7 days
Abalone, red	Intertidal to 100	All regions, including islands	crevices in rocky reefs, kelp beds, boulder outcrops, under canopy of red urchins	rocky reefs, kelp beds, boulder outcrops	largest abalone species in the world	4-7 days
Abalone, white	80-200	South, mainland and islands	exposed rocky areas	exposed rocky areas	maximum age estimated at 40 years	4-7 days
Squid, market	0 to at least 600	NC,SC,S	over soft bottom	over soft bottom	short-lived; average squid in commercial fishery is year old.	unknown
Clam, chione (several species)	Intertidal to 165	South, mainland and islands	sandy mud, estuaries	sandy mud, estuaries	smooth chione subject to habitat loss due to harbor development	unknown

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
Clam, littleneck (several species)	Intertidal	All regions, including islands	cobble beds	cobble beds	prized food item	unknown
Clam, geoduck	0-360	All regions	sand, sand/mud, estuaries	sand, sand/mud, estuaries	individuals may exceed 10 pounds	2 weeks
Clam, Manila	Intertidal	All regions	sand, sand/mud, estuaries	sand, sand/mud, estuaries	introduced from Japan; important recreational species	3 weeks
Cockles	Intertidal to 660	All regions, including islands	sand, sand/mud, mud, estuaries	sand, sand/mud, mud, estuaries	one species may live to 16 years	unknown
Limpets	Intertidal to 100	All regions, including islands	rocky reefs	rocky reefs	some species may live 15 years	less than 1 week
Mussels (several species)	Intertidal to 130	All regions, including islands	rocky reefs, pilings	rocky reefs, pilings	bio-accumulator of toxins	1 month
Octopus (several species)	Intertidal to 660	All regions, including islands	rocky reefs, kelp beds, soft bottom	rocky reefs, kelp beds, soft bottom	eggs are attached to substrate and brooded by females	1 month or less
Scallop, rock	Intertidal to 100	All regions, including	rocky reefs, pier pilings, rock	rocky reefs, pier pilings,	intolerant of salinity less than	5 weeks

Species	Primary Depth Range in Feet	Primary Geographic Range Within CA (4 Regions)	Habitat Preference: Juveniles	Habitat Preference: Adults	Unique or Significant Life History Characteristics	Larval Duration (potential larval dispersal)
		islands	jetties	rock jetties	25 ppt	
Sea hare (two species)	0-60	NC,SC,S	hard and soft bottom, kelp beds	hard and soft bottom, kelp beds	large nerve ganglia make them useful for research	4-5 weeks
Sea stars (many species)	Intertidal to deepest canyons	All regions, including islands	rocky reefs, hard bottom, sand	rocky reefs, hard bottom, sand	some species adapted to exposure at low tides	unknown
Snail, moon	Intertidal to 500	All regions, including islands	soft bottom	soft bottom	has aquiferous system of spongy sinuses in foot	2 weeks
Snail, top (several species)	0-100	S	rocky reefs, kelp beds, including canopy	rocky reefs, kelp beds, including canopy	common in upper kelp canopy	unknown
Snail, turban (several species)	Intertidal to 250	All regions, including islands	shallower rocky reefs, kelp beds, including canopy	rocky reefs, kelp beds, including canopy	feeds primarily on kelp and coralline algae	unknown
Whelk, Kellet's	0-230	South, including islands	rocky reefs, kelp beds, gravel, sand	rocky reefs, kelp beds, gravel, sand	spawning aggregations of up to 20 individuals occur in spring	unknown
Worms (polychaetes)	Intertidal to deepest canyons	All	rocky reefs in mussel beds, cobble beds, soft bottom	rocky reefs in mussel beds, cobble beds, soft bottom	several species have toothed proboscis	variable

Appendix D- Summary Tables of Entrainment Studies

Associated with the Draft Staff Report Including the Draft Substitute Environmental Documentation for the Proposed Desalination Amendment

Tables begin on next page

Table D. Summary of studies measuring percent reduction in entrainment

Source	Velocity (m/s)	Screen Type	Species (life stage)	Organism length or diameter (mm)	% Reductions Slot Size (mm)				
					0.5	0.75	1	2	3
Bureau of Reclamation, 2007*	0.13	WW	Gizzard shad (eggs)	0.5	NSR				
			Gizzard shad (larvae)	4.2	NSR				
			Fathead minnow (eggs)	1.0	100				
			Smallmouth bass (larvae)	8.5	100				
			Blue catfish (eggs)	3.8	100				
			Blue catfish (larvae)	12.1	100				
ERPI, 2005a	0.15-0.3	WW	Grubby (larvae)	≤3 - ≥10	≥80		≥45		
			Sand lance (larvae)	4-6	≥80		NSR		
			Winter flounder (larvae)	4-6	≥44		NSR		
			Unidentified (eggs)	0.88	≥92		NSR		
ERPI, 2005b	0.15	WW	Shad spp. (larvae)	≤3 - ≥10	NSR		NSR		
			Freshwater drum (larvae)	≤3 - ≥10	NSR		NSR		
			Carp (larvae)	≤3 - ≥10	NSR		NSR		
			Temperate basses (larvae)	≤3 - ≥10	NSR		NSR		
			Eggs, (unidentified)	0.88	≥92		NSR		
	0.3	WW	Shad spp. (larvae)	≤3 - ≥10	NSR		NSR		
			Freshwater drum (larvae)	≤3 - ≥10	NSR		NSR		
			Carp (larvae)	≤3 - ≥10	NSR		54.3		
			Temperate basses (larvae)	≤3 - ≥10	NSR		NSR		
			Unidentified (eggs)	0.88	≥92		NSR		
Foster et al, 2012	NR	WW	Northern anchovies	8-19			74.8		
			Gobies	6-13			39.9		
Hanson, 1981		WW	Yellow perch	<8			NSR		
		WW	Yellow perch	13			100		
Tetratech, 2002	NR	FM	Fish (larvae)	NR	84				
TVA, 1976	NR	FM	Basses (larvae)	5.5-15.5	≥99		≥75		
Tenera, 2013a	NR	WW/ FM	Kelpfishes (larvae)	2-25		73.3	64.6	24.9	1.4
			Sculpins (larvae)	2-25		85.9	81.1	64.4	49.7
			Flatfishes (larvae)	1-25		78.8	72.8	51.5	33.0
			Monkeyface prickleback (larvae)	3-25		75.7	62.1	12.8	0.5
			Combtooth Blennies (larvae)	2-20		81.9	72.1	32.4	8.4
			Clingfishes (larvae)	2-20		83.0	75.8	48.8	26.9
			Anchovies (larvae)	2-25		55.4	45.1	5.5	0
			Croakers (larvae)	1-20		81.9	74.9	46.1	17.6
			Gobies (larvae)	1-25		74.6	66.5	35.7	8.3
			Silversides (larvae)	2-25		76.0	68.5	34.8	3.0
			Pacific barracuda (larvae)	1-20		68.2	53.1	15.8	4.4
			Rockfishes (larvae)	2-25		77.7	69.7	43.4	22.3
			Cabezon (larvae)	2-25		79.1	70.1	39.3	20.6
			Sea basses (larvae)	1-25		84.8	79.6	59.9	41.0
			Picklebacks (larvae)	3-25		80.4	58.2	3.9	0
USEPA, 2011	NR	FM/TS	Fish (larvae)	NR	86				
			Fish (eggs)	NR	95				
USEPA, 2011	0.15	WW	Larvae/eggs	NR	84.7		13.8		
	0.3	WW	Larvae/eggs	NR	25		NSR		
USEPA, 2011	0.15	WW	Larvae/eggs	NR	83.7		14.9		
	0.3	WW	Larvae/eggs	NR	80.8		12.6		
USEPA, 2011	0.15	WW	Larvae	NR			93.6		
USEPA, 2011	NR	WW	Fish (larvae and juveniles)	NR			66	62.4	
Weisberg, 1987	0.2	WW	Bay Anchovy (eggs)	NR			NSR	NSR	NSR
			Bay Anchovy (larvae)	<4			NSR	NSR	NSR
			Bay Anchovy (larvae)	5-7			47.1	55.5	45.3
			Bay Anchovy (larvae)	8-10			87.2	77.8	66.2
			Naked goby (larvae)	<4			NSR	NSR	NSR
			Naked goby (larvae)	7-8			97.3	79.3	77.5

* Screen size is actually 0.6 mm NR – Not Recorded NSR – No Significant Reduction WW – Wedgewire screen s
FM– Fine Mesh TS – Traveling Screen

Table D-2. Estimated percentage reductions in mortality (relative to an open intake) to the population surviving past the size where they would be subject to entrainment,1 based on probabilities of screen entrainment for larvae from 15 taxonomic categories of fishes for six WWS slot widths. (Modified Table 4 from Tenera 2013)

Taxon	Size Range (mm)	Percentage Reduction in Entrainment[1]					
		0.75 mm	1 mm	2 mm	3 mm	4 mm	6 mm
kelpfishes	2–25	73.3	64.6	24.9	1.4	0.0	0.0
sculpins	2–25	85.9	81.1	64.4	49.7	36.0	14.1
flatfishes	1–25	78.8	72.8	51.5	33.0	18.8	4.6
monkeyface prickleback	3–25	75.7	62.1	12.8	0.5	0.0	0.0
combtooth blenny	2–20	81.9	72.1	32.4	8.4	1.5	0.0
clingfishes	2–20	83.0	75.8	48.8	26.9	13.1	2.6
anchovies	2–25	55.4	45.1	5.5	0.0	0.0	0.0
croakers	1–20	81.9	74.9	46.1	17.6	1.7	0.0
gobies	1–25	74.6	66.5	35.7	8.3	0.2	0.0
silversides	2–25	76.0	68.5	34.8	3.0	0.0	0.0
Pacific barracuda	1–20	68.2	53.1	15.8	4.4	1.3	0.1
rockfishes	2–25	77.7	69.7	43.4	22.3	10.6	2.4
cabezon	2–25	79.1	70.1	39.3	20.6	10.6	2.9
sea basses	1–25	84.8	79.6	59.9	41.0	22.7	0.1
pricklebacks	3–25	80.4	58.2	3.9	0.1	0.0	0.0
Average % Reduction in Entrainment		**77.1**	**67.6**	**34.6**	**15.8**	**7.8**	**1.8**

[1] - Extrapolated to the size at which the larvae are no longer susceptible to entrainment (estimated to be 20–25 mm [0.98 in] for this analysis).

Table D-3. Estimated total entrainment for seven taxonomic categories of fishes at DCPP for two year-long time periods: July 1997–June 1998 and July 1998–June 1999, and estimated entrainment and percentage reductions in entrainment for six WWS slot widths. (Modified Table 8 from Tenera 2013)

Taxon	Percent Reduction in Entrainment[1]					
	0.75 mm	1 mm	2 mm	3 mm	4 mm	6 mm
sculpins	10.7	2.9	0.1	<0.1	<0.1	0.0
rockfishes	15.1	4.3	<0.1	<0.1	<0.1	0.1
kelpfishes	18.4	4.6	0.2	<0.1	0.0	0.0
monkeyface prickleback	36.5	5.2	<0.1	<0.1	<0.1	0.0
anchovies	13.2	9.0	0.7	0.0	0.0	0.0
cabezon	28.1	7.0	<0.1	<0.1	0.0	0.0
flatfishes	6.9	3.7	<0.1	0.0	0.0	0.0
Average Percent Reduction in Entrainment	**18.4**	**5.2**	**0.2**	**<0.1**	**<0.1**	**0.0**

Table D-4. Estimated percentage reductions in mortality (relative to an open intake) to the population surviving past the size where they would be subject to entrainment,1 based on probabilities of screen entrainment for larvae from seven taxonomic categories of fishes measured during DCPP entrainment studies conducted October 1996 through June 1999. Mortality adjusted from estimates in Table D-2 based on length range of larvae measured from the studies, except for anchovies. (Modified Table 9 from Tenera 2013)

Taxon	Percent Reduction in Entrainment[1]					
	0.75 mm	1 mm	2 mm	3 mm	4 mm	6 mm
sculpins	69.2	58.7	24.3	5.5	0.5	0.0
rockfishes	46.2	32.0	5.2	0.5	0.0	0.0
kelpfishes	72.1	63.0	21.8	0.8	0.0	0.0
monkeyface prickleback	62.8	42.2	0.9	0.0	0.0	0.0
anchovies[3]	55.4	45.1	5.5	0.0	0.0	0.0
cabezon	36.3	19.0	0.6	0.0	0.0	0.0
flatfishes	34.1	17.7	0.2	0.0	0.0	0.0
Average Percent Reduction in Entrainment	**53.7**	**39.7**	**8.4**	**1.0**	**0.1**	**0.0**

[1] - Extrapolated to the size at which the larvae are no longer susceptible to entrainment (estimated to be 20–25 mm [0.98 in] for this analysis). Not the reduction in adult equivalents.
[2] - percentage reductions are the same as the values in Table D-2.

Appendix E- Guidance Documents for Assessing Entrainment Including Additional Information on the Following Loss Rate Models: Fecundity Hindcasting (FH), Adult Equivalent Loss (AEL) and Area Production Forgone using an Empirical Transport Model (ETM/APF)

Associated with the Draft Staff Report Including the Draft Substitute Environmental Documentation for the Proposed Desalination Amendment

Documents included:

Steinbeck, J.R., J. Hedgepeth, P. Raimondi, G. Cailliet and D.L. Mayer. 2007. Assessing Power Plant Cooling Water Intake System Entrainment Impacts.

Raimondi, P. 2011. Variation in Entrainment Impact Based on Different Measures of Acceptable Uncertainty. Prepared for California Energy Commission, Public Interest Energy Research Program. http://www.energy.ca.gov/2011publications/CEC-500-2011-020/CEC-500-2011-020.pdf

ASSESSING POWER PLANT COOLING WATER INTAKE SYSTEM ENTRAINMENT IMPACTS

JANUARY 2007

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EXECUTIVE SUMMARY

Steam electric power plants and other industries that withdraw cooling water from surface water bodies are regulated in the U.S. under Section 316(b) of the Clean Water Act of 1972. Of the industries regulated under section 316(b), steam electric power plants have the largest cooling water volumes with some large plants exceeding two billion gallons per day. Environmental effects of cooling water withdrawal result from impingement of larger organisms on screens that block material from entering the cooling water system and the entrainment of smaller organisms into and through the system.

Concerns regarding the environmental effects of entrainment result from the large volume of cooling water potentially used by coastal power plants. In California, the 21 coastal power plants potentially withdraw up to 64 billion liters (17 billion gallons) of seawater per day. This process results in the loss of billions of aquatic organisms, including fishes, fish larvae and eggs, crustaceans, shellfish and many other forms of aquatic life from California's coastal ecosystem each year. There has been increased focus on the effects of power plant cooling water intake systems because the biological resources of the world's oceans, and California's coast in particular, are in serious decline. Long-term declines, which started in the early 1970s, have occurred in 60 percent of the fishes for which landings are reported. Despite the potential contribution of cooling water withdrawal to these declines, recent studies have only been completed at a few of the California power plants (California Energy Commission 2005). Regulations for Section 316(b) of the Clean Water Act published in July 2004 (USEPA 2004) will result in new studies on the environmental effects of cooling water systems at many of the existing power plants in California and throughout the country. The results of these studies will help determine the environmental effects of cooling water withdrawal on biological communities.

While the assessment of impingement effects is relatively straightforward, the assessment of entrainment effects require thoughtful consideration of all aspects of the study design. The difficulties in entrainment assessments arise from several factors. The organisms entrained include planktonic larvae of fishes and invertebrates that are difficult to sample and identify. The entrained larvae are also part of larger source water populations that may extend over large areas or be confined to limited habitats making it difficult to determine the effects of entrainment losses. The early life histories of most fishes on the Pacific coast are also poorly described limiting the usefulness of demographic models for assessing entrainment effects. All of these factors make the assessment of cooling water system entrainment difficult. The purpose of this report is to present, by example, some of the considerations for the proper design and analysis of entrainment studies.

This report describes three studies for assessing entrainment at coastal power plants in California. They represent a range of marine and estuarine habitats: the South Bay Power Plant in south San Diego Bay, and the Morro Bay and Diablo Canyon Power Plants in central California. These studies utilized a multiple modeling approach for assessing entrainment effects. When appropriate life history information was available for a species, demographic modeling techniques were used to calculate the numbers of adults represented by the losses of fish eggs and larvae due to entrainment. The primary approach for assessment at these plants was the Empirical Transport Model (*ETM*), originally developed for use with power plants entraining water from rivers, and then adapted for use on the open coast and in estuaries in southern California. The *ETM* utilizes the same principles used in fishery management to estimate effects of fishing mortality on the sustainability of a stock. Just as fishery managers use catch and population size to estimate fishery mortality, the *ETM* requires estimates of both entrainment and source water larval populations. The source water population is the abundance of organisms at risk of entrainment as determined by biological and hydrodynamic/oceanographic data. The process of defining the source water and obtaining an estimate of its population varied among the three plants and also among species within studies. The purpose of this paper is to present the multiple modeling approaches used for power plant entrainment assessments, with the main focus being a comparison of the processes used to define the source water populations used in the *ETM* modeling from the three power plants.

The results showed that standard demographic models were generally not usable with species found along the California coast due to the absence of life history information for most of them. The results for the *ETM* ranged from very small levels (<1.0%) of proportional mortality due to entrainment for wide ranging pelagic species such as northern anchovy to levels as high as 50% for fishes with more limited habitat that were spawned near power plant intake structures. The results of the *ETM* were generally consistent with the biology and habitat distributions of the fishes analyzed.

Based on our experiences with these and other studies we believe that a prescriptive approach to the design of entrainment assessments is not possible, and therefore, we provide some general considerations that might be helpful in the design, sampling, and analysis of entrainment impact assessments. These include ensuring that organisms that could be affected by entrainment are effectively sampled and that the sampling will account for any endangered, threatened, or other listed species that could be affected by entrainment. In addition to identifying species potentially affected, it is critical to determine the source water areas potentially affected including the distribution of habitats that might be differentially affected by CWIS entrainment. The sampling plan also needs to account for the design, location, and hydrodynamics of the power plant intake structure. The sampling frequency should accommodate important species that might have short spawning seasons. This may require that the sampling frequency be seasonally adjusted based on presence of certain species. The relative effects of entrainment estimated by the *ETM* model should be much less subject to interannual variation than absolute estimates using Fecundity Hindcasting (*FH*), Adult Equivalent Loss (*AEL*) or other demographic models. Therefore, if source water sampling is done in conjunction with entrainment sampling then one year is a reasonable period of sampling for these studies. The size of the source water sampling area should be based on the hydrodynamics of the system. In a closed system this may be the entire source water. In an open system, ocean or tidal currents and dispersion should be used to determine the appropriate sampling area for estimating daily entrainment mortality (*PE*) for the larger source water population.

Some practical considerations for sample collection and processing include adjusting the sample volume for the larval concentrations in the source waters. This is best done using preliminary sampling with the gear proposed for the study. Age of larvae are best determined using analysis of otoliths, but if this is not possible be sure that length frequencies measured from the entrainment samples are realistic based on available life history and account for egg stages that would be subject to entrainment if fish eggs are not sorted and identified from the samples. This is easily accommodated in the *ETM* approach by adding the duration of the planktonic egg stage to the larval duration calculated from the otolith or length data.

Although we believe that the *ETM* is best approach for assessment, results from multiple models provide additional information for verifying results and for determining effects at the adult population level. One approach for assessment at the adult population level is through converting *ETM* results into an estimate of the habitat necessary to replace the production lost due to entrainment (Area of Production Foregone [APF]). The APF is calculated by multiplying the area of habitat present within the estimated source water by the proportional entrainment mortality estimated from *ETM*. This approach may be useful for scaling restoration projects to help offset losses due to entrainment.

The *ETM* can also be used to estimate the number of equivalent adults lost by entrainment by applying the mortality estimate to a survey of the standing stock. This can be compared with estimates from *FH* and *AEL*. When making these types of comparisons it is important to hindcast or extrapolate the *FH* and *AEL* model estimates to the same age. This may not necessarily result in the same estimates from both models unless the data used in the two models are derived from a life table assuming a stable age distribution. The USEPA (2002) used *AEL* and another demographic modeling approach, production foregone, to estimate the number of age-1 individuals lost due to power plant impingement and entrainment. The accuracy of estimates from any of these demographic models is subject to the underlying uncertainty in aging, survival, and fecundity estimates and population regulatory, behavioral, or environmental factors that may be operating on the subject populations at the time the life history data were collected.

Uncertainty associated with the *ETM* is primarily derived from sampling error that can be controlled by careful design using some of the guidelines provided in this report. With a good sampling design, the *ETM* provides a site-specific, empirically based approach to entrainment assessment that is a major improvement over demographic modeling approaches. In addition, the results can be used to estimate entrainment effects on other planktonic organisms, in estimating cumulative effects of multiple power plants and other sources of mortality, and in scaling restoration efforts to offset losses due to entrainment. We hope that the information in this report will assist others in the design and analysis of CWIS assessments that will be required as a result of the recent publication of new rules for Section 316(b) of the Clean Water Act (USEPA 2004).

1.0 INTRODUCTION

Steam electric power plants and other industries (e.g., pulp and paper, iron and steel, chemical, manufacturing, petroleum refineries, and oil and gas production) use water from coastal areas for cooling resulting in impacts to the marine organisms occupying the affected water bodies. Industries that withdraw cooling water from surface water bodies are regulated in the U.S. under Section 316(b) of the Clean Water Act of 1972 [33 U.S. Code Section 1326(b)]. Section 316(b) requires "…that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts." Of the industries regulated under section 316(b), steam electric power plants have the largest cooling water volumes ranging from tens of thousands to millions of $m^3 d^{-1}$ (Veil et al. 2003). A survey in 1996 reported that 44% of the power plants in the U.S. utilized a steam electric process involving once-through cooling (Veil 2000). Electricity is generated at these plants by heating purified water to create high-pressure steam, which is expanded in turbines that drive generators and produce electricity (Figure 1-1). After leaving the turbines, steam passes through a condenser where high volume cooling water flow cools and condenses the steam, which is then re-circulated back through the system.

Regulatory guidance for complying with section 316(b), that was first proposed by the U.S. Environmental Protection Agency (EPA) in 1976, was successfully challenged in the courts by a group of 58 utility companies in 1977 and never implemented (Bulleit 2000). As a result, section 316(b) was implemented by the states using a broad range of approaches; some states developed fairly comprehensive programs while others never adopted any formal regulations (Veil et al. 2003). The EPA has recently published new regulations for 316(b) compliance (USEPA 2004) as part of the settlement of a lawsuit against the EPA by environmental groups headed by the Hudson Riverkeeper (Nagle and Morgan 2000). As a result of these new regulations power plants throughout the U.S. are now required to reduce the environmental effects of their cooling water intake systems (CWIS).

The withdrawal of water by once-through cooling water systems has two major impacts on the biological organisms in the source water body: impingement and entrainment (Figure 1-1). Almost all power plants with once-through cooling employ some type of screening device to block large objects from entering the cooling water system (impingement). Fishes and other aquatic organisms large enough to be blocked by the screens may become impinged if the intake velocity exceeds their ability to move away. These organisms will remain impinged against the screens until intake velocity is reduced such that organisms can move away or the screen is backwashed to remove them. Some organisms are killed, injured, or weakened by impingement. Small planktonic organisms or early life stages of larger organisms that pass through the screen mesh are entrained in the cooling water flow. These organisms are exposed to high velocity and pressure due to the cooling water pumps, increased temperatures and, in some cases, chemical treatments added to the cooling water flow to reduce biofouling.

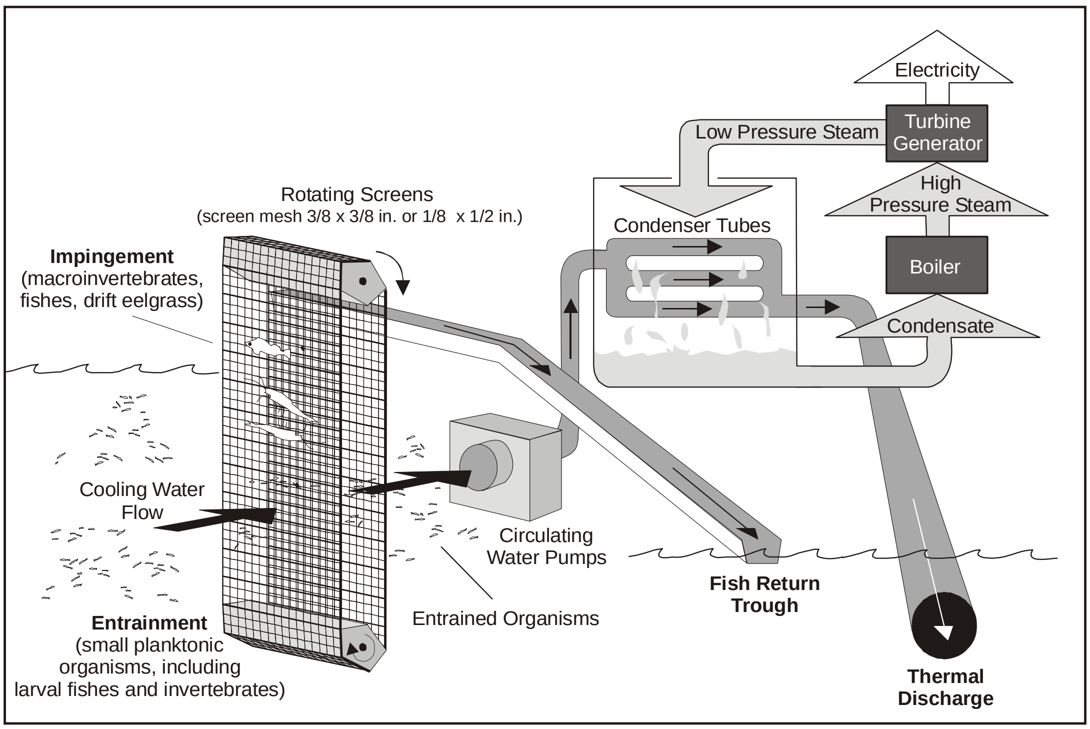


Figure 1-1. Conceptual diagram of power plant cooling water systems at South Bay, Morro Bay, and Diablo Canyon Power Plants, and relationship of impingement and entrainment processes to circulating water system. A fish return trough is present only at the South Bay Power Plant.

Most impingement and entrainment [316(b)] studies on CWIS effects at power plants were completed in the late 1970s and early 1980s using draft guidance issued by the EPA (USEPA 1977). More recently, many power plants throughout the country began to upgrade and expand their generating capacities due to increased demands for power. The California Energy Commission (CEC), which had regulatory authority for these projects in California, required utility companies to determine the impacts of these CWIS changes. Although existing

CWIS are regulated in California through National Pollution Discharge Eliminations System (NPDES) permits issued by the nine Regional Water Quality Control Boards (RWQCB) in the state, the projects done under the regulatory authority of the CEC also required coastal zone permits under the California Coastal Act and therefore were conducted in compliance with the California Environmental Quality Act (CEQA). The CEC and the RWQCBs required new studies in anticipation of the publication of new EPA regulations, but also because data on CWIS impacts were not available for some of the plants and studies at other plants were usually over 20 years old. As a result, we had the opportunity in California to develop approaches to assessing CWIS impacts that might prove useful to researchers at power plants throughout the U.S. These studies involved regulatory agency staff, scientists, consultants, and industry representatives, usually meeting and working under the heading of Technical Workgroups. This collaborative process was first used for studies at the Pacific Gas & Electric Company Diablo Canyon Power Plant and was initiated and directed by Mr. Michael Thomas at the Central Coast Regional Water Quality Control Board (CCRWQCB) (Ehrler et al. 2003). This process was also used on studies for plant re-powering projects under CEC and RWQCB review at the Moss Landing, Morro Bay, Potrero and Huntington Beach Power Plants.

This paper focuses on methods for assessing only entrainment effects (not impingement), and specifically, entrainment effects on ichthyoplankton. Entrainment affects all types of planktonic organisms, but most studies do not assess holoplankton (phytoplankton and zooplankton that are planktonic for their entire life) because their broad geographic distributions and short generation times reduce the effects of entrainment on their populations. In contrast, the potential for localized effects on certain fish populations is much greater, especially for power plants located in riverine or estuarine areas where a large percentage of the local population may be at risk of entrainment (Barnthouse et al. 1988, Barnthouse 2000). Although the potential for similar effects exists for certain invertebrate meroplankton (e.g. crab and clam larvae), taxonomy of early larval stages of many invertebrates is not sufficiently advanced to allow for assessments at the species-level. The different larval stages of many invertebrates may also require different mesh sizes and sampling techniques that increase the costs and complexity of a study. In contrast, as a result of programs such as the California Coastal Oceanographic Fisheries Investigations (CalCOFI) program, operating since 1950, ichthyoplankton of the west coast have been well described and long-term data sets exist on the abundances of many larval fishes (Moser 1996).

The best-documented and most extensive 316(b) studies from the period of the late 1970s and early 1980s were from the Hudson River power plants (Barnthouse et al. 1988, Barnthouse 2000). Impacts of cooling water withdrawals from three plants were extensively studied using long-term, river-wide sampling and analyzed using mathematical models designed to predict the effects on striped bass and other fish populations. After many years of debate surrounding a lawsuit, the case was settled out of court. Two of the most important factors in laying the groundwork for the settlement were the converging estimates of the effects from different researchers and the development of models that estimated conditional mortality from empirical data that reflected the “complex interactions of a host of factors” and helped identify the “relative importance of each component of the analysis” (Englert and Boreman 1988).

Numerous demographic modeling approaches have been proposed and used for projecting losses from CWIS impacts (Dey 2003). Equivalent adult (Horst 1975, Goodyear 1978), production foregone (Rago 1984), and variations of these approaches and models (Dey 2003) translate entrainment losses of egg and larval stages into equivalent units (adult fishes, biomass, etc.) that otherwise would not have been lost to the population. Although these models are the most commonly used methods for CWIS assessment and were used by the EPA to support the new 316(b) regulations (USEPA 2004), there can be problems with their application and interpretation. The models require life history parameters (larval duration, survival, fecundity, etc.) that are available for only a limited number of species, generally those managed for commercial or recreational fishing. Our experience has shown that on the California coast, taxa (the term ‘taxa’ [‘taxon’ singular] is used to refer to individual species or broader taxonomic categories that cannot be identified to species) that are usually entrained in highest numbers are small, forage fishes that have very limited life history information available.

However, these models are attractive because their interpretation appears to be straightforward since they convert larval forms into “equivalent units” that are more easily understood by the public, regulators, and managers. The estimates of numbers or biomass of fish from the models can also be added to losses from impingement and compared with commercial or recreational fishery data to provide cost estimates of the losses. Unfortunately, these interpretations are available for only a few taxa, there is usually no scale for determining the significance of the losses to the source water populations, and the studies are only done for a 1-2 yr period, not accounting for inter-annual variation in larval abundances.

Our assessments included a modified version of the Empirical Transport Model (*ETM*) (Boreman et al. 1978, 1981) which circumvented the problems with existing demographic modeling. This model was first developed for use with power plants entraining water from rivers, but MacCall et al. (1983) used the same general approach for entrainment assessments at power plants on the open coast and in estuaries in southern California. In contrast to demographic models, it does not require detailed life history information. The *ETM* provides an estimate of the mortality caused by entrainment to a source water population independent of any other sources of mortality, i.e., conditional mortality (Ricker 1975). Inherent in this approach is the requirement for an estimate of the source water population of larvae affected by entrainment. The source water population is the abundance of organisms at risk of entrainment as determined by biological and hydrodynamic/oceanographic data. The *ETM* is based on the same principles used in fishery management to estimate effects of fishing mortality on a source water population or stock (Boreman et al. 1981, MacCall et al. 1983). Although not specifically required for calculating estimated losses, an estimate of the source water population is also required to provide a context for the losses estimated by demographic models.

The process of defining the source water and obtaining an estimate of its population varies among studies and also among taxa within studies. The purpose of this paper is to present the multiple modeling approaches used for power plant entrainment assessments, with the main focus being a comparison of the processes used to define the source water populations used in the *ETM* modeling from three power plants in California, South Bay Power Plant (SBPP), Morro Bay Power Plant (MBPP), and Diablo Canyon Power Plant (DCPP), which represent a range of marine and estuarine habitats (Figure 1-2). This comparison allows us to compare the approaches and assess the influence of the source water on the proportional mortality of affected fish and invertebrate larval taxa.

The source water population definitions for the three studies were based on the hydrodynamic and biological characteristics of the water bodies where the facilities were located. This is necessary to characterize the sources of the water that is drawn into a power plant. This is fairly simple if the source of cooling water is a lake that is so well mixed that the larval concentrations are uniform. In this case the only necessary information to estimate the mortality on the larvae is the volume of the lake and the plant cooling water volume. In this simple example the mortality is the ratio of the cooling water volume to the source water volume since the concentration of larvae entrained will be equal to the concentration in the source water. In the case of SBPP, samples were collected throughout the entire source water since the larval composition in the habitats within the south part of San Diego Bay were potentially different even though the source water volume for SBPP was treated as a closed system similar to the lake in the above example. The source water for MBPP included both bay and ocean components requiring biological sampling in both locations and calculations to include the effects of tides on the source water. The effects of ocean currents affected the source water potentially entrained for DCPP and the ocean component of the MBPP source water. As a result the source water potentially affected by entrainment was much larger than the areas sampled for these two studies requiring additional measurements and modifications to the model. The many factors that need to be considered in the design of these kinds of studies can be examined by comparing the different approaches taken at the three facilities.

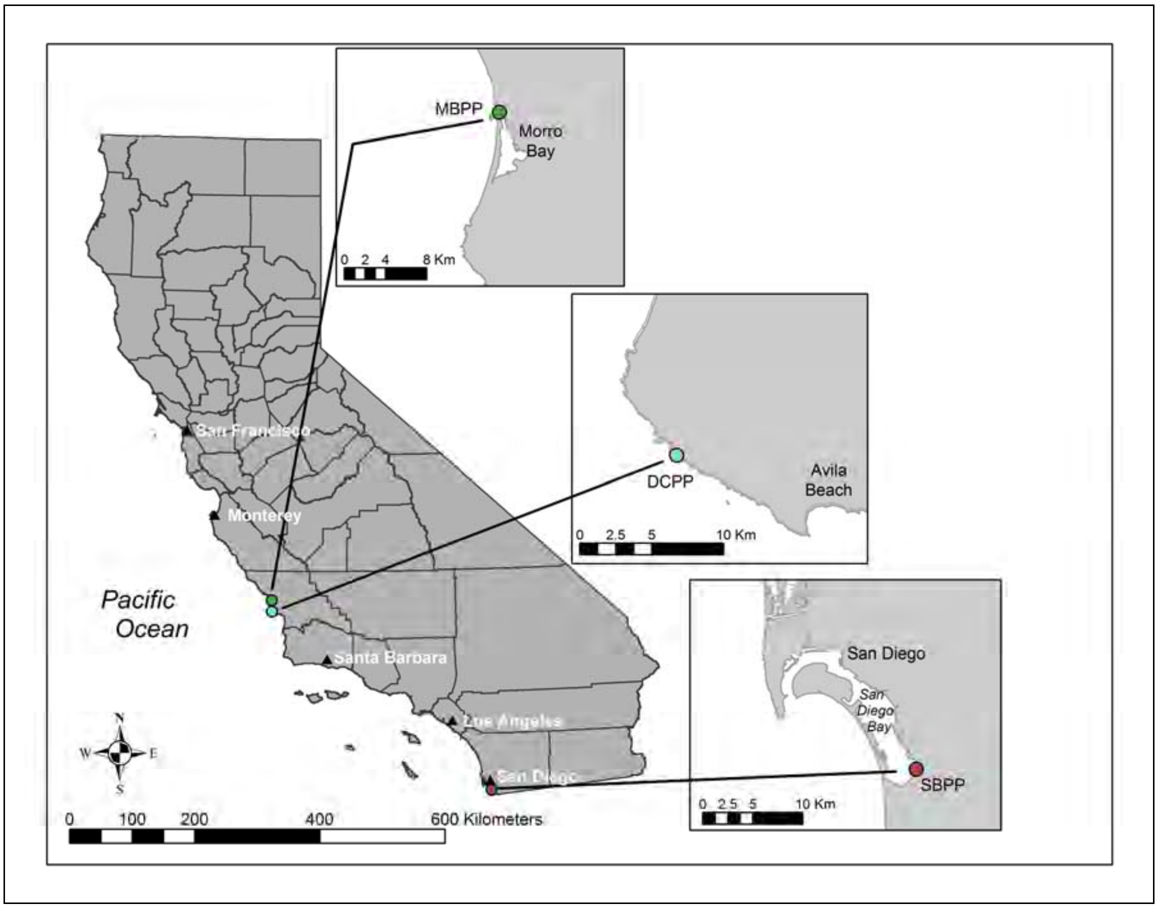


Figure 1-2. Locations of Morro Bay (MBPP), Diablo Canyon (DCPP), and South Bay Power Plants (SBPP).

During the course of these studies we have modified the assessment approaches and this process has continued as we have participated in additional, more recent studies. Therefore one of the additional purposes of this paper is to present these more recent changes in our assessment methods even though they may differ from methods presented in the three example studies.

Our experiences resulting from these studies are especially pertinent with the recent publication of new rules for Section 316(b) of the Clean Water Act (USEPA 2004), and CEC and California Coastal Commission (CCC) requirements for modernizing power plants in California. The new 316(b) rules require that information on the source water body be submitted as part of 316(b) compliance [40 CFR 125.95(b)(2)]. Although not stated in the new rules, it seems appropriate that CWIS impacts would be evaluated based on the source water body information. The CEC and CCC have required this in recent studies and most likely will continue this practice. Hopefully the information in this paper will assist others in the design and evaluation of CWIS assessments that will be required under the new rules.

2.0 METHODS

2.1 POWER PLANT DESCRIPTIONS

The studies we will be presenting as examples were conducted at three power plants: SBPP, MBPP, and DCPP (Figure 1-2). The CWIS for all three plants share several features: shoreline intake structures with stationary trash racks that consist of vertical steel bars to prevent larger objects and organisms from entering the system and traveling water screens (TWS) located behind the bar racks that screen out smaller organisms and debris from the system (Figure 1-1).

Entrainment occurs to organisms that pass through the smaller mesh of the TWS. These organisms are exposed to increased temperatures and pressures as they pass through CWS. The surfaces of the piping in the CWS can be covered with biofouling organisms that feed on organisms that pass through the system. Although studies have shown that there may be some survival after CWS passage (Mayhew et al. 2000), most of these studies were conducted at power plants in rivers and estuaries on the east coast or in the Gulf of Mexico where biofouling was not recognized as a large problem compared with coastal environments. In addition, these studies only examined survival after passage through the system, and did not include comparisons of intake and discharge concentrations where losses due to cropping should be factored into CWS survival. For example, during testing used to determine the appropriate entrainment sampling location losses between the intake and discharge at the Moss Landing Power Plant sometimes exceeded 95 percent and were always greater than 50 percent (Pacific Gas and Electric Co. 1983). For these reasons, our assessments of CWS effects have assumed that entrained organisms experience 100% mortality.

The SBPP, operated by Duke Energy, is located on the southeastern shore of San Diego Bay in the city of Chula Vista, California, approximately 16 km north of the U. S. – Mexican border (Figure 2-1). The plant draws water from San Diego Bay for once-through cooling of its four electric generating units, which can produce a maximum of 723 MWe (Table 2-1). With all pumps in operation, maximum water flow through the plant is 1,580 m^3min^{-1} (2.3 million m^3d^{-1}).

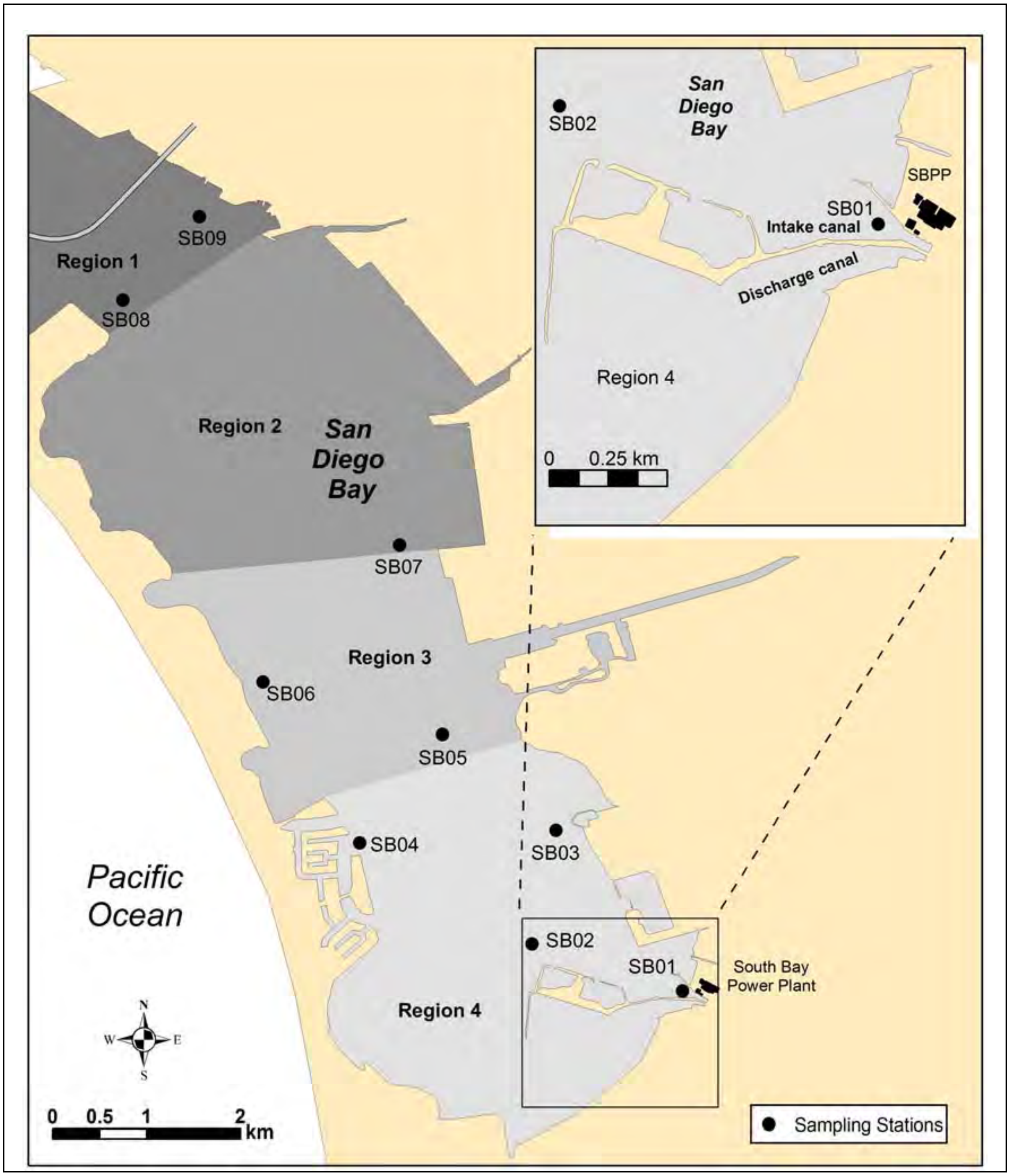


Figure 2-1. Location of South Bay Power Plant entrainment (SB01) and source water stations and detail of power plant intake area. Shaded areas represent regions of the bay used in calculating bay volumes.

The MBPP, operated by Duke Energy, is located on the northeastern shoreline of Morro Bay, which is approximately midway between San Francisco and Los Angeles, California (Figure 2-2). The plant draws water from Morro Bay for once-through cooling of its four electric generating units, which can produce a total of 1,002 MWe (Table 2-1). With all pumps in operation, water flow through the plant is 1,756 m^3min^{-1} (2.53 million m^3d^{-1}). Morro Bay studies were done as part of the permitting requirements for an upgrade to the plant that result in a decrease in flow to 1,086 m^3min^{-1} (1.56 million m^3d^{-1}). Therefore, all of the entrainment estimates and modeling were calculated using this flow rate.

Table 2-1. Characteristics of the South Bay (SBPP), Morro Bay (MBPP) and Diablo Canyon (DCPP) Power Plants.

Power Plant	Number of Power Generating Units	Total Maximum Megawatt Electric (Mwe) Output	Number of Circulating Water Pumps	Total Maximum Daily Flow (m^3)
SBPP	4	723	8 (2/unit)	$2.3x10^6$
MBPP	4	1,002	8 (2/unit)	$2.5x10^6$
DCPP	2	2,200	4 (2/unit)	$9.7x10^6$

The DCPP, operated by Pacific Gas and Electric Company, is located on the open coast midway between the communities of Morro Bay and Avila Beach on the central California coast in San Luis Obispo County (Figure 2-3). The intake structure for the plant is located behind two breakwaters that protect it from waves and surge. The plant has two nuclear-fueled generating units that can produce a total of 2,200 MWe (Table 2-1). With the main pumps and smaller auxiliary seawater system pumps in operation, total water flow through the plant is 6,731 m^3min^{-1} or (9.7 million m^3d^{-1}).

2.2 SOURCE WATER AND SOURCE POPULATION DEFINITIONS

The concept of defining the source water potentially affected by CWS operation is inherent in the assessment process, but was not defined as a necessary component of a 316(b) assessment until the recent publication of the new 316(b) rules. The new rules require all existing power plants with CWS capacities greater than 189,000 m^3d^{-1} to complete a Comprehensive Demonstration Study that includes a qualitative description of the source water. A more detailed quantitative definition of source water is not necessary for demographic modeling approaches, but is required to place calculated losses into context. The Empirical Transport Model (*ETM*) requires a more specific definition since the model calculates the conditional mortality due to entrainment on an estimate of the population of organisms in the source water that are potentially subject to entrainment.

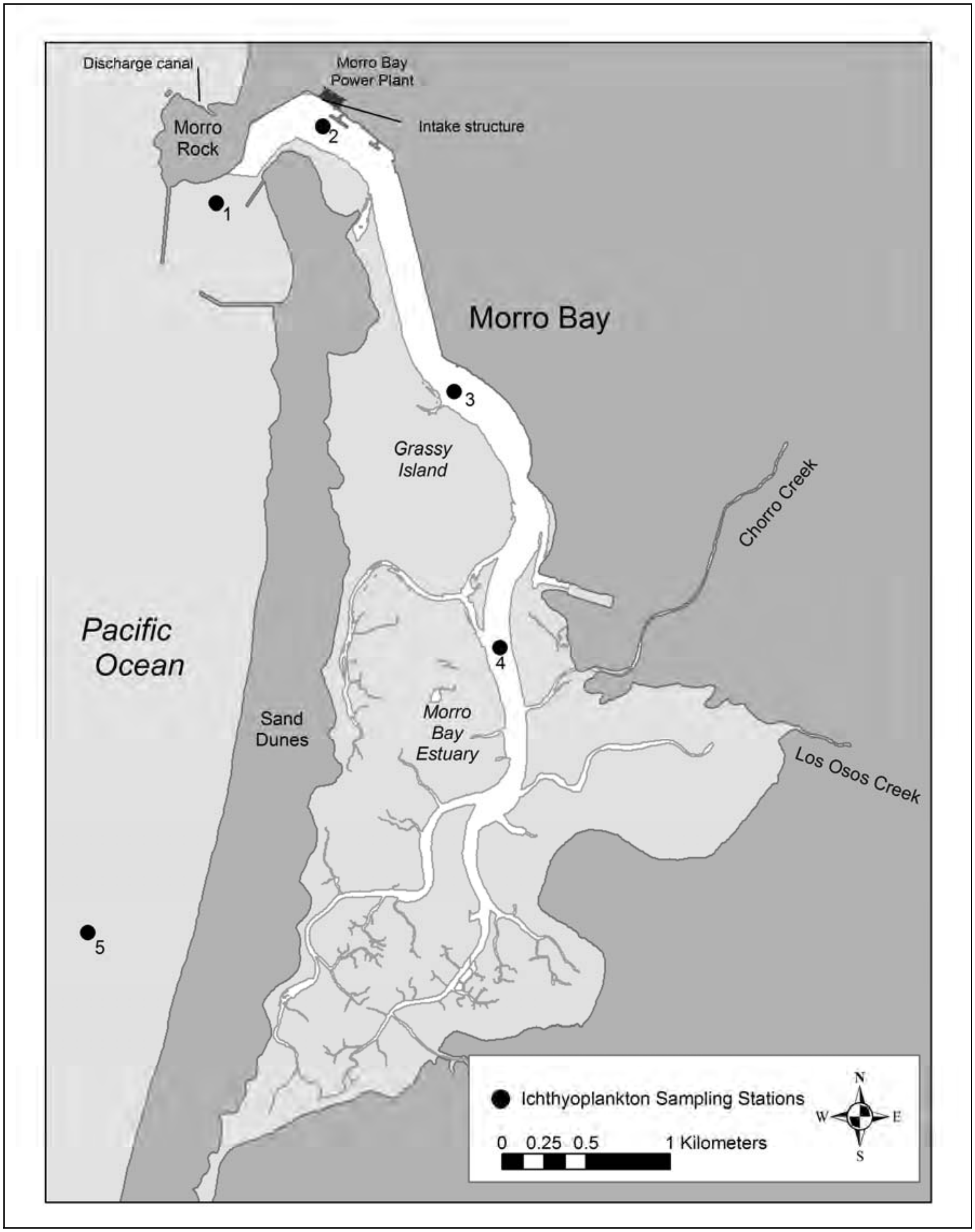


Figure 2-2. Locations of Morro Bay Power Plant entrainment (Station 2) and source water stations. White area depicts the main tidal channels in the bay, light gray areas are submerged at high tide, and dark gray areas are above the mean high tide line.

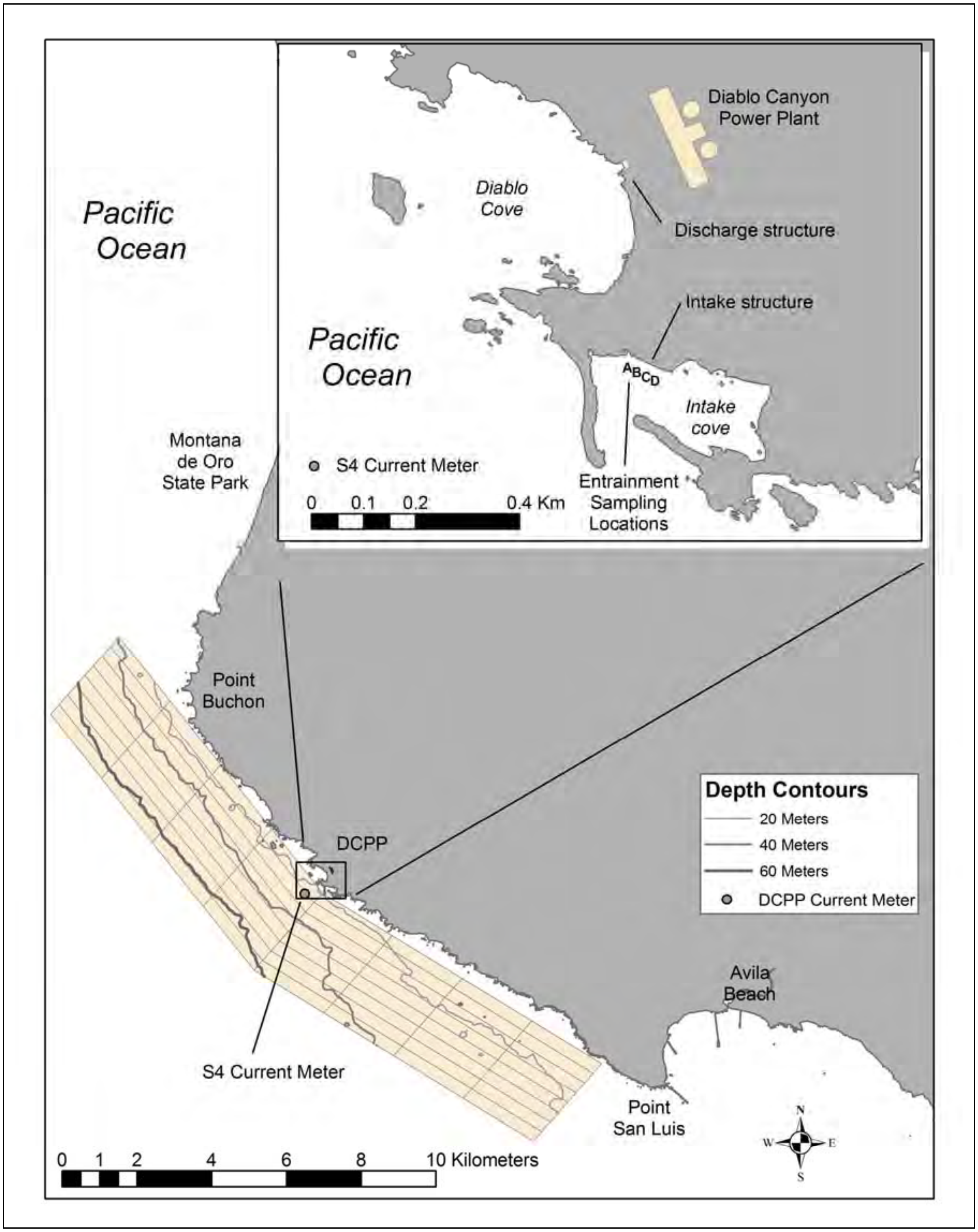


Figure 2-3. Locations of Diablo Canyon Power Plant (DCPP) entrainment stations (A, B, C, D, in insert) and source water sampling grid.

Critical to properly defining the source water for these studies was physical data that was either collected during the studies or from other sources to estimate the volume of the areas sampled and the total size of the source water. At SBPP and MBPP, hydrographic data collected for the study from several sources was used to estimate volume of the two water bodies. That volume was used as the total source water volume for SBPP. In addition to the volume of Morro Bay, current data from offshore and information on tides was used to estimate the total source water volume which included both bay and ocean components. Data from the same current meter used in the DCPP study were used in the MBPP study to calculate an average current speed over the period of January 1, 1996 – May 31, 1999. Current direction was ignored in calculating the average speed. The current speed was used to estimate unidirectional displacement over the period of time that the larvae in the sampling area offshore from Morro Bay were exposed to entrainment (described below). At DCPP, hydrographic data from National Oceanic and Atmospheric Administration was used to estimate the volumes of each of the 64-nearshore sampling stations (described below). In addition, data on alongshore and onshore current velocities were measured using an InterOceans S4 current meter positioned approximately 1 km west of the DCPP intake at a depth of approximately 6 m (Figure 2-3). The direction in degrees true from north and speed in cm/s were estimated for each hour of the nearshore study grid survey periods. These data were used to estimate the size of the area that could have acted as a source for larvae in the nearshore sampling area (described below).

South Bay Power Plant

The SBPP draws ocean water from the southernmost end of San Diego Bay (Figure 2-1). Allen (1999) divided San Diego Bay into four eco-regions and defined the south and south-central eco-regions as the area from the Coronado Bridge to the southern end of San Diego Bay. Analyses of current patterns and tidal dispersion were used to justify the use of the south and south-central eco-regions (south of the Coronado Narrows) as an appropriate source volume for the purposes of modeling the effects of entrainment by SBPP. These analyses were done by Dr. John Largier, formerly at Scripps Institute of Oceanography, and now at Bodega Marine Laboratory of the University of California at Davis, and Dr. David Jay, Oregon Health and Science University (Tenera Environmental 2004). The analysis of tidal currents measured at 18 locations throughout the interior of San Diego Bay showed that tidal currents exhibited a local maximum in the south bay at the Coronado Narrows and increased toward the bay mouth. Estimates of tidal dispersion were formed using data from the same 18 current meters, which showed spatial patterns generally similar to those from Largier (1995).

The results of Largier (1995) showed that tidal dispersion had a local maximum at the Coronado Narrows, consistent with the idea that the Narrows acts as the “mouth” of south bay. South of the Narrows currents and tidal dispersion are much reduced. Mixing throughout the south bay was estimated to take from one week to a month, typical of the period of time that the larvae were estimated to be exposed to entrainment. The results suggested that larvae are likely removed from the south bay primarily, but not exclusively, by dispersion and that advection may only be dominant during winter river-flow events. The analyses confirmed, in a quantitative manner, Allen’s (1999) definitions of eco-regions in San Diego Bay and helped verify the use of the Coronado Narrows as a logical seaward boundary for the SBPP source volume.

Since retention times in the south bay exceeded the average larval durations for most of the taxa examined, the source water was treated as a static volume. Volume was calculated as the volume of water below Mean Water Level (MWL, the average of a large number of tidal observations) from the southern end of San Diego Bay northward to the Coronado Narrows (Figure 2-1). Computing the source volume required compiling the areas and volumes below fixed elevations (horizontal strata). Variations in tidal range required that the South Bay be divided into four regions, with tidal datum levels determined for each, either directly from a tide gauge in the region or by interpolation from adjacent gauges. Tide gauges were available in Regions 2, 3 and 4, whereas datum levels in Region 1 had to be determined by interpolation. Bathymetry for Regions 1 and 2 and the periphery of Regions 3 and 4 were obtained from the U.S. Navy and supplemented with data collected for this study. Estimates of the average concentrations of the organisms inside the bay were multiplied by the sum of the estimated volumes from the four areas (Table 2-2) to obtain estimates of the bay source water populations that were used in the calculations of mortality for the *ETM*.

Table 2-2. Source water body surface area and water volume at mean water level (MWL) by region for south San Diego Bay.

Region	Datum	Height (m)	Area (m^2)	Volume (m^3)
1	MWL	0.90	4,241,241	33,754,018
2	MWL	0.90	10,173,006	70,387,388
3	MWL	0.91	6,355,524	25,060,179
4	MWL	0.93	9,556,875	20,410,508
			30,326,646	149,612,092

Morro Bay Power Plant

The MBPP source water was divided into two sub-areas, bay water and nearshore coastal water, because the location of the intake structure near the harbor entrance entrained both bay and nearshore taxa (Figure 2-2). The source water for MBPP could not be treated as a static volume, such as the source water for SBPP, because of the location of the power plant intake near the harbor entrance, which made it subject to tidal flows on a daily basis, and the smaller volume of the bay relative to an area such as San Diego Bay. To compensate for daily tidal movement past MBPP, the volume of the Morro Bay source water component was calculated as the sum of the bay's twice daily exchange of its 15.5 million m^3 tidal prism, adjusted for tidal exchange, (Mean High Water to Mean Low Water) and the bay's non-tidal volume of 5.4 million m^3. The volume of the tidal prism was adjusted to account for the portion of the Morro Bay outflow that returned with the incoming tide. Since volume was used to estimate the total supply of entrained larvae, inclusion of the re-circulated tidal prism volume would double count a portion of the larval supply and underestimate potential entrainment effects. This was accounted for using a tidal exchange ratio (TER), calculated for Morro Bay. The TER is the fraction of the total tidal exchange that consists of "new" water coming into the estuary, i.e., water that did not leave the estuary on the previous tidal cycle (Largier et al. 1996). In Morro Bay, the "total tidal exchange" is synonymous with the tidal prism, except for the amount estimated by TER.

The TER is difficult to estimate from measurements because the currents that prevail outside of any estuary mouth are complex and variable, and it is quite sensitive to processes inside and outside the estuary, especially complex currents, river inflow and density stratification (Largier et al. 1996). However, a method was developed (Largier et al. 1996) that measures the TER from the change in salinity of water flowing in and out of the entrance of an estuary. Applying this method, the Morro Bay TER was calculated to be between 70 and 80% of the average daily tidal prism by Dr. David Jay (Tenera Environmental 2001). A TER of 75% was used in calculating the bay source water volume, which was equal to the twice-daily tidal exchange of the average tidal prism, adjusted for the TER, added to the bay's non-tidal volume. Estimates of the average concentrations of organisms from the stations inside the bay (Stations 1–4) were multiplied by this volume to obtain estimates of the bay source water populations (Table 2-3). Since tidal exchange was used in calculating the source volume for Morro Bay, the plant's intake flow volume was calculated over a complete daily tidal cycle of two highs and two lows which was 24 hours and 50 minutes.

Table 2-3. Volumes for Morro Bay and Estero Bay source water sub-areas.

Area	Volume (m^3)
Morro Bay	15,686,663
Estero Bay Sampling Area	20,915,551

The area sampled outside Morro Bay in Estero Bay was treated as a static volume (Table 2-3) that was equal to the volume of Morro Bay uncorrected for tidal exchange. This volume for Estero Bay was used because it represented the volume of water exchanged with the bay that could be subject to entrainment. Estimates of the average concentrations of the organisms from the station just inside the bay (Station 1) and the station down-coast (Station 5) were multiplied by this volume to obtain estimates of the Estero Bay populations in the area sampled. The total size of the source water beyond the area sampled was estimated using ocean current data. Morro Bay and Estero Bay larval estimates were calculated separately so that the large source volume in Estero Bay did not inflate the source water estimates for bay taxa that were in much lower abundances outside the bay.

Diablo Canyon Power Plant

The DCPP nearshore sampling was designed to only provide information on abundance and distribution in the vicinity of DCPP of larval fishes and the invertebrates selected for detailed assessment, since it was recognized that the actual source water would be much larger for some taxa and also vary by taxa and seasonally due to changing oceanographic conditions. In establishing the nearshore sampling area, we considered that ocean currents in the area generally move both up and down the coast past DCPP. The currents also showed inshore/offshore oscillations, but these occurred less frequently and generally at a lower magnitude. The nearshore sampling area contained 64 stations or ‘cells’ (Figure 2-3) that was centered on the Intake Cove at DCPP. The northern extent of the sampling area was near Point Buchon and the southern half, a mirror image of the northern portion, extended to near Point San Luis. The shape of the sampling area reflected a slight bend (approximately 20º) in the coast at DCPP. The sampling area extended a distance of 8.7 km to both the north and south and an average distance of 3 km offshore. Regions inshore of the sampling area were in shallow water with partially submerged rocks, making the areas unsafe for boat operations and sampling. Volumes in each of the 64 cells were estimated using the surface area of the cell and the average depth based on available bathymetry data. The number of larvae in each cell was estimated by multiplying the average concentration during each survey by the volume of water sampled.

2.3 SAMPLING

Sampling at all three of the facilities was designed to provide estimates of both entrainment and source water concentrations that accounted for the differences in the cooling water volumes at the three plants and were representative of the range of habitats and organisms potentially affected by entrainment in each area. As a result of the differences among the three plants and funding available, the combined entrainment and source water sampling efforts ranged from five stations for the MBPP study to 68 stations for the DCPP study.

Sample collection methods were similar to those developed and used by CalCOFI in their larval fish studies (Smith and Richardson 1977). Sampling at all three plants was conducted using a bongo frame with two 71-cm diameter rings with plankton nets constructed of 333-*u*m mesh. Each net was fitted with a Dacron sleeve and a cod-end container to retain the organisms. Each net was equipped with a calibrated General Oceanics flowmeter, which allowed the calculation of the amount of water filtered. Net lengths varied according to the depth of the water sampled. Shorter nets, 1.8 m in length, were used for entrainment sampling in the shallower intake cove at DCPP. Longer nets, 3.3 m in length were used for all other sampling. All of the nets were lowered as close to the bottom as possible and retrieved using oblique or vertical tows to sample the entire water column. Once the nets were retrieved from the water all of the collected material was rinsed into the codend. The target volume of each tow at both the entrainment and source water stations was 40-60 m^3 for both nets combined. The sample volume was checked when the nets reached the surface and the tow continued or started over if the target volume was not collected. The contents of both nets were either combined into one sample immediately after collection, or treated as a single sample for analysis.

Entrainment sampling at all three plants was done in the waters outside of the plant CWIS as close as possible to the intake structure bar racks. This sampling design assumed that the concentrations from the waters in front of the CWIS are the same as the concentrations in the cooling water flow. Sampling was done outside of the CWIS because of the numerous problems involved in sampling inside the plant or at the discharge. Sampling inside the plant usually involves sampling with a pump that generally obtains a small volume relative to plankton nets in a given period of time. Although samples inside the CWIS may be well mixed, the cooling water flow inside the system is exposed to biofouling organisms that can significantly reduce the concentration of larval fish and other organisms. Sampling outside the plant also allowed entrainment samples to be used in characterizing source water populations. This was critical to the *ETM* calculations and allowed source water estimates to be calculated for taxa that may have only been collected from entrainment samples.

South Bay Power Plant

Entrainment and source water sampling was conducted monthly from January 2001 through January 2002 (Tenera Environmental 2004). Entrainment samples were collected from Station SB1 located in the SBPP intake channel (Figure 2-1). Each tow proceeded out the intake channel against the prevailing intake current. The intake channel was bounded by a separation dike to the south and a shallow mudflat to the north, and there was a constant current flow toward the intake structure. Therefore it was assumed that all of the water sampled at the entrainment station would be drawn through the SBPP cooling water system. Entrainment samples were collected over a 24-hour period, with each period divided into six 4-hour sampling cycles. Two replicate tows were collected consecutively at the entrainment station during each cycle. Source water samples at Stations SB2-SB9 were collected from the same vessel during the remainder of each cycle (Figure 2-1). A single tow was completed at each of the source water stations during each of the six 4-hr cycles.

The stations for the SBPP study (Figure 2-1) were stratified to include four channel locations on the east side of the bay and four shallower locations on the west side of the bay. The source water stations ranged in depth from approximately –2 m Mean Lower Low Water (MLLW) at SB8 to –12 m MLLW at SB9. This station array was chosen to include a range of depths and adjacent habitats in south San Diego Bay that would characterize the larval fish composition in the source water. For example, stations on the east side of the bay were adjacent to salt marsh habitat and would tend to have a greater proportion of larvae from fishes with demersal eggs that spawned in salt marsh channels, such as gobies, while deeper channel stations in the northern end of the study area would tend to have more larvae of species that spawn in open water such as northern anchovy (*Engraulis mordax*).

Morro Bay Power Plant

Entrainment and source water sampling was conducted from December 1999 through December 2000 (Tenera Environmental 2001). Entrainment samples were collected weekly from in front of the MBPP intake structures (Station 2; Figure 2-2). Samples were collected over a continuous 24-hour period with each period divided into six, 4-hour sampling cycles. Two tows were conducted during each cycle. During the same period, monthly source water samples were collected at four stations in addition to the entrainment station (Figure 2-2). Initially, source water surveys were collected twice per day during daylight hours on high and low tides, but after two months of sampling in February 2000, sample collection for source water surveys was expanded to cover the entire 24-hour period and was no longer linked to tidal cycle.

Fewer stations were sampled in the MBPP study relative to the SBPP study due to the smaller size of the estuary. Station 1 was located just inside the entrance to Morro Bay and was intended to characterize water from outside the bay that was subject to entrainment during incoming tides. Only two other source water stations (stations 3 and 4) were located in Morro Bay because the areas that could be sampled in the south part of the bay were limited to narrow navigation channels. This was not considered to be a problem because of the large tidal prism relative to the size of the bay resulted in shallower portions of the bay draining through the deeper navigation channels where the sampling occurred. Station 5 was located outside of the bay approximately 4.7 km down coast (i.e., south of the harbor mouth) and was intended to characterize open coastal taxa potentially subject to entrainment.

Diablo Canyon Power Plant

Collection of the DCPP entrainment samples occurred from October 1996 through June 1999 (Tenera Environmental 2000). This was the longest period of sampling among the three studies. The sampling was continued longer than one-year because of El Niño conditions during the first year, which were agreed by the Technical Workgroup as not representative of normal conditions. Entrainment samples were collected once per week from four permanently moored sampling stations located directly in front of the intake structure that were sampled in a random order during eight 3-hour cycles (Figure 2-3). Two samples were collected at each station during each cycle. The first 9 surveys were collected with 505 *u*m mesh nets, but due to extrusion of larval fishes through the net mesh observed during these first few surveys, subsequent surveys were collected with 335 *u*m mesh.

The boundaries and shape of the nearshore sampling area were chosen to ensure that the area would be large enough to characterize the larvae from the fishes potentially influenced by the large volume of the DCPP CWIS, and would be representative of the variety of nearshore habitats found in the area. These were the same reasons used to justify the large sampling effort (64 stations) relative to the SBPP and MBPP studies. Sampling of the nearshore study area occurred monthly from July 1997 through June 1999. Two randomly positioned stations within each of the 64 cells of the grid were sampled once each survey. The study grid was sampled continuously over 72 hours using a “ping-pong” transect to limit temporal and spatial biases in the sampling pattern and to optimize shipboard time. The starting cell (constrained to the 28 cells on the perimeter of the grid) and the initial direction of the transect (constrained to the two cells diagonally, adjacent to the starting cell) were selected at random. When the adjacent diagonal cell had previously been sampled, one of the two adjacent cells in the direction of travel was randomly selected to be sampled next. To minimize temporal variation between entrainment and study grid sampling, source water surveys were scheduled to bracket the 24-hour entrainment survey, overlapping by one day before and after the collection of entrainment samples.

Entrainment and nearshore sampling efforts did not start at the same times and therefore the entire sampling period was divided into five analysis periods. All of the weekly entrainment samples from October 1996 through November 1998 were processed so this period was divided into two yearlong analysis periods. Results for these periods are not presented because they were only used to generate estimates directly from entrainment data. The nearshore sampling period was also divided into two yearlong analysis periods. Only the entrainment samples collected during the sampling of the nearshore area were processed from December 1998 through June 1999 so entrainment data from July 1998 through June 1999 were used to generate model estimates for a fifth analysis period that could be directly compared with model estimates that incorporated data from the nearshore sampling area.

2.4 SELECTION OF TAXA FOR DETAILED ASSESSMENT

Although almost all planktonic forms (phyto-, zoo-, and ichthyoplankton) are affected by entrainment, these three studies and most other 316(b) studies have focused on a few organism groups, typically ichthyoplankton and zooplankton. The effects on phytoplankton and invertebrate holoplankton are typically not studied because their large abundances, wide distributions, and short generation times should make them less susceptible to CWIS impacts. The groups of organisms selected for assessment in these studies included larval fishes and larvae from commercially or recreationally important invertebrates such as *Cancer* spp. crabs and California spiny lobster (*Panulirus interruptus*).

The workgroup also looked at including kelp spores, fish eggs, squid paralarvae, and abalone and bivalve larvae in the assessment. The risk of a significant impact on adult kelp populations by entrainment of kelp spores was determined to be negligible due to the large number of spores produced along the coast. Additionally, it is not possible to identify the species of kelp based on gametes or spores. Fish eggs were not included because they are difficult to identify to species and the most abundant fishes in these studies had egg stages that were not likely to be entrained; they either have demersal/adhesive eggs or are internally fertilized and extrude free-swimming larvae. Squid paralarvae are also unlikely to be entrained because they are competent swimmers immediately after hatching. Abalone larvae were not included because they are at low risk of entrainment and cannot be effectively sampled or identified during early life stages when they would be susceptible to entrainment (Tenera Environmental 1997). In addition, algal spores, fish eggs, and abalone and bivalve larvae would all require smaller mesh than the mesh used for ichthyoplankton and separate sampling efforts.

The final list of fish and invertebrates analyzed in each of the studies (Table 2-4) was determined by technical workgroups after all of the samples had been processed and data from the entrainment samples summarized. The assessments included taxa from the organism groups that were in highest abundance in the entrainment samples (generally those comprising up to 90% of the total abundance) and commercially or recreationally important fishes and invertebrates that were in high enough abundances to allow for their assessment. It was also realized that organisms having local adult and larval populations (i.e., source not sink species) were more important than species such as the northern lampfish (*Stenobrachius leucopsarus*), which is an offshore, deep-water species whose occurrence in entrainment was likely due to onshore currents that transported the larvae into coastal waters from their primary habitat. These ‘sink species’ were not included in the assessments.

Table 2-4. Taxa used in assessments at South Bay (SBPP), Morro Bay (MBPP) and Diablo Canyon (DCPP) power plants.

Scientific Name	**Common Name**
SBPP – taxa comprising 99 percent of total entrainment abundance	
Clevlandia ios, Ilypnus gilberti, Quietula y-cauda	CIQ goby complex
Gillichthys mirabilis	longjaw mudsucker
Anchoa spp.	anchovies
Atherinopsidae	silversides
Hypsoblennius spp.	combtooth blennies
MBPP – taxa comprising 90 percent of total entrainment abundance plus commercial taxa	
unidentified Gobiidae	gobies
Leptocottus armatus	Pacific staghorn sculpin
Stenobrachius leucopsarus	northern lampfish
Quietula y-cauda	shadow goby
Hypsoblennius spp.	combtooth blennies
Sebastes spp. V_De	KGB rockfishes
Atherinopsis californiensis	jacksmelt
Clupea pallasii	Pacific herring
Genyonemus lineatus	white croaker
Scorpaenichthys marmoratus	cabezon
Cancer antennarius	brown rock crab
Cancer jordani	hairy rock crab
Cancer anthonyi	yellow crab
Cancer gracilis	slender crab
Cancer productus	red rock crab
Cancer magister	Dungeness crab
DCPP – ten most abundant taxa plus commercial taxa	
Sardinops sagax	Pacific sardine
Engraulis mordax	northern anchovy
Sebastes spp. V / *S. mystinus*	blue rockfish complex
Sebastes spp. V_De/V_D_	KGB rockfish complex
Oxylebius pictus	painted greenling
Artedius lateralis	smoothhead sculpin
Orthonopias triacis	snubnose sculpin
Scorpaenichthys marmoratus	cabezon
Genyonemus lineatus	white croaker
Cebidichthys violaceus	monkeyface prickleback
Gibbonsia spp.	Clinid kelpfishes
Rhinogobiops nicholsii	blackeye goby
Citharichthys spp.	sanddabs
Paralichthys californicus	California halibut
Cancer antennarius	brown rock crab
Cancer gracilis	slender crab

The list of taxa reveals one of the problems with these studies. In some cases larvae cannot be identified to the species level and can only be identified into broader taxonomic groupings. Myomere and pigmentation patterns were used to identify many species, however this can be problematic for some species. For example, sympatric members of the family Gobiidae share morphologic and meristic characters during early life stages (Moser 1996) making identification to the species level difficult. In the MBPP study we grouped those gobiids we were unable to identify to species into an “unidentified gobiid” category (i.e., unidentified Gobiidae). In the SBPP study we were able to determine that the unidentified gobies were comprised of three species (Table 2-4). Larval combtooth blennies (*Hypsoblennius* spp.) can be easily distinguished from other larval fishes (Moser 1996). However, the three sympatric species along the central California coast cannot be distinguished from each other on the basis of morphometrics or meristics. These combtooth blennies were grouped into the “unidentified combtooth blennies” category (i.e., *Hypsoblennius* spp.). Many rockfish species (*Sebastes* spp.) are closely related, and the larvae share many morphological and meristic characteristics, making it difficult to visually identify them to species (Moser et al. 1977, Moser and Ahlstrom 1978, Baruskov 1981, Kendall and Lenarz 1987, Moreno 1993, Nishimoto in prep.). Identification of larval rockfish to the species level relies heavily on pigment patterns that change as the larvae develop (Moser 1996). Of the 59 rockfishes known from California marine waters (Lea et al. 1999), at least five can be reliably identified to the species level as larvae (Laidig et al. 1995, Yoklavich et al. 1996): blue rockfish (*Sebastes mystinus*), shortbelly rockfish (*S. jordani*), cowcod (*S. levis*), bocaccio (*S. paucispinis*), and stripetail rockfish (*S. saxicola*). The *Sebastes* larvae we collected could only be identified into broad sub-generic groupings based on pigment patterns; these larvae were grouped using information provided by Nishimoto (in prep.; Table 2-5). The use of these broad taxonomic categories presents problems in determining the most appropriate life history parameters to use in the demographic models. This involved calculating an average value or determining the most appropriate value from different sources and species.

Table 2-5. Pigment groups of some preflexion rockfish larvae from Nishimoto (in-prep).

The code for each group is based on the following letter designations:

V_ = long series of ventral pigmentation (starts directly at anus)	De = elongating series of dorsal pigmentation (scattered melanophores after continuous ones)
V = short series of ventral pigmentation (starts 3-6 myomeres after anus)	d = develops dorsal pigmentation (1-2 or scattered melanophores)
D_ = long series of dorsal pigmentation (4 or more in a continuous line) extending to above anus	P = pectoral blade pigmentation
D = short series of dorsal pigmentation (4 or more in a continuous line) not extending to anus	p = develops pectoral pigmentation (1-2 or scattered melanophores)

CODE		SPECIES	COMMON NAME
V D	Long ventral series, short dorsal series, no pectoral pigment		
		S. atrovirens	kelp
		S. chrysomelas	black and yellow
		S. maliger	quillback
		S. nebulosus	China
		S. semicinctus	halfbanded
V De	Long ventral series, elongating dorsal series, pectoral pigment		
Or		S. auriculatus	brown
V DeP		*S. carnatus*	gopher
Or		*S. caurinus*	copper
V dep		*S. dalli*	calico
		S. rastrelliger	grass
V	Short ventral series, no dorsal series, no pectoral		
		S. aleutianus	rougheye
		S. alutus	Pacific Ocean perch
		S. brevispinis	silvergrey
		S. crameri	darkblotched
		S. diploproa	splitnose
		S. elongatus	greenstriped
		S. macdonaldi	Mexican
		S. miniatus	vermilion
		S. nigrocinctus	tiger
		S. proriger	redstripe
		S. rosaceus	rosy
		S. ruberrimus	yelloweye
		S. serriceps	treefish
		S. umbrosus	honeycomb
		S. wilsoni	pygmy
		S. zacentrus	sharpchin

2.5 OTHER BIOLOGICAL DATA

All of the assessment models required some life history information from a species to enable the calculation of entrainment effects. Age-specific survival and fecundity rates are required for the fecundity hindcasting (*FH*) and adult equivalent loss (*AEL*) demographic models. Calculation of *FH* requires egg and larval survivorship up to the age of entrainment plus estimates of lifetime fecundity, while *AEL* requires survivorship estimates from the age at entrainment to adult recruitment. Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood was not available for many of the taxa considered in the assessments at the three plants. Life history information was gathered from the scientific literature and other sources. Uncertainty surrounding published life history parameters is seldom known and rarely reported, but the likelihood that it is very large needs to be considered when interpreting results from the demographic approaches for estimating entrainment effects. Accuracy of the estimated entrainment effects from demographic models such as *FH* and *AEL* depend on the accuracy of age-specific mortality and fecundity estimates. In addition, these data are unavailable for many species limiting the application of these models to large numbers of species.

All three modeling approaches (*FH*, *AEL*, and *ETM*) required an age estimate of the entrained larvae. The larval ages were estimated using the length of the entrained larvae and an estimate of the larval growth rate for each species obtained from the scientific literature and other sources. The size range from the minimum to the average size of the larvae was used to calculate the average age of the entrained larvae that was used in the *FH* and *AEL* models, while the size range from the minimum to the maximum size of the larvae was used to calculate the maximum age of the entrained larvae and the period of time that the larvae were subject to entrainment for the *ETM* model. Minimum and maximum lengths used in these calculations were adjusted to account for potential outliers in the measurements by using the 1^{st} and 99^{th} percentile values in the calculations. These values were chosen based on our examination of the distributions of the length measurements and other values may be more appropriate for other studies or species depending upon the data. The size range was estimated for each taxon from a representative sample of larvae from the SBPP and MBPP studies, while all of the entrained larvae of the taxa selected for detailed assessment were measured from the DCPP study. All of the measurements were made using a video capture system attached to a microscope and Optimas™ image analysis software.

2.6 DATA REDUCTION

Entrainment Estimates

Estimates of daily larval entrainment for all ichthyoplankton and selected invertebrate larvae for all of the plants were calculated from data collected at the entrainment stations located directly in front of the power plant intake structures. Daily entrainment estimates were used to calculate daily incremental entrainment mortality estimates used in the *ETM*. Estimates of entrainment over annual study periods were used in the *FH* and *AEL* demographic modeling.

Daily entrainment estimates and their variances were derived from the mean concentration of larvae (number of larvae per cubic meter of water filtered) calculated from the samples collected during each 24-hr entrainment survey. These estimates were multiplied by the daily intake flow volume for each plant (MBPP and SBPP studies used engineering estimates of cooling water flow and DCPP used actual daily flow) to obtain the number of larvae entrained per day for each taxon as follows:

$$E_i = v_i \cdot \overline{\rho}_i \,, \qquad (1)$$

where v_i = total intake volume for the survey day of the i^{th} survey period, and $\overline{\rho}_i$ = average concentration for the survey day of the i^{th} survey period.

Entrainment was estimated for the days within each weekly (MBPP and DCPP) or monthly survey period (SBPP). The number of days in each period was determined by setting the sampling date at the mid-point between sample collections. Daily cooling water intake volumes were then used to calculate entrainment for the study period by summing the product of the entrainment estimates and the daily intake volumes for each survey period. These estimates and their associated variances were then added to obtain annual estimates of total entrainment and variance for each taxon as follows:

$$E_T = \sum_{i=1}^{n} \left(\frac{V_i}{v_i} \right) E_i \,, \qquad (2)$$

where

v_i = intake volume on the survey day of the ith survey period (i=1,...,n);
V_i = total intake volume for the ith survey period (i=1,...,n); and
E_i = the estimate of daily entrainment during the entrainment survey of the ith survey period.

with an associated variance of

$$Var(E_T) = \sum_{i=1}^{n} \left(\frac{V_i}{v_i} \right)^2 Var(E_i) \, , \tag{3}$$

using the sampling variances of entrainment on the survey day of the i^{th} period, $Var(E_i)$. The daily sampling variance for SBPP and MBPP was calculated using the average concentrations from samples collected during each cycle, while the daily sampling variance for DCPP was calculated by treating each sampling cycle as a separate strata using data from the four entrainment stations. Both methods underestimated the true variance because they did not incorporate the variance associated with the within-survey period variation and daily variations in intake flow due to waves, tide, and other factors not measured by the power plant. One hundred percent mortality was assumed for all entrained organisms.

For the study at DCPP estimates of annual entrainment were scaled to better represent long-term trends for a taxa by using ichthyoplankton data collected inside the Intake Cove at DCPP (Figure 2-3). These data were used to calculate an index of annual trends in larval abundance for the period of 1990 through 1998. This multi-year annualized index consisted of five months (February–June) of larval fish concentrations from 1990, six months (January–June) from 1991, and seven months (December–June) from all subsequent years. The estimated annual entrainment (E_T) was adjusted to the long-term average using the following equation:

$$E_{Adj-T} = \left(\frac{\overline{I}}{I_i} \right) \cdot E_T \, , \tag{4}$$

where

E_{Adj-T} = adjusted estimate of total annual entrainment to a long-term average, 1990 − 1998;

I_i = index value from DCPP Intake Cove surface plankton tows for each ith year; and

$\overline{I}$ = average index value from DCPP Intake Cove surface plankton tows, 1990 − 1998.

The abundances used in calculating the index were not expected to be representative of the abundances calculated from the DCPP entrainment data since they were only collected during 5 to 7 months of the year in contrast to the entrainment sampling that occurred continuously from October 1996 through June 1999. The use of the index assumes that the difference in abundance is approximately equal over time, although the validity of this assumption probably varied among taxa. Variance for adjusted annual entrainment can then be expressed as follows:

$$Var(E_{Adj-T}) = \left(\frac{\bar{I}}{I_i}\right)^2 \cdot Var(E_T), \tag{5}$$

assuming the indices are measured without error. Ignoring the sampling error of the indices will underestimate the true variance, but will qualitatively account for the change in scale associated with multiplying the annual entrainment estimate by a scalar. The variance of $E_{Adj\text{-}T}$, however, does not take into account the between-day, within-station variance, interannual variation, nor the variance associated with the indices used in the adjustment. Hence, the actual variance of the $E_{Adj\text{-}T}$ estimate is likely to be greater than the value expressed above.

The Intake Cove surface tow index was assumed to have the following relationship:

$$E(I_i) = C \cdot E_i\ , \tag{6}$$

where

$E(I_i) =$ expected value of the index for the *i*th year;
$E_i =$ entrainment for the *i*th year; and
$C =$ proportionality coefficient.

If this relationship holds true and the differences over time are constant, then the inter-annual variance in the index has the following relationship:

$$Var(I_i) = C^2 Var(E_i). \tag{7}$$

Therefore, the coefficients of variation (CV) for I and E across n years have the following relationship:

$$CV(\bar{I}) = \frac{\sqrt{\frac{Var(I)}{n}}}{\bar{I}} \approx \frac{\sqrt{\frac{C^2 Var(E)}{n}}}{C\bar{E}} = CV(\bar{E})\ . \tag{8}$$

Hence, the CV for the Intake Cove surface tow index should be a measure of the CV for entrainment across years. In the case of E and I, variances include sampling errors that may not be equal. Therefore, the CV of I was used to estimate variation in entrainment across years.

The use of adjusted entrainment in *FH* and *AEL* models at DCPP provided results that better represented average long-term effects. Adjusted entrainment values were not used in calculating *ETM* results because the computation of *ETM* relies on a proportional entrainment (*PE*) ratio using estimates from paired entrainment and nearshore larval sampling. Moreover, if the assumptions of the *ETM* model are valid, then the estimate already represents average long-term entrainment effects because the *PE* ratio should largely be a function of the ratio of the cooling water to source water volumes, which is constant if the plant is operating at full power compared to ichthyoplankton abundances that vary over time. This would especially be true if the *PE* were averaged over several taxa, assuming that the effects of larval behavior cancel across all the species. As a result the use of adjusted entrainment in *FH* and *AEL* models also provided a better basis to compare results from all three models when they were converted into a common currency through the use of population or fishery stock assessments. This advantage of the ETM could be affected if actual cooling water flows varied considerably seasonally and among years.

2.7 SOURCE WATER ESTIMATES

Average concentrations calculated from source water stations were used to estimate source water populations of species or taxa groups using the same method used for calculating entrainment estimates for each i^{th} survey period. At SBPP a single source water estimate was calculated, while at MBPP, separate estimates were calculated for Morro Bay and Estero Bay source water components.

At DCPP separate estimates were calculated for each of the 64 grid stations based on the depth and surface area of each station. In addition, an adjustment was made to the estimated number of larvae in the row 1 cells of the study grid to help compensate for the inability to safely collect samples inshore of the grid (Figure 2-3). The estimated volume of water directly inshore of the study grid was multiplied by the concentration of larvae collected in the row 1 cells, except for cells directly offshore from the power plant and the cell furthest upcoast which is more offshore than the rest of the cells in row 1 due to the bend in the coastline at Point Buchon. The adjustment was not done for the volume of water inshore of that cell because it would have added a substantial volume to that cell and the composition and abundance would not have been representative of the other inshore areas. The average concentration from the entrainment stations was used for the areas inshore from the two cells directly offshore from the Intake Cove where entrainment samples were collected. The estimated number of larvae in each grid station and from the areas inshore of the grid was added to obtain an estimate of the sampled source water populations.

2.8 IMPACT ASSESSMENT MODELS

Demographic Approaches

Adult equivalent loss models (Goodyear 1978) evolved from impact assessments that compared power plant losses to estimates of adult populations or commercial fisheries harvests. In the case of adult fishes impinged by intake screens, the comparison was relatively straightforward. To compare numbers of impinged sub-adults and juveniles and entrained larval fishes to adults, it was necessary to convert these losses to adult equivalents using demographic factors such as survival rates. 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 survival for several age classes of larvae.

Demographic approaches, exemplified by *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 used two different but related demographic approaches in assessing entrainment impacts at all three facilities: *AEL* (Goodyear 1978), which uses the larval losses to estimate the equivalent number of adult fishes that would not have been lost to the population and *FH* (Horst 1975, Goodyear 1978, MacCall, pers. comm.), which estimates the number of adult females at the age of maturity whose reproductive output has been lost due to entrainment. The method is similar to the Egg Production Method described by Parker (1980, 1985) and implemented in Parker and DeMartini (1989) at San Onofre Nuclear Generating Station except they used only eggs to hindcast adult equivalents.

Both *AEL* and *FH* approaches require an estimate of the age at entrainment for each taxon that was estimated by dividing the difference between the smallest (represented by the 1^{st} percentile value) and the average lengths of a representative sample of larvae measured from the entrainment samples by a larval growth rate obtained from the literature. This assumes that the period of vulnerability to entrainment starts when the larvae are either hatched or released and that the smallest larvae in our samples represent newly hatched or released larvae. This minimum value was checked against reported hatch and release sizes for the taxa analyzed in these studies and in most cases was less than these reported values.

Additionally, age-specific survival and fecundity rates are required for calculating *FH* and *AEL*. *FH* requires egg and larval survivorship up to the age of entrainment plus estimates of fecundity, age at maturity and longevity, while *AEL* requires survivorship estimates from the age at entrainment to adult recruitment. 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. In addition, the *FH* method assumes that all of the females instantaneously reach 100% maturity at the age of maturity.

Species-specific survivorship information from egg or larvae to adulthood was limited for many of the taxa considered in these studies. These rates when available were inferred from the literature along with estimates of uncertainty. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large needs to be considered when interpreting results from the demographic approaches for estimating entrainment effects. The ratio of the standard deviation to the mean (*CV*) was assumed to be 30% for all life history parameters used in the models for the SBPP and MBPP studies and 100% for the DCPP study. The larger *CV* was used at DCPP because it was the first study we conducted and we wanted to use a large *CV* to ensure that the confidence intervals adequately reflected the large degree of uncertainty associated with the estimates. The smaller *CV* used for SBPP and MBPP does not reflect increased confidence in the life history data, but our realization that the larger *CV* used at DCPP resulted in confidence intervals for the estimates that spanned several orders of magnitude minimizing their usefulness in the assessment.

Fecundity Hindcasting

The *FH* approach couples larval entrainment losses to adult fecundity using survivorship between stages to estimate the numbers of adult females at the age of maturity whose reproductive output has been lost due to entrainment, i.e., hindcasting the numbers of adult females at the age of maturity effectively removed from the reproductively active population. Accuracy of the estimate of impacts using this model is dependent upon an accurate estimate of survival from parturition through the estimated average age at entrainment and 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 at 50:50, then fecundity and mortality are integrated into an estimate of adult loss at the age of female maturity by converting entrained larvae back into adult females and multiplying by two to approximate the total number of equivalent adults at the age of female maturity.

A potential advantage of *FH* is that survivorship need only be estimated for a relatively short period of the larval stage (e.g., egg to larval entrainment). The method requires age-specific mortality rates and fecundities to estimate equivalent adult losses. Furthermore, this method, as applied assumes a 50:50 male:female ratio, hence the loss of a single female's reproductive potential was equivalent to the loss of two adult fish. Other assumptions included the following:

- Life history parameter values from the literature are representative of the population for the years and location of the study.
- Size of the stock does not affect survivorship or the rate of entrainment mortality (no density dependence).
- Reported values of egg mass were lifetime averages in order to calculate an unbiased estimate of lifetime fecundity.
- Total lifetime fecundity was accurately estimated by assuming that the mortality rate was uniform between age-at-maturity and longevity.
- 'Knife-edge' recruitment into the adult population at the age of maturity.
- Loss of the reproductive potential of one female was equivalent to the loss of an adult female at the age of maturity.

The estimated number of females at the age of maturity whose lifetime reproductive potential was lost due to entrainment was calculated for each taxon as follows:

$$FH = \frac{E_T}{TLF \cdot \prod_{j=1}^{n} S_j}, \qquad (9)$$

where

E_T = total entrainment estimate;

S_j = survival rate from parturition to the average age of the entrained larvae at the end of the j^{th} stage; and

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

While E_T was used in the modeling at SBPP and MBPP, $E_{Adj\text{-}T}$ was used at DCPP. In practice, survival was estimated by either one or several age classes, depending on the data source, to the estimated age at entrainment. The expected *TLF* was approximated by the following expression:

$$\begin{aligned} TLF &= \text{Average eggs/year} \cdot \text{Average number of years of reproductive life} \\ &= \text{Average eggs/year} \cdot \left(\frac{\text{Longevity - Age at maturation}}{2} \right). \end{aligned} \quad (10)$$

The number of years of reproductive potential was approximated as the midpoint between the ages of maturity and longevity. This approximation was based on the assumption of a linear uniform survivorship curve between these events (i.e., a uniform survival rate). Total lifetime fecundity for the studies at SBPP was calculated by adding 1 to the difference between longevity and age-at-maturity. This was done to account for spawning during the two ages used in the calculation. For heavily exploited species such as northern anchovy and sardine (*Sardinops sagax*), the expected number of years of reproductive potential may be much less than predicted using this assumption. Therefore, for the DCPP study the estimated longevity for heavily exploited fishes was based on the oldest observed individual caught by the fishery, rather than by the oldest recorded fish. If life table data are available for a taxon, then the lifetime fecundity should be estimated directly rather than using the approximation presented in Equation10. The variance of *FH* was approximated by the Delta method (Seber 1982) and is presented in Appendix A.

Adult Equivalent Loss

The *AEL* approach uses abundance estimates of entrained or impinged organisms to project the loss of equivalent numbers of adults based on stage-specific survival and age-at-recruitment (Goodyear 1978). The primary advantage of this approach, and of *FH*, is that it translates power plant-induced early life-stage mortality into numbers of adult fishes, which 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). Other assumptions of *AEL* using data on survivorship from entrainment to recruitment into the fishery assume the following:

- Published values of life history parameters are representative of the fish population in the years and location for the specific study.
- If survivorship values from the literature are limited to single observations, values are assumed constant over time or representative of the mean survivorship.
- Survival rates used in the calculations are representative and constant for the life stage of the larvae or fish in the calculations.
- Size of the stock does not affect survivorship or the rate of entrainment mortality (no density dependence).

In some cases, survival rates estimated for a similar fish species were used. Should survivorship data from one species be substituted for another, then there is the following additional assumption:

- Values of survivorship for the two species are the same.

For fish species where larval survival data are missing, expected survival could be estimated using fecundity combined with juvenile and adult survival data. This approach requires the following additional assumption:

- The fish population is stationary in size such that each adult female contributes two new offspring to the population of adults during its lifetime.

Starting with the number of age class *j* larvae entrained, it is conceptually easy to convert the numbers to an equivalent number of adults lost at some specified age class using the following formula:

$$AEL = \sum_{j=1}^{n} E_j S_j \, , \tag{11}$$

where,

n = number of age classes;

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

S_j = survival rate for the j^{th} age class of the 1..n classes between entrainment and adulthood.

In practice, survival was estimated by either one or several age classes, depending on the data source, from the estimated age at entrainment to recruitment into the fishery. Survivorship to recruitment, at an adult age, was apportioned into several age stages, and *AEL* was calculated as follows:

$$AEL = E_T \prod_{j=1}^{n} S_j \ , \qquad (12)$$

where,

S_j= survival rate over the j[th] age class.

The variance of *AEL* was approximated by the Delta method (Seber 1982) and is presented in Appendix A.

Alignment of FH and AEL Estimates

AEL and *FH* can be compared by assuming a stationary population where an adult female must produce two adults (i.e., one male and one female). These two adults are products of survival and total lifetime fecundity (*TLF*) modeled by the following expression:

$$2 = S_{egg} \cdot S_{larvae} \cdot S_{adult} \cdot TLF, \qquad (12)$$

which leads to the following:

$$S_{adult} = \frac{2}{TLF \cdot S_{egg} \cdot S_{larvae}}. \qquad (13)$$

Substituting into the overall form of the following *AEL* equation:

$$AEL = E_T \cdot S_{adult} \ , \qquad (14)$$

yields the following:

$$AEL = \frac{2(E_T)}{S_{egg} \cdot S_{larva} \cdot TLF}. \qquad (15)$$

Assuming a 50:50 sex ratio, without independent survival rates, *AEL* and *FH* are deterministically related as *AEL*≡2*FH*. The two estimates can be aligned so that female age at maturity is also the age of recruitment used in computing *AEL*. Otherwise, an alignment age can be accomplished by solving the simple exponential survival growth equation (Ricker 1975, Wilson and Bossert 1971):

$$N_t = N_0 \cdot e^{-Z(t-t_0)} \ , \qquad (16)$$

by substituting numbers of either equivalent adults or hindcast females, their associated ages, and mortality rates into the equation where,

N_t = number of adults at time t;
N_0 = number of adults at time t_0;
Z = instantaneous rate of natural mortality; and
t = age of hindcast animals (*FH*) or extrapolated age of animals (*AEL*).

This allows for the alignment of ages for a population under equilibrium in either direction so they are either hindcast or extrapolated to the same age such that *AEL*≡2*FH*. Estimates of entrainment mortality calculated from *AEL* and *FH* approaches can be compared for similar time periods in taxa for which independent estimates are available for (1) survival from entrainment to the age at maturity, and (2) entrainment back to the number of eggs produced. This comparison serves as a method of cross-validating the two demographic models. Substantial differences between the model estimates may indicate that the population growth rate implied by the model parameters is unrealistically high or low.

FH estimates the number of females at the age of maturity whose reproductive output is lost. The total number of females N_F of all ages in the population can be estimated by the average fecundity as

$$N_F = \frac{E_T}{\bar{F} \cdot \prod_{j=1}^{n} S_j} . \qquad (17)$$

AEL can be extrapolated to all mature female ages and summed to make a comparison to 2•N_F using the preceding assumptions. The number of females whose reproductive output is lost in the population, N_F, will be greater than the females estimated by *FH*. The analogue, sum of extrapolated *AEL* over adult ages, will be greater than *AEL* and represents the number of adult males and females lost.

Empirical Transport Model

The *ETM* estimates conditional probability of mortality (P_M) associated with entrainment and requires an estimate of proportional entrainment (*PE*) as an input. Proportional entrainment is an estimate of the daily entrainment mortality on larval populations in the source water, independent of other sources of mortality. Following Ricker (1975), *PE* is an estimate of the conditional mortality rate. Proportional entrainment was calculated using the ratio of intake and source water abundances. In previous entrainment studies using the *ETM* method, intake concentrations were assumed from weighted population concentrations (Boreman et al. 1981). As proposed by the U.S. Fish and Wildlife Service (Boreman et al. 1978, 1981), *ETM* has been used to assess entrainment effects at the Salem Nuclear Generating Station in Delaware Bay, New Jersey and at other power stations along the east coast of the United States (Boreman et al. 1978, 1981; PSE&G 1993). Variations of this model have been discussed in MacCall et al. (1983) and used to assess impacts at the San Onofre Nuclear Generating Station (SONGS; Parker and DeMartini 1989).

The *ETM* estimates conditional mortality due to entrainment, while accounting for spatial and temporal variability in distribution and vulnerability of each life stage to cooling water withdrawals. The original form of the *ETM* incorporated many time-, space-, and age-specific estimates of mortality as well as information regarding spawning periodicity and larval duration (Boreman et al. 1978, 1981). Most of this information is limited or unknown for the taxa that were investigated for our studies. Thus, the applicability of this form of the *ETM* will be limited by the absence of empirically derived or reported demographic parameters needed as input to the model. The approach used in these studies only requires an estimate of the time the larvae are susceptible to entrainment. By compounding the *PE* estimate over time, the *ETM* can be used to estimate entrainment over a time period using assumptions about species-specific larval life histories, specifically the length of time in days that the larvae are in the water column and exposed to entrainment.

On any one sampling day *i*, the conditional entrainment mortality can be expressed as follows:

$$PE_i = \frac{E_i}{N_i}, \qquad (18)$$

where

E_i = total numbers of larvae entrained during a day during the i^{th} survey; and

N_i = numbers of larvae at risk of entrainment, i.e., abundance of larvae in the sampled source water during a day during the i^{th} survey.

Survival over one day = 1-PE_i, and survival over the number of days (d) that the larvae are vulnerable to entrainment = $(1\text{-}PE_i)^d$, where d is estimated from the lengths of a representative sample of larvae collected over the entire study period. Values used in calculating PE are population estimates based on respective larval concentrations and volumes of the cooling water system flow and source water areas. The estimate of daily entrainment (E_i) was calculated using the methods described previously. The abundance of larvae at risk in the source water during the i^{th} survey can be directly expressed as follows:

$$N_i = V_S \cdot \overline{\rho}_{N_i} , \qquad (19)$$

where

V_S = the static volume of the source water (N); and

$\overline{\rho}_{N_i}$ = the average larval concentration in the source water during the i^{th} survey.

We note that the daily estimate of survival used by MacCall et al. (1983) and Boreman et al. (1981) is $S=e^{-PE}$, which assumes the Baranov catch equation, $E=FN$, where F corresponds to PE and N is the average population size (Ricker 1975). Our estimate of daily survival assumes that N is the population size prior to entrainment. In our studies the outcome is approximately the same regardless of the type of survival estimates because PE values were weighted by large populations. When entrainment becomes relatively large it is recommended to use the Baranov-based estimate as in MacCall et al. (1983) because mortality estimates are reflective of average population size and also are larger.

At SBPP, and for taxa that were determined to primarily inhabit Morro Bay in the MBPP study, the estimated volumes of source water bodies previously described were used to estimate the abundance using an average concentration based on all of the samples from the source water for a given survey on a single day. At DCPP the equation to estimate PE for a day on which entrainment was sampled was:

$$PE = \frac{N_E}{N_G} , \qquad (20)$$

where

$N_E =$ estimated number of larvae entrained during the day, calculated as (estimated concentration of larvae in the water entrained that day) $\times$ (design specified daily cooling water intake volume); and

$N_G =$ estimate of larvae in nearshore sampling area that day, calculated as $\sum_{i=1}^{64}$[(average concentration per cell) $\cdot$ (cell volume)] for i = 1, ..., 64 grid cells.

where the estimated cell concentrations were obtained from the 72-hour source water survey that contained the 24-hour entrainment sampling period. In addition, an adjustment was made to the estimated number of larvae in the row 1 cells of the study grid to help compensate for the inability to safely collect samples inshore of the grid (Figure 2-3). The estimated volume of the water directly inshore of the study grid was multiplied by the concentration of larvae collected in the row 1 cells, except for cells A1, D1, and E1, as previously described.

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 as the following:

$$P_M = 1 - \sum_{i=1}^{n} f_i (1 - P_S PE_i)^d , \qquad (21)$$

where

$PE_i =$ estimate of proportional entrainment for the ith survey ($i = 1,...,n$);

$P_S =$ proportion of sampled source water to total estimated source water;

$f_i =$ annual proportion of total larvae hatched during the ith survey; and

$d =$ estimated number of days that the larvae are exposed to entrainment.

To establish independent survey estimates, it was assumed that each new survey represented a new, distinct cohort of larvae that was subject to entrainment. Each of the surveys was weighted using the proportion of the total population at risk during the i^{th} survey (f_i). In the original study plan and analyses for MBPP and DCPP studies we proposed to use the proportion of larvae entrained during each survey period as the weights for the *ETM* model. Weights were proposed to be calculated as follows:

$$f_i = \frac{E_i}{E_T} , \qquad (22)$$

where E_i is estimated entrainment during the i^{th} survey, and E_T is estimated entrainment for the entire study period. This formulation conflicts with the formula for *PE* that uses the population in the source water during each survey to define the population at risk. If the weights are meant to represent the proportion of the population at risk during each survey then the weights should be calculated as follows:

$$f_i = \frac{N_i}{N_T}, \quad (23)$$

where N_i is the source population spawned during the i^{th} survey, and N_T is the sum of the N_i s for the entire study period. Weights calculated using the entrainment estimates redefined the population at risk as the population entrained and represented a logical inconsistency in the model. Weights calculated using the source water estimates were used at SBPP and were used in final analyses of the data from the MBPP and DCPP studies in this paper.

The number of days that the larvae of a specific taxon were exposed to the mortality estimated by *PE*, was estimated using length data from a representative number of larvae from the entrainment samples. At SBPP, a single estimate of larval exposure was used in the calculations. The number of days (*d*) from hatching to entrainment was estimated by calculating the difference between the values of the 1st and upper 99th percentiles of the length measurements for each entrained larval taxon and dividing this range by an estimate of the larval growth rate for that taxon that was obtained from the scientific literature. The 1st and upper 99th percentiles were used to eliminate potential outlier measurements in the length data. In earlier studies at MBPP and DCPP, two estimates of *d* were calculated for each taxon and these were used to calculate two *ETM* estimates. The first estimate used an estimate of *d* calculated using the difference in length between the 1st and upper 99th percentiles and was used to represent the maximum number of days that the larvae were exposed to entrainment. The second estimate used an estimate of *d* calculated using the difference in length between the 1st percentile and the average length and was used to represent the average number of days that the larvae were exposed to entrainment.

The estimate of P_S in the *ETM* model is defined by the ratio of the area or volume of sampled source water to a larger area or volume containing the population of inference (Parker and DeMartini 1989). If an estimate of the larval (or adult) population in the larger area is available, the value of P_S can be computed directly using the estimate of the larval or adult population in the sampling area, defined by Ricker (1975) as the proportion of the parental stock. If the distribution in the larger area is assumed to be uniform, then the value of P_S for the proportion of the population will be the same as the proportion computed using area or volume.

For the SBPP study the entire source water was sampled (P_S = 1.0) and P_S was not incorporated in the *ETM*. At the MBPP, P_S was not incorporated in the *ETM* for fishes that were primarily associated with the estuarine habitats in Morro Bay. The P_S was included for fish and crab taxa whose adult distributions extended out into the nearshore waters. Estimates of the population of inference for these taxa were unavailable, therefore, P_S was estimated using the distance the larvae could have traveled based on the duration of exposure to entrainment and current speed as follows:

$$P_S = \frac{L_G}{L_P}, \qquad (24)$$

where

L_G = length of sampling area; and
L_P = length of alongshore current displacement based on the period (*d*) of larval vulnerability for a taxon.

The length of alongshore displacement was calculated using average current speed for the period of January 1, 1996 – May 31, 1999 from an InterOceans S4 current meter deployed at a depth of -6 m MLLW in approximately 30 m of water about 1 km west of the DCPP Intake Cove, south of Morro Bay. The current direction was ignored in the calculations, but was predominantly alongshore. The current speed was used to estimate unidirectional displacement over the period of time that the larvae were exposed to entrainment. The value of alongshore displacement (L_P) was compared with the alongshore length of the sampled waterbody (L_G). The distance between the west Morro Bay breakwater and Station 5 is 4.8 km; a value of 9.6 km (twice the distance) was used for L_G. This value was used because it places Station 5 in the center of the sampled waterbody.

For the MBPP study we only presented a single estimate of P_M for the taxa that used an adjustment for P_S in the *ETM*, because any changes due to the increased duration were inversely proportional to the changes in P_S, and resulted in nearly equal estimates of P_M. (The exponential model [MacCall et al. 1983], $1-e^{P_s PE t}$, gives equal estimates for P_S inversely proportional to *t*). The estimate of the standard error is increased due to the extended period of entrainment risk, so two estimates of the standard error were presented for these taxa.

The sampling for the DCPP study was also extrapolated to provide an estimate of entrainment effects outside the nearshore sampling area. Boreman et al. (1981) point out that if any members of the population are located outside the sampled area, then the *ETM* will overestimate the conditional entrainment mortality for the entire population. In their study of entrainment at SONGS, Parker and DeMartini (1989) incorporated the inference population (which was an extrapolation to the entire Southern California Bight from the coast to a depth of 75 m, an area extending about 500 km) directly into their estimate of *PE*. In the DCPP *ETM* analyses, *PE* was multiplied by the estimated fraction of the population in the nearshore sampling area (P_s). The size of the population affected by entrainment varied from relatively small (e.g., the size of the sampling area) to very large (e.g., fishery management units, zoogeographic range). For some species an area approximately the size of the study grid represented the population of inference, and in these cases, $P_S \approx 1$. For other species, the population of inference was larger than the study grid. The population of inference depended not only on the species, but also what appealed usefully to intuition, as a number of methods could be used for extrapolation. Therefore, the *ETM* was calculated over a range of values of P_S for each of the taxa selected for detailed assessment. The resulting curves were used to determine the *ETM* at any value of P_S. The curves were interpreted as a continuous probability function representing the risk of entrainment to the larvae at different values of P_S. Point estimates of P_M (and their ranges) were also calculated for each taxon.

The relationship between P_M and P_S was represented by the sets of curves for each of the taxa analyzed for DCPP. Two point estimates of P_S were also computed to account for the variation in the distribution of adult fishes included in the assessment. For offshore and subtidal taxa whose larval distribution extends to the offshore edge of the study grid, P_S was calculated as follows:

$$P_S = \frac{N_G}{N_P}, \qquad (25)$$

where N_G is the number of larvae in the study grid, and N_P is the number of larvae in the population of inference. The numerator N_G, presented earlier in the calculation of *PE*, was calculated as follows:

$$N_{G_i} = \sum_{k=1}^{64} A_{G_k} \cdot \bar{D}_k \cdot \rho_{\text{i,k}} \;, \tag{26}$$

where

A_{G_k} = area of grid cell k;

$\bar{D}_k$ = average depth of the *k*th grid cell; and

ρ_{ik} = concentration (per m^3) of larvae in *k*th grid cell during survey *i*.

N_P was estimated by an offshore and alongshore extrapolation of the study grid concentrations, using water current measurements. The following conceptual model was formulated to extrapolate larval concentrations (per m^3) offshore of the grid:

$$P_S = \frac{N_G}{N_P} = \frac{\sum_{i=1}^{K_G} L_{G_j} \cdot W_j \cdot \bar{D}_j \cdot \rho_j}{\sum_{i=1}^{K_P} L_{P_j} \cdot W_j \cdot \bar{D}_j \cdot \rho_j} \;, \tag{27}$$

where

L_{G_j} = alongshore length of grid in the *j*th stratum;

W_j = width of *j*th stratum;

L_{P_j} = alongshore length of population in *j*th stratum based on current data;

$\bar{D}_j$ = average depth of *j*th stratum; and

ρ_j = average density of larvae in *j*th stratum.

For this model, the grid was subdivided into K_G alongshore strata (i.e., K_G=8 rows in the grid) and the population into $K_G > K_G$ alongshore strata. This approach described discrete values in intervals of a continuous function. Therefore, to ease implementation, an essentially equivalent formula used grid cell concentrations during the i^{th} sampling period, $\rho_{i,k}$ for a linear extrapolation of density (# per m^2 calculated by multiplying $\rho_{i,k}$ by the cell depth) as a function of offshore distance, *w*:

$$P_{S_i} = \frac{N_{G_i}}{N_{P_i}} = \frac{N_{G_i}}{N_{G_i}\left(\frac{L_{P_i}}{L_G}\right) + L_{P_i} \int_{W_0}^{W_{Max}} \rho(w)dw} \;, \tag{28}$$

where L_P = alongshore length of population in the i^{th} study period based on current displacement. The limits of integration are from the offshore margin of the study grid, W_O, to a point estimated by the onshore movement of currents or where the density is zero or biologically limited, W_{max}. Note that this point will usually occur outside the study grid area and that the population number, N_P, is composed of two components that represent the alongshore extrapolation of the grid population and the offshore extrapolation of the alongshore grid population (Figure 2-3).

Alongshore and onshore current velocities used in the calculations were measured at a current meter positioned approximately 1 km west of the DCPP intake at a depth of approximately 6 m (Figure 2-3). The direction in degrees true from north and speed in cm/s were estimated for each hour of the nearshore study grid survey periods. Figure 2-4 shows the results of current meter analysis in which hourly current vectors were first rotated orthogonal to the coast by 49 degrees west of north. The movement of water was then tracked during the period from April 1997 through June 1999. A total alongshore length can be calculated from these data using the maximum up-coast and down-coast current movement over the larval duration period prior to each survey period. The maximum upcoast and downcoast current vectors measured during each survey period were added together to obtain an estimate of total alongshore displacement. This contrasts with the approach for the MBPP where average current speed was used in calculating alongshore movement. Transport of larvae into the nearshore via onshore currents was also accounted for and used to set the limits of the offshore density extrapolation. Within this scenario, there were two subclasses:

1. For species in which the regression of density versus offshore distance had a negative slope, the offshore distance predicted where density was zero (i.e., integral of zero) was calculated. The alongshore distance was calculated from the water current data.
2. For species in which the regression of density versus offshore distance had a slope of $\geq$0, either the offshore distance from the water current data or an average distance based on the depth distribution of the adults offshore was used. Literature values (e.g., CalCOFI) were used to place a limit on both the distance and density values used in the offshore extrapolation.

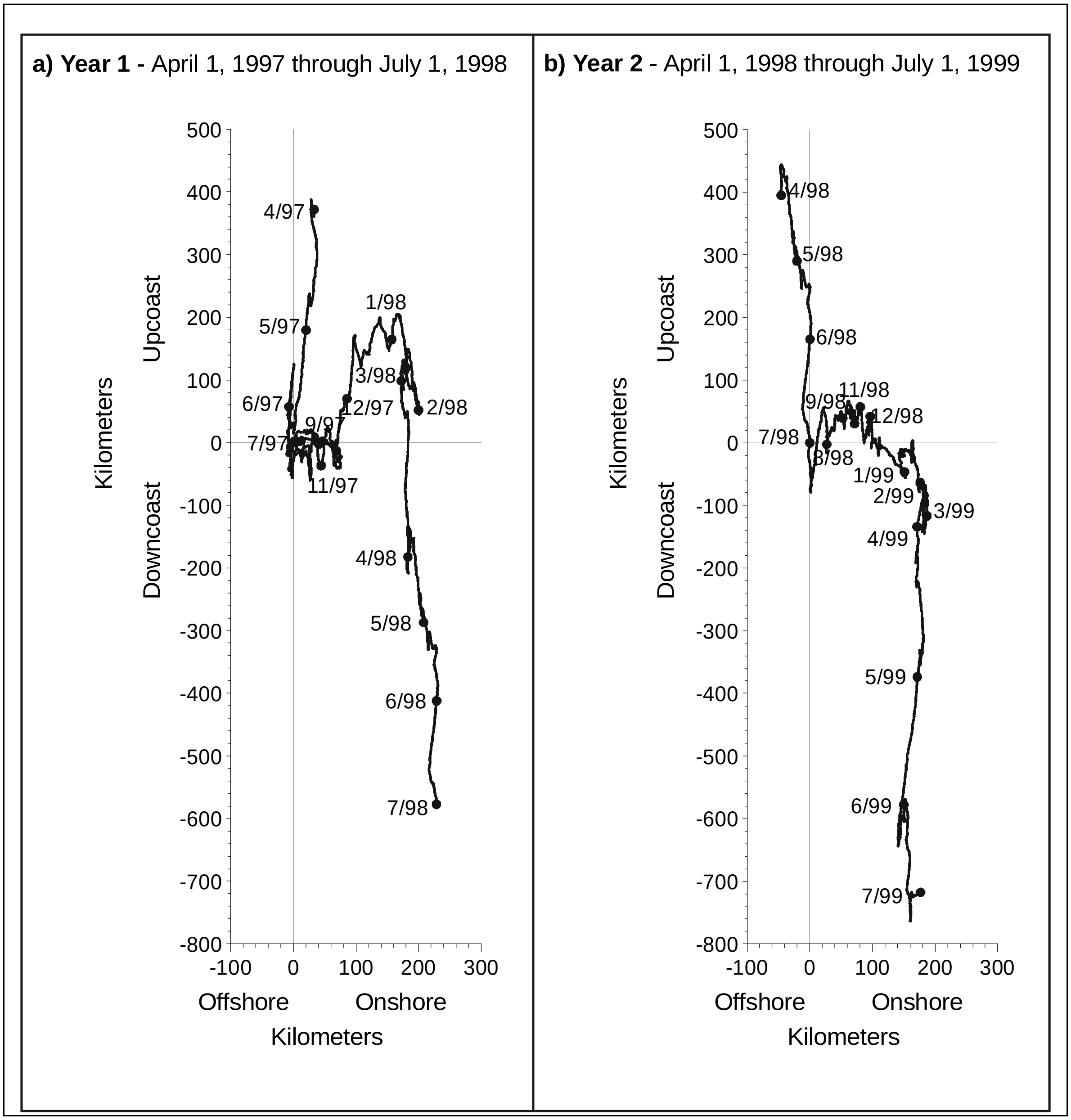


Figure 2-4. Relative cumulative upcoast/downcast and onshore/offshore current vectors from current meter located approximately 1 km west of the Diablo Canyon Power Plant intake at a depth of 6 m. Dates on current vectors are the dates of each survey.

Parameter values needed in performing the extrapolation were obtained by using analysis of covariance based on all of the data from the surveys for the study period from July 1997 through June 1999. The following quadratic model was tested in the analysis:

$$\rho_{ij} = \alpha_i + \beta w_{ij} + \gamma w^2_{if} + \varepsilon_{ij} , \qquad (29)$$

where

$\varepsilon_i =$ normally distributed error term with mean of zero;
$w_{ij} =$ distance for the *i*th observation in the *j*th survey;
ρ_{ij} = larval density per m^2 for the *i*th observation in the *j*th survey; and
α, β, γ = regression coefficients.

The following linear model produced a better fit in all cases:

$$\rho_{ij} = \alpha_i + \beta w_{ij} + \varepsilon_{ij} . \tag{30}$$

A common slope, β , for all surveys and unique intercepts, α_i , for each survey were derived from the model. It is reasonable to assume a common slope, but differences in abundance between surveys required fitting different intercepts.

Similar to the demographic models there are also assumptions associated with the *ETM* approach. Although there are fewer life history parameters necessary for the *ETM*, it shares with the demographic models the assumption that the life history data used to calculate the period of time the larvae are exposed to entrainment are representative of the population in the years and location for the specific study and accurately estimates the period of larval exposure. Since the *ETM* is only estimating the entrainment mortality on the population of larvae, assumptions regarding compensation would only be important in interpreting the effects on adult populations. An assumption inherent to all the models is that the sampling resulted in representative estimates of entrainment for the period surveyed. Additional assumptions of the *ETM* include the following:

- The sampling resulted in representative estimates of the source water populations of larvae susceptible to entrainment and that the PE estimated from the entrainment and source water population samples is representative of entrainment mortality during the survey period.
- The estimates of the source water population represent the proportion for the survey period (fi) of total larval production.
- The samples during each survey period represent a new and independent cohort of larvae.

Although it would seem that there are also assumptions associated with the definition of the source water population relative to the population of inference, these assumptions become less critical if the *ETM* results are converted, for example, to Area of Production Foregone (APF). The APF is a useful method for converting the results of *ETM* into a context for resource managers and is presented in Section 4.0.

Variance calculations for *PE* are presented in Appendix A. Variance calculations for the estimate of P_M are not presented because of the different approaches and parameters that will be used in the *ETM* calculations for each study.

3.0 RESULTS

Detailed results for an example taxon from each plant are presented to compare the modeling approaches for different source water body types. Results at SBPP are presented for the arrow, cheekspot, and shadow (*Clevlandia ios, Ilypnus gilberti,* and *Quietula y-cauda* [CIQ]) goby complex, which was the most abundant fish larvae collected during the study. At Morro Bay and Diablo Canyon, the kelp, gopher, and black-and-yellow (*S. atrovirens, S. carnatus,* and *S. chrysomelas* [KGB]) rockfish complex results provided illustrative data. These results provide example calculations for the *FH* and *AEL* models as well as for the *ETM* so that all three modeling approaches can be compared between sites.

The example taxa are indicative of the source water at the three study sites. Since SBPP used a fixed source water body volume the *ETM* model for all of the taxa analyzed, including CIQ gobies, was calculated similarly. At MBPP, the *ETM* model for the taxa that were designated as primarily inhabitants of Morro Bay was calculated using a fixed source water volume using calculations identical to those for CIQ gobies for the SBPP study. Therefore, we decided to present the *ETM* results for the KGB rockfish at MBPP since the source water for this taxon included both the bay and a nearshore area, the size of which was estimated using current meter data. A similar approach was taken for the DCPP study and, therefore, the results for the KGB rockfish complex are also presented for that study to provide a comparison with the results for MBPP.

3.1 SOUTH BAY POWER PLANT

A total of 23,039 larval fishes in 20 taxonomic categories ranging from ordinal to specific classifications was collected from 144 samples at the SBPP entrainment station (SB1) during monthly sampling from February 2001 through January 2002 (Table 3-1). These samples were used to estimate that total annual entrainment of fish larvae was 2.42×10^9. Entrainment samples were dominated by gobies in the CIQ complex, which comprised about 76% of the total estimated entrainment. Five taxa evaluated for entrainment effects (Table 2-4) comprised greater than 99% of the total number of fish larvae entrained. No invertebrates were evaluated because only a single *Cancer* crab megalopae was collected.

The entrainment and source water stations extend over a distance of greater than 9 km in south San Diego Bay and include both channel and shallow mudflat habitats. Despite the differences in location and habitat, CIQ complex gobies were the most abundant fish larvae at all of the stations (Appendix B). Other fishes showed considerable variation in abundance among stations. For example, combtooth blennies (*Hypsoblennius* spp.) were much more abundant along the eastern shore north of SBPP where there are more piers and other structures, whereas longjaw mudsuckers (*Gillichthys mirabilis*) were in highest abundance near the power plant. Overall, taxa richness generally increased from the entrainment station in the far south end of the bay to Station SB9 in the north.

Table 3-1. Total annual entrainment estimates of larval fishes at South Bay Power Plant based on monthly larval densities (sampled at Station SB1 from February 2001 through January 2002) and the plant's designed maximum circulating water flows; *n*=144 tows at one station. Data and estimates for taxa comprising <0.01 percent of the composition not presented individually but lumped under other taxa.

Taxa	Common Name	Total Larvae Collected	Est. Total Annual Entrainment	Entrain. Percent Comp.	Entrain. Cum. Percent
CIQ goby complex	gobies	17,878	1,830,899,000	75.64	75.64
Anchoa spp.	bay anchovies	4,390	514,809,000	21.27	96.91
Hypsoblennius spp.	combtooth blennies	226	22,335,000	0.92	97.83
Gillichthys mirabilis	longjaw mudsucker	249	21,953,000	0.91	98.74
Atherinopsidae	silversides	140	14,521,000	0.60	99.34
Syngnathus spp.	pipefishes	101	10,013,000	0.41	99.75
Acanthogobius flavimanus	yellowfin goby	19	2,261,000	0.09	99.85
Strongylura exilis	Calif. needlefish	8	740,000	0.03	99.88
Sciaenidae	croakers	6	706,000	0.03	99.91
	Other 11 taxa	22	2,291,000	0.09	100.00
	Total	23,039	2,420,528,000		

SBPP Results for CIQ Gobies

The following sections present results for demographic and empirical transport modeling of SBPP entrainment effects. All three modeling approaches are presented for the CIQ goby complex. CIQ goby larvae were most abundant at the entrainment station during June and July (Figure 3-1). Brothers (1975) indicated that the peak spawning period for arrow goby occurred from November through April, while spawning in cheekspot and shadow goby was more variable and can occur throughout the year. A peak spawning period for shadow goby in June and July of Brothers' (1975) study corresponds to the increased larval abundances during those months in this study.

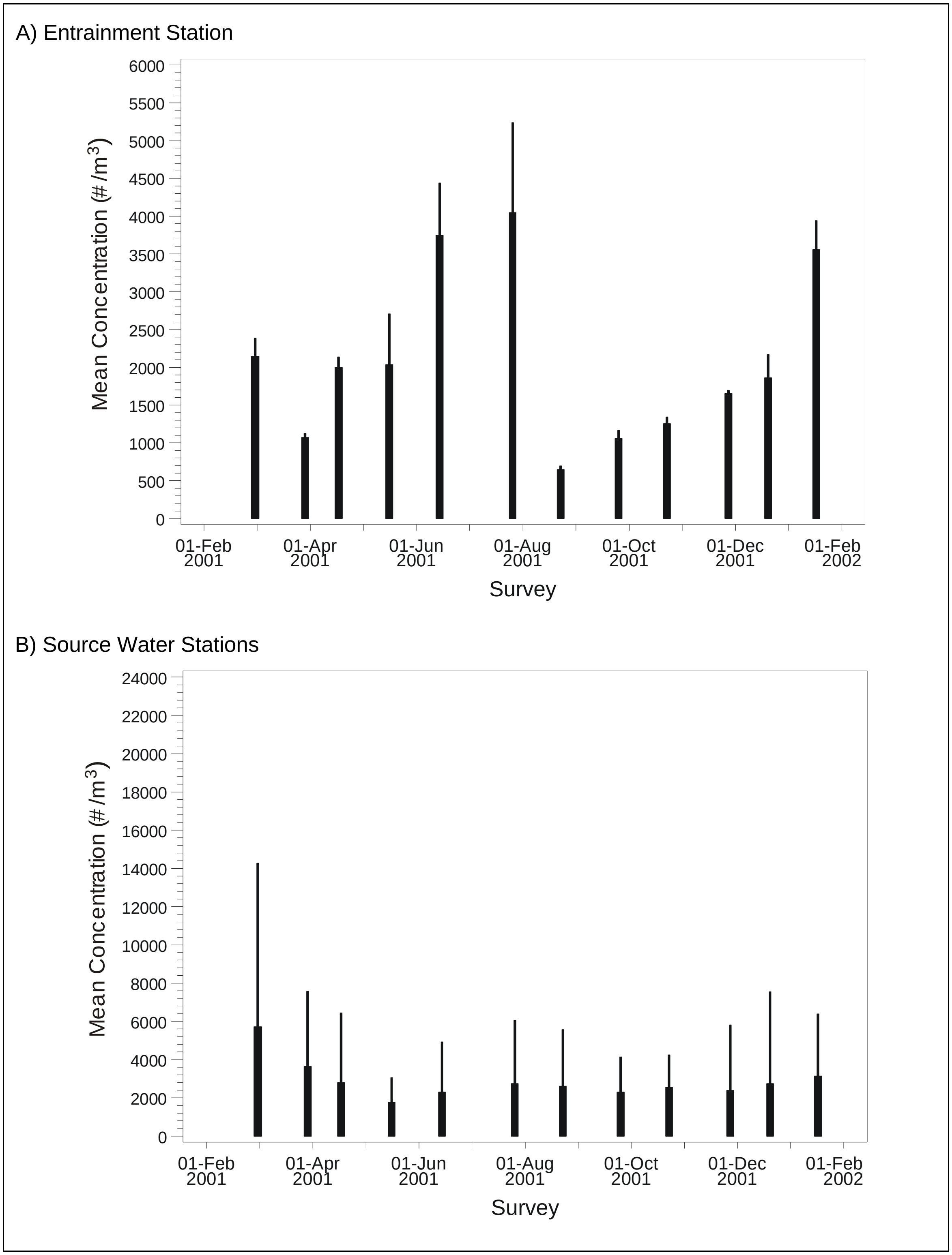


Figure 3-1. Monthly mean larval concentration (standard error shown at top of dark bars) of the *Clevlandia ios, Ilypnus gilberti*, and *Quietula y-cauda* (CIQ) goby complex larvae at SBPP; A) intake entrainment station and B) source water stations.

The *ETM* required an estimate of the length of time the larvae are susceptible to entrainment. The length frequency distribution for a representative sample of CIQ goby larvae showed that the majority of larvae were recently hatched based on the reported hatch size of 2–3 mm (Moser 1996) (Figure 3-2). The mean length of the collected CIQ goby larvae was 3.1 mm and the difference between the lengths of the 1st (2.2 mm) and 99th (5.8 mm) percentile values were used with a growth rate of 0.16 mm^{-d} estimated from Brothers (1975) to determine that CIQ goby larvae were vulnerable to entrainment for a period of 22.9 days. The growth rate of 0.16 mm^{-d} was determined using Brothers (1975) reported transformation lengths for the three species and an estimated transformation age of 60 d.

The comprehensive comparative study of the three goby species in the CIQ complex by Brothers (1975) also provided the necessary life history information for both *FH* and *AEL* demographic models and shows how life history data from the scientific literature are used in the modeling.

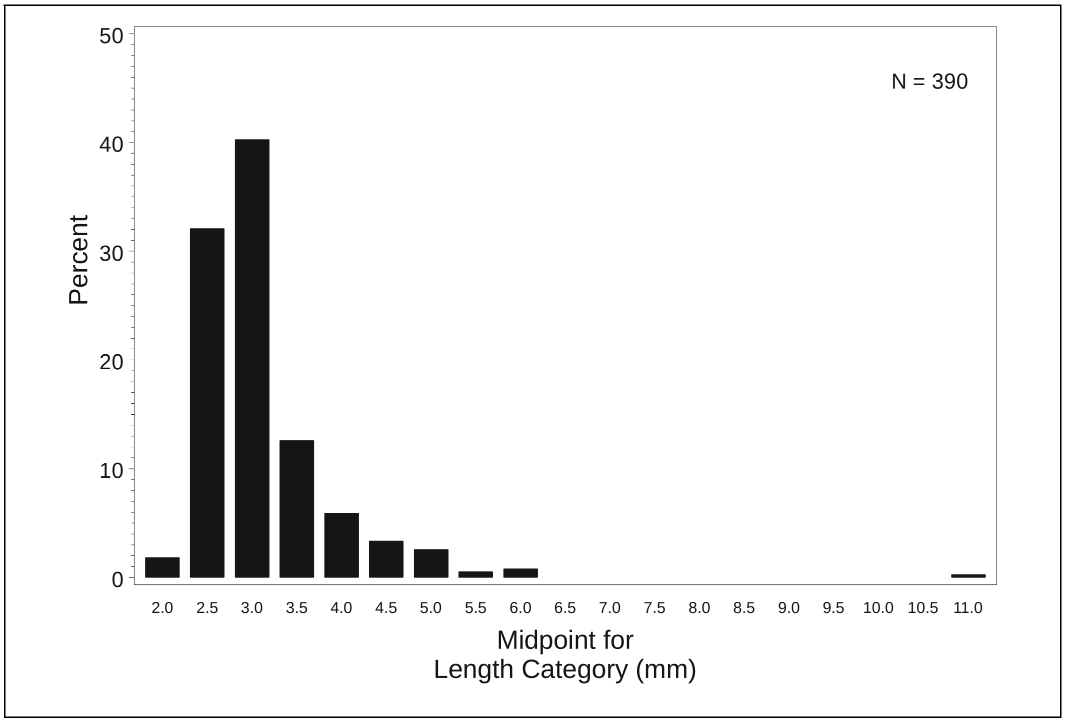


Figure 3-2. Length frequency distribution for *Clevlandia ios, Ilypnus gilberti*, and *Quietula y-cauda* (CIQ) goby complex larvae from the South Bay Power Plant entrainment station.

Fecundity Hindcasting

The annual entrainment estimate for CIQ gobies was used to estimate the number of adult females at the age of maturity whose reproductive output was lost due to entrainment (Table 3-2). No estimates of egg survival for gobies were available, but because goby egg masses are demersal (Wang 1986) and parental care, usually provided by the adult male, is common in the family (Moser 1996), egg survival is probably high and was assumed to be 100 percent. Average larval mortality of 99% over the two months between hatching and transformation for the three species of CIQ gobies from Brothers (1975) was used to estimate a daily survival rate of 0.931 as follows: $0.931 = (1-0.99)^{(6/365.25)}$. Mean length and length of the first percentile (2.2 mm) were used with the growth rate of 0.16 mm^{-d} to estimate a mean age at entrainment of 5.8 d. Survival to average age at entrainment was then estimated as $0.931^{5.8} = 0.659$. An average batch fecundity estimate of 615 eggs was based on calculations from Brothers (1975) on size-specific fecundities for the three species. Brothers (1975) found eggs at two to three different stages of development in the ovaries; therefore, an estimate of 2.5 spawns per year was used in calculating *FH* (615 eggs/spawn × 2.5 spawns/year = 1,538 eggs/year). The TLF for the studies at SBPP was calculated by adding 1 to the difference between the average ages of maturity (1.0) and longevity (3.3) from Brothers (1975) to account for spawning of a portion of the population during the first year. The *FH* model was used to estimate that the number of adult females at the age of maturity whose lifetime reproductive output was entrained through the SBPP circulating water system was 1,085,000 (Table 3-2). The standard error for the entrainment estimate was used to estimate a confidence interval based on just the sampling variance that was considerably less than a confidence interval for the estimate calculated using an assumed CV of 30% for all of the life history parameters.

Table 3-2. Results of fecundity hindcasting (*FH*) modeling for CIQ goby complex larvae entrained at South Bay Power Plant. The upper and lower estimates are based on a 90% confidence interval of the mean. *FH* was recalculated using the upper and lower confidence interval estimates for total entrainment.

	Estimate	**Estimate Std. Error**	***FH* Lower Estimate**	***FH* Upper Estimate**	***FH* Range**
FH Estimate	1,085,000	1,880,000	63,000	18,782,000	18,719,000
Total Entrainment	1.83×10^9	21,725,000	961,000	1,209,000	248,000

Adult Equivalent Loss

Three survival components were used to estimate *AEL*. These were 1) larval survival from the age of entrainment to the age of settlement, 2) survival from settlement to age 1, and 3) from age 1 to the average female age. Larval survival from average age at entrainment through settlement at 60 days was estimated as $0.931^{60-5.8} = 0.021$ using the same daily survival rate used in formulating *FH*. Brothers (1975) estimated that mortality in the first year following settlement was 91% for arrow, 66–74% for cheekspot, and 62–69% for shadow goby. These estimates were used to calculate a daily survival rate of 0.995 as follows:

$$0.995 = \frac{(1-0.91)^{1/(365.25-60)} + (1-0.70)^{1/(365.25-60)} + (1-0.65)^{1/(365.25-60)}}{3}$$

This value was used to calculate a finite survival of 0.211 for the first year following settlement as follows: $0.211 = 0.995^{(365.25-60)}$. Adult daily survival from one year through the average female age of 1.71 years from life table data for the three species provided by Brothers (1975) was estimated as 0.99. This value was used to calculate a finite survival of 0.195 as follows: $0.195 = (0.99)^{((1.71*365.25)-365.25)}$. The product of the three survival estimates and the entrainment estimate were used to estimate that the number of larvae entrained through the SBPP circulating water system number were equivalent to the loss of 1,580,000 adult CIQ gobies (Table 3-3). The standard error for the entrainment estimate was used to estimate a confidence interval based on just the sampling variance that was considerably less than a confidence interval for the estimate calculated using an assumed CV of 30% for all of the life history parameters.

Table 3-3. Results of adult equivalent loss (*AEL*) modeling for CIQ goby complex larvae entrained at South Bay Power Plant. The upper and lower estimates are based on a 90% confidence interval of the mean. *AEL* was recalculated using the upper and lower confidence interval estimates for total entrainment.

	Estimate	**Estimate Std. Error**	***AEL* Lower Estimate**	***AEL* Upper Estimate**	***AEL* Range**
AEL Estimate	1,580,000	2,739,000	91,300	2.74×10^7	2.73×10^7
Total Entrainment	1.83×10^9	2.17×10^7	1,399,000	1,760,000	361,000

Empirical Transport Model

The *ETM* estimates for CIQ gobies were calculated using the data in Appendix C and a larval duration of 22.9 days. Average larval concentrations from the entrainment and source water sampling were multiplied by the cooling water and source water volumes, respectively, to obtain the estimates that were used in calculating *PE* estimate for each survey. Weights were calculated by multiplying the source water estimate for each survey by the number of days in the survey period. Estimates for the surveys were summed and the proportion (f_i) for each survey calculated.

Daily mortality (PE_i) estimates ranged from 0.004 to 0.025 for the twelve surveys with an average value of 0.012 (Table 3-4). This average *PE* was similar to the volumetric ratio of the cooling water system to source water volumes (0.015), which was bounded by the range of PE_i estimates. PE_i estimates equal to the volumetric ratio would indicate that the CIQ goby larva were uniformly distributed throughout the source water and were withdrawn by the power plant at a rate approximately equal to that ratio. The small range in both the PE_i estimates and the values of f_i indicate that goby larvae were present in the source water throughout the year. The largest fractions of the source water population occurred in the February (f_i = 0.2165) and July (f_i = 0.1064) surveys which was consistent with the spawning periods for arrow and shadow gobies, respectively. June and July surveys also had the highest entrainment station concentrations resulting in higher PE_i estimates for those surveys (Figure 3-1).

Results for Other Taxa

The modeling results for other taxa selected for detailed assessment showed that both demographic modeling approaches could only be calculated for the CIQ goby complex (Table 3-5) due mainly to a lack of larval survival estimates for the life stages between larvae and adult. The alignment of the 2**FH* and *AEL* estimates would have been improved by extrapolating *AEL* to the age of maturity rather that the average female age of 1.7 years. Differences in the *FH* model results among taxa were generally proportional to entrainment estimates as shown by decreasing 2**FH* estimates for the top four taxa. As the results for the *ETM* model show, proportional effects of entrainment on the source populations vary considerably for the five taxa and do not reflect differences in entrainment estimates, but the combination of larval concentrations at entrainment and source water stations. The *ETM* estimates of P_M ranged from 0.031 (3.1%) to 0.215 (21.5%) with the estimated effects being lowest for combtooth blennies and highest for CIQ gobies and longjaw mudsuckers.

Table 3-4. Estimates of proportional entrainment (*PE*) and proportion of source water population present for CIQ goby larvae at South Bay Power Plant entrainment and source water stations from monthly surveys conducted from February 2001 through January 2002.

Survey Date	*PE* Estimate	Proportion of Source Population for Period (*f*)
28-Feb-01	0.0057	0.2165
29-Mar-01	0.0045	0.0977
17-Apr-01	0.0109	0.0491
16-May-01	0.0175	0.0475
14-Jun-01	0.0247	0.0620
26-Jul-01	0.0225	0.1064
23-Aug-01	0.0038	0.0675
25-Sep-01	0.0070	0.0704
23-Oct-01	0.0075	0.0661
27-Nov-01	0.0105	0.0773
20-Dec-01	0.0103	0.0584
17-Jan-02	0.0173	0.0811
Average =	0.0118	

Table 3-5. Summary of estimated South Bay Power Plant entrainment effects based on fecundity hindcasting (*FH*), adult equivalent loss (*AEL*), and empirical transport (*ETM*) estimates of proportional mortality (P_m) models. The *FH* estimate is multiplied by 2 to test the relationship that 2·*FH*≡*AEL*.

Taxa	Entrainment Estimate	% Source Numbers	*2*FH*	*AEL*	P_M
CIQ goby complex	1.83×10^9	76.75	2,170,000	1,580,000	0.215
anchovies	5.15×10^8	15.12	214,000	*	0.105
combtooth blennies	2.23×10^7	5.93	21,500	*	0.031
longjaw mudsucker	2.19×10^7	0.17	2,960	*	0.171
silversides	1.45×10^7	0.65	*	*	0.146

* Information unavailable to compute model estimate.

3.2 MORRO BAY POWER PLANT

A total of 30,270 larval fishes in 87 taxonomic categories ranging from ordinal to specific classifications was collected from 609 samples at the MBPP entrainment station during weekly sampling from January 2000 through December 2000 (Table 3-6). These data were used to estimate total annual entrainment of fish larvae at 5.08×10^8. Entrainment samples were dominated by unidentified gobies, which comprised 77% of the total estimated entrainment of fish larvae. The top seven taxa comprising greater than 90% of the total and three other commercially or recreationally important fishes in the top 95% (white croaker *Genyonemus lineatus*, Pacific herring *Clupea pallasii*, and cabezon *Scorpaenichthys marmoratus*) were evaluated for entrainment effects along with six species of *Cancer* crab megalopae (Table 2-4) (results for *Cancer* crab not presented).

Table 3-6. Total annual entrainment estimates of fishes and invertebrates at Morro Bay Power Plant based on weekly larval densities sampled at Station 2 (n=609 tows) from January to - December 2000 and the plant's maximum circulating water flows. Data and estimates for taxa comprising <0.01 percent of the composition are not presented individually but lumped as other taxa.

Taxon	Common Name	Total Collected	Estimated Annual # of Entrained Larvae	Percent of Total	Cumulative Percent
Gobiidae unid.	gobies	22,964	393,261,000	77.37	77.37
Leptocottus armatus	Pacific staghorn sculpin	1,129	17,321,000	3.41	80.78
Stenobrachius leucopsarus	northern lampfish	1,018	14,549,000	2.86	83.64
Quietula y-cauda	shadow goby	845	13,504,000	2.66	86.30
Hypsoblennius spp.	combtooth blennies	572	10,042,000	1.98	88.27
Sebastes spp. V_De	KGB rockfishes	360	6,407,000	1.26	89.53
Atherinopsis californiensis	jacksmelt	384	6,266,000	1.23	90.76
Rhinogobiops nicholsi	blackeye goby	226	3,778,000	0.74	91.51
Gillichthys mirabilis	longjaw mudsucker	186	3,286,000	0.65	92.15
Lepidogobius lepidus	bay goby	181	3,233,000	0.64	92.79
Clupea pallasii	Pacific herring	242	3,030,000	0.60	93.39
Scorpaenichthys marmoratus	cabezon	171	2,888,000	0.57	94.54
Atherinopsidae unid.	silversides	163	2,720,000	0.54	95.08
Atherinops affinis	topsmelt	153	2,575,000	0.51	95.58
Sebastes spp. V	rockfishes	150	2,453,000	0.48	96.07
Tarletonbeania crenularis	blue lanternfish	142	2,213,000	0.44	96.50
Engraulis mordax	northern anchovy	155	2,136,000	0.42	96.92
larval fish - damaged	larval fish - damaged	74	1,283,000	0.25	97.18
Gibbonsia spp.	clinid kelpfish	98	1,141,000	0.22	97.40
Bathymasteridae unid.	ronquils	67	1,119,000	0.22	97.62
Cottidae unid.	sculpins	59	1,009,000	0.20	97.82
Artedius lateralis	smoothhead sculpin	46	739,000	0.15	97.96
Oligocottus spp.	sculpin	40	620,000	0.12	98.09
Stichaeidae unid.	pricklebacks	41	616,000	0.12	98.21
Chaenopsidae unid.	tube blennies	31	551,000	0.11	98.32
Cebidichthys violaceus	monkeyface eel	28	505,000	0.10	98.41
Bathylagus ochotensis	popeye blacksmelt	28	495,000	0.10	98.51
	59 other taxa	483	7,564,000	2.93	100.00
	Total Larvae	30,270	508,296,000		

Species composition for entrainment at MBPP was much more diverse than the results from SBPP. This may have resulted from the more frequent weekly sampling at MBPP and the location of the power plant near the entrance to the bay relative to the back bay location of SBPP. Entrainment was dominated by fishes that primarily occur as adults in the bay, such as gobies, but also included numerous fishes that are more typically associated with nearshore coastal habitats, such as rockfish and cabezon.

MBPP Results for the KGB Rockfish Complex

Detailed results and details on the data used in the three modeling approaches at MBPP are presented for the KGB larval rockfish complex. KGB rockfish had the sixth highest estimated entrainment (6,407,000) or 1.3% of the total larval fishes (Table 3-6). Consistent with the annual spawning period for most rockfishes (Parrish et al. 1989), larvae occurred in entrainment samples from January through June with the highest abundances in April (Figure 3-3). Results from source water surveys showed the same abundance peaks seen in samples collected at the MBPP intake station (Figure 3-4). Although not collected every month, KGB rockfish larvae were collected from all of the stations inside Morro Bay during the April survey. They reached their greatest concentration at the Estero Bay Station 5 during the May survey when they were less common at the stations inside Morro Bay.

The length frequency distribution for a representative sample of KGB rockfish larvae showed a relatively narrow size range of 3.4 to 5.4 mm (1^{st} and 99^{th} percentile values = 3.5 and 5.1) with an average size of 4.3 mm (Figure 3-5). These results indicate that most of the larvae are less than the maximum reported size at extrusion of 4.0–5.5 mm (Moser 1996) and are therefore subject to entrainment for a relatively short period of time. There are no studies on the larval growth rates for the species in the KGB rockfish complex so a larval growth rate of 0.14 mm^{-d} from brown rockfish (Love and Johnson 1999, Yoklavich et al. 1996) was used in estimating that the average age at entrainment was 5.5 d and the maximum age at entrainment, based on the 99^{th} percentile values was 11.3 d.

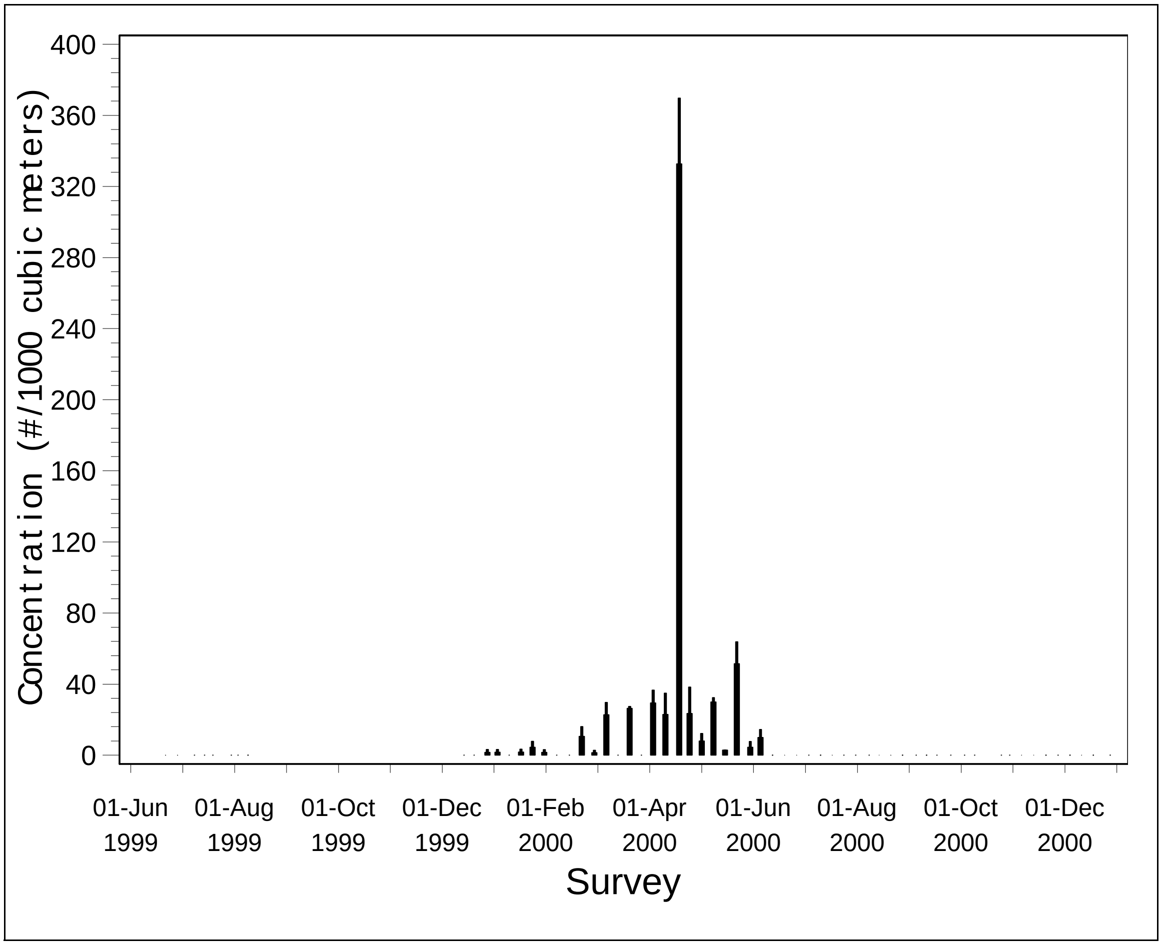


Figure 3-3. Weekly mean larval concentration of kelp, gopher, and black-and-yellow (KGB) rockfish complex larvae at the Morro Bay Power Plant intake entrainment station.

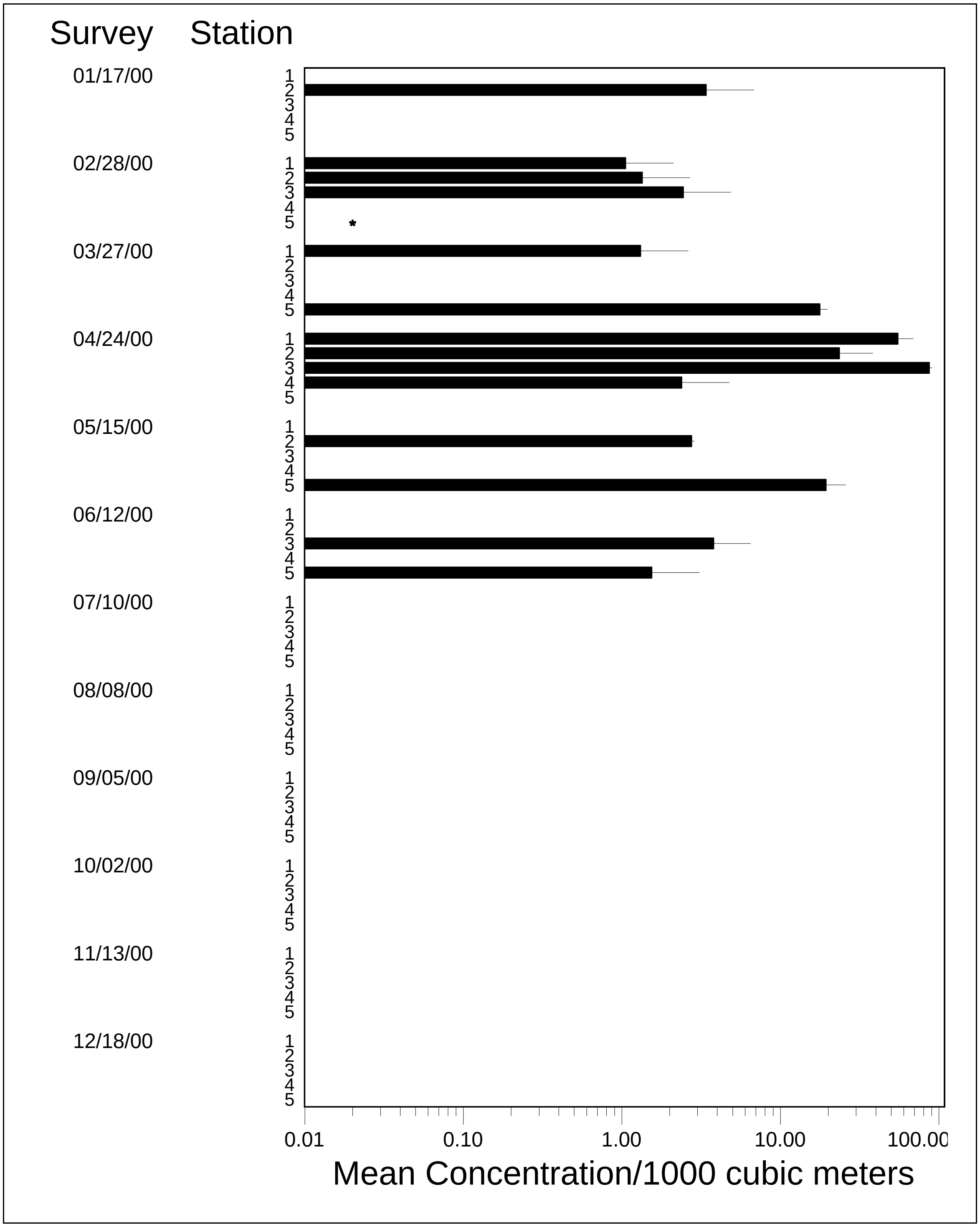


Figure 3-4. Comparison of average concentrations of kelp, gopher, and black-and-yellow (KGB) rockfish complex larvae at the Morro Bay Power Plant intake (Station 2), Morro Bay source water (Stations 1, 3, and 4), and Estero Bay (Station 5) from January 2000 through December 2000 with standard error indicated (+1 SE). Entrainment data only plotted for paired surveys. *No samples were collected during February 2000 at Station 5. Note that data are plotted on a $\log_{10}$ scale.

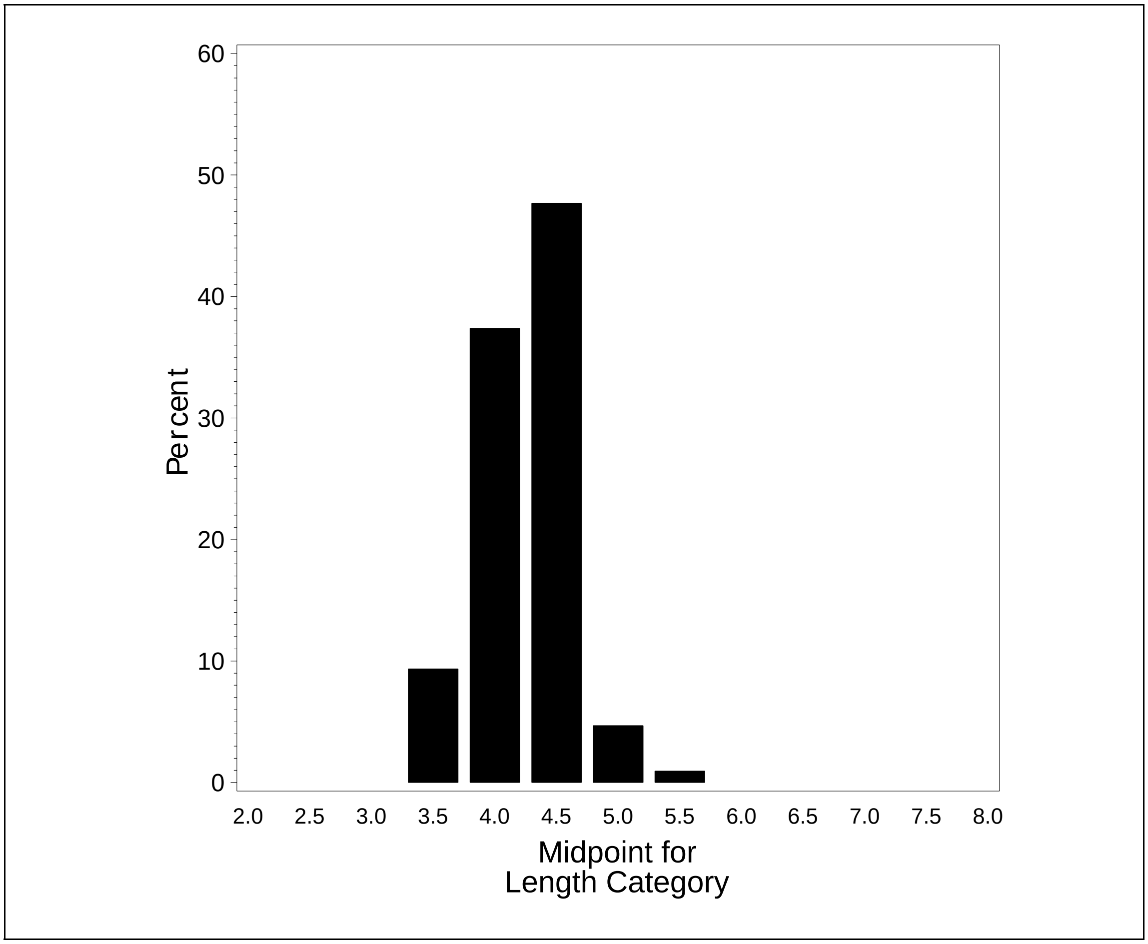


Figure 3-5. Length frequency distribution for kelp, gopher, and black-and-yellow (KGB) rockfish complex larvae from the Morro Bay Power Plant entrainment station.

Fecundity Hindcast Model

Total annual larval entrainment for KGB rockfish was used to estimate the number of adult females at the age of maturity whose reproductive output was lost due to entrainment (Table 3-7). The parameters required for formulation of *FH* estimates for KGB rockfishes were compiled from references on different rockfish species. Rockfishes are viviparous and release larvae once per year. A finite survival rate of 0.463 for the larvae from time of release to the average age at entrainment was estimated using an instantaneous mortality rate of 0.14/day from blue rockfish (Mary Yoklavich, NOAA/NMFS/PFEG, Pacific Grove, CA, pers. comm. 1999) over 5.5 days ($0.463 = e^{(-0.14*5.5)}$). An average annual fecundity estimate of 213,000 eggs per female was used in calculating *FH* (DeLacy et al. 1964: 52,000-339,000; MacGregor 1970: 44,118-104,101 and

143,156-182,890; Love and Johnson 1999: 80,000-760,000). Estimates of five years as the age at maturity and 15 years for longevity were used in calculating *FH* (Burge and Schultz 1973, Wyllie Echeverria 1987, Lea et al. 1999). The model estimated that the reproductive output of 13 adult females at the age on maturity was entrained by the MBPP (Table 3-7). Variation due to sampling error had only a small effect on the range of estimates.

Adult Equivalent Loss

Total annual MBPP entrainment of KGB rockfish was used to estimate the number of equivalent adults theoretically lost to the population. The parameters required for formulation of *AEL* estimates for KGB rockfish were derived from data on larval blue rockfish survival. Survivorship of KGB rockfishes from parturition to an estimated recruitment age of three years was partitioned into six stages (Table 3-8). The estimate of *AEL* was calculated assuming the entrainment of a single age class having the average age of recruitment. The estimated number of equivalent adults corresponding to the number of larvae that would have been entrained by the proposed MBPP combined-cycle intake was 23 (Table 3-9). The uncertainty of the *AEL* estimate due to sampling error was very small.

Although the *FH* and *AEL* estimates were very close to the theoretical relationship of $2FH \equiv AEL$, the *AEL* was only extrapolated to age three. The estimate would decrease by extrapolating to five years, the age of maturity used in the *FH* calculations.

Table 3-7. Annual estimates of adult female kelp, gopher, and black-and-yellow (KGB) rockfish losses at Morro Bay Power Plant based on larval entrainment estimates using the fecundity hindcasting (*FH*) model for the January – December 2000 data. Upper and lower estimates represent the changes in the model estimates that result from varying the value of the corresponding parameter in the model.

	Estimate	**Estimate Std. Error**	**Upper *FH* Estimate of**	**Lower *FH* Estimate**	***FH* Range**
FH Estimate	13	8	37	5	32
Entrainment	6,407,000	189,000	14	12	2

Table 3-8. Survival of the kelp, gopher, and black-and-yellow (KGB) rockfish complex larvae to an age of three years, based on blue rockfish (*Sebastes mystinus*) data.

Lifestage	Day (Start)	Day (End)	Instantaneous Natural Daily Mortality (*Z*)	Lifestage Survival (*S*)
Early larval 1	0	5.5	0.14	0.463
Early larval 2	5.5	20	0.14	0.131
Late larval	20	60	0.08	0.041
Early juvenile	60	180	0.04	0.008
Late juvenile	180	365	0.0112	0.126
Pre-recruit	365	1,095	0.0006	0.645

Note: Survival was estimated from release as $S = e^{(-Z)(Day(end)-Day(Start))}$. Daily instantaneous mortality rates (*Z*) for blue rockfish larvae were used to calculate KGB larval survivorship and were provided by Mary Yoklavich (NOAA/NMFS/PFEG, Pacific Grove, CA, pers. comm. 1999). Annual instantaneous mortality was assumed as 0.2/year after two year average age of entrainment was estimated as 5.5 days based on average size at entrainment and a growth rate of 0.14 mm/day (0.006 in./day) (Yoklavich et al. 1996).

Empirical Transport Model

The estimated P_M value for the KGB rockfish complex was 0.027 (2.7%) for the period of entrainment risk applied in the model (11.3 days) (Table 3-10) (All of the data used in the *ETM* calculations are in Appendix D). The model included an adjustment for P_S (0.088) because this taxon occupies nearshore habitats that extend well beyond the sampling areas. The value of P_S was computed by using alongshore distance of the sampled source water area (9.6 km) and dividing it by the alongshore distance the larvae could have traveled during the 11.3 day larval duration at an average current speed of 11.3 cm/s. The *PE* estimates ranged from 0 to 0.3097 (Table 3-10). Although the largest *PE* estimate occurred for the January survey, the largest fraction of the population was collected during the April survey (f_i = 0.7218) when the *PE* estimate was an order of magnitude lower.

Table 3-9. Annual estimates of adult kelp, gopher, and black-and-yellow (KGB) rockfish losses at Morro Bay Power Plant due to entrainment using the adult equivalent loss (*AEL*) model for the January – December 2000 data. Upper and lower estimates represent the changes in the model estimates that result from varying the value of the corresponding parameter in the model.

	Estimate	Estimate Std. Error	Upper *AEL* Estimate	Lower *AEL* Estimate	*AEL* Range
AEL Estimate	23	15	69	8	61
Total Entrainment	6,407,000	189,000	24	22	2

Table 3-10. Estimates of KGB rockfish larvae at MBPP entrainment and source water stations from monthly surveys conducted from January 2000 through December 2000 used in calculating empirical transport model (*ETM*) estimates of proportional entrainment (*PE*) and annual estimate of proportional mortality (P_M). The daily cooling water intake volume used in calculating the entrainment estimates was 1,619,190 m^3, and the volume of the source water used in calculating the source water population estimates was 15,686,663 m^3. Bay volume = 20,915,551 m^3. The larval duration used in the calculations was 11.28 days. More detailed data used in the calculations are presented in Appendix E.

Survey Date	Bay *PE*	Offshore *PE*	Total *PE*	Proportion of Source Population for Period (f)
17-Jan-00	0.3097	0	0.3097	0.0099
28-Feb-00	0.1052	0.0988	0.0509	0.0239
27-Mar-00	0	0	0	0.1076
24-Apr-00	0.0533	0.0661	0.0295	0.7218
15-May-00	0.3785	0.0220	0.0208	0.1197
12-Jun-00	0	0	0	0.0169
10-Jul-00	0	0	0	0
8-Aug-00	0	0	0	0
5-Sep-00	0	0	0	0
2-Oct-00	0	0	0	0
27-Nov-00	0	0	0	0
18-Dec-00	0	0	0	0
	$\bar{x}$ = 0.0705	$\bar{x}$ = 0.0156	$\bar{x}$ = 0.0342	

Results for Other Taxa

The modeling results for other taxa selected for detailed assessment showed that both demographic models could only be used with about half of the fishes analyzed (Table 3-11). Differences in the demographic model results among taxa were generally proportional to the differences in entrainment estimates as shown by the decreasing 2**FH* estimates for the six fishes analyzed. An exception was KGB rockfishes that had lower model estimates in proportion to their entrainment due to the longer lifespan and later age of maturity of this taxa group relative to the other fishes analyzed. The *ETM* estimates of P_M for the analyzed fishes ranged from 0.025 (2.5%) to 0.497 (49.7%) with the estimated effects being lowest for fishes with source populations that extended outside the bay into nearshore areas. The highest estimated effects occurred for combtooth blennies that are commonly found as adults among the fouling communities on the piers and structures that are located along the waterfront near the MBPP intake.

Table 3-11. Summary of estimated Morro Bay Power Plant entrainment effects based on fecundity hindcasting (*FH*), adult equivalent loss (*AEL*), and empirical transport (*ETM*) estimates of proportional mortality (P_M) models. The *FH* estimate is multiplied by 2 to test the relationship that 2·*FH* = *AE*L. *ETM* model (P_M) calculated using nearshore extrapolation of source water population.

Taxon	Common Name	Total Entrainment	2**FH*	*AEL*	P_M
Gobiidae	unidentified gobies	3.9×10^8	796,000	268,000	0.116
Leptocottus armatus	Pacific staghorn sculpin	1.7×10^7	*	*	0.051
Stenobrachius leucopsarus	northern lampfish	1.5×10^7	*	*	0.025
Quietula y-cauda	shadow goby	1.3×10^7	12,700	7,440	0.028
Hypsoblennius spp.	combtooth blennies	1.0×10^7	8,720	8,080	0.497
Sebastes spp. V_De	KGB rockfishes	6.4×10^6	26	*	0.027
Atherinopsis californiensis	jacksmelt	6.3×10^6	*	*	0.217
Genyonemus lineatus	white croaker	3.0×10^6	106	*	0.043
Clupea pallasii	Pacific herring	3.0×10^6	86	532	0.164
Scorpaenichthys marmoratus	cabezon	2.9×10^6	*	*	0.025

* - Information unavailable to compute model estimate.

3.3 DIABLO CANYON POWER PLANT

There were 97,746 larval fishes identified and enumerated from the 4,693 entrainment samples processed for the DCPP study (Table 3-12). These were placed into 178 different taxonomic categories ranging from ordinal to specific classifications. This list of taxa was much more diverse than the studies at SBPP and MBPP due to length of the sampling effort, number of samples collected, and greater variety of habitats found in the area around the DCPP. The taxa in highest abundance were those whose adults were generally found close to shore, in shallow water. One exception was the thirteenth most abundant taxon, the northern lampfish, whose adults are found midwater and to depths of 3,000 m (Miller and Lea 1972). Fourteen fish taxa (Table 2-4) were selected for detailed assessment using the *FH*, *AEL*, and *ETM* approaches based on their numerical abundance in the samples and their importance in commercial or recreational fisheries.

There were 43,785 larval fishes identified and enumerated from the 3,163 samples processed from the nearshore sampling area. These comprised 175 different taxa ranging from ordinal to specific levels of classification. Adults of these taxa live in a variety of habitats, from intertidal and shallow subtidal to deep-water and pelagic habitats. The taxa in highest abundance in the nearshore sampling area were those whose adults were typically pelagic or subtidal; the more intertidally or nearshore distributed species were found in lower abundance in the sampling area.

DCPP Results for the KGB Rockfish Complex

Larval rockfishes in the KGB complex showed distinct seasonal peaks of abundance at the DCPP intake structure, with their greatest abundance tending to occur between March and July (Figure 3-6). An El Niño began developing during the spring of 1997 (NOAA 1999) and was detected along the coast of California in fall of that year (Lynn et al. 1998). This may have slightly affected the density in 1998 compared with the previous year. The El Niño event did not affect seasonal peaks in abundance between years; during both periods KGB rockfish larvae first starting appearing in February, reached peak abundances in April-May, and were not present following late-July.

Table 3-12. Fishes collected during Diablo Canyon Power Plant entrainment sampling. Fishes comprising less than 0.4% of total not shown individually but lumped under "other taxa".

Taxon	Common Name	Count	Percent of Total	Cumulative Percent
Sebastes spp. V_De (KGB rockfish complex)	rockfishes	17,576	18.0	18.0
Gibbonsia spp.	clinid kelpfishes	9,361	9.6	27.6
Rhinogobiops nicholsi	blackeye goby	7,658	7.8	35.4
Cebidichthys violaceus	monkeyface eel	7,090	7.3	42.6
Artedius lateralis	smoothhead sculpin	5,598	5.7	48.4
Orthonopias triacis	snubnose sculpin	4,533	4.6	53.0
Genyonemus lineatus	white croaker	4,300	4.4	57.4
Cottidae unid.	sculpins	3,626	3.7	61.1
Gobiidae unid.	gobies	3,529	3.6	64.7
Engraulis mordax	northern anchovy	3,445	3.5	68.3
Stichaeidae unid.	pricklebacks	2,774	2.8	71.1
Sebastes spp. V (blue rockfish complex)	rockfishes	2,731	2.8	73.9
Stenobrachius leucopsarus	northern lampfish	2,326	2.4	76.3
Sardinops sagax	Pacific sardine	2,191	2.2	78.5
Scorpaenichthys marmoratus	cabezon	1,938	2.0	80.5
Oligocottus spp.	sculpins	1,708	1.7	82.2
Bathymasteridae unid.	ronquils	1,336	1.4	83.6
Oxylebius pictus	painted greenling	1,133	1.2	84.8
Oligocottus maculosus	tidepool sculpin	1,035	1.1	85.8
Liparis spp.	snailfishes	900	0.9	86.7
Chaenopsidae unid.	tube blennies	817	0.8	87.6
Pleuronectidae unid.	righteye flounders	698	0.7	88.3
Clinocottus analis	wooly sculpin	683	0.7	89.0
Sebastes spp. V_D	rockfishes	656	0.7	89.7
Ruscarius creaseri	roughcheek sculpin	633	0.6	90.3
Artedius spp.	sculpins	623	0.6	90.9
Lepidogobius lepidus	bay goby	541	0.6	91.5
Bathylagus ochotensis	popeye blacksmelt	497	0.5	92.0
Paralichthys californicus	California halibut	378	0.4	92.4
Parophrys vetulus	English sole	361	0.4	92.8
Sebastes spp.	rockfishes	357	0.4	93.1
Osmeridae unid.	smelts	356	0.4	93.5
Neoclinus spp.	fringeheads	352	0.4	93.9
	144 other taxa	6,006	6.1	100.0
	Total Larvae	97,746		

There were 17,863 larval KGB rockfishes identified from 774 of samples collected at the DCPP intake structure between October 1996 and June 1999 representing 20% of the entrainment samples collected and processed during that period. Annual estimated numbers of KGB rockfish larvae entrained at DCPP varied relatively little between the 1996–97 Analysis Period 1 (268,000,000) and the 1997–98 Analysis Period 2 (199,000,000) (Table 3-13). An approximation of 95% confidence intervals (± 2 std. errors) for the two estimates overlap indicating that the differences between them were probably not statistically significant and that entrainment of KGB rockfish larvae was relatively constant between years.

Estimates of annually entrained KGB rockfish larvae were adjusted (Table 3-13) to the long-term average DCPP Intake Cove surface plankton tow index, calculated as the ratio between the 9 yr average of DCPP Intake Cove sampling (Figure 3-7) and the average annual index estimated from these same tows during the year being adjusted. Average indices for the years 1997 and 1998 were 0.070 and 0.065 larvae/m^3, respectively, and the long-term average index for 1990–98 was 0.072 larvae/m^3. Thus, the ratios used to adjust the 1997 and 1998 estimates of larvae entrained were 1.03 and 1.13, respectively, indicating that larval density was slightly lower than the long-term average during those years. Adjustments resulted in an estimate of 275,000,000 entrained KGB rockfish larvae for 1996–97 Analysis Period 1 and 222,000,000 for 1997–98 Analysis Period 2 (Table 3-13). The same trends in overall abundance as noted for unadjusted entrainment values were apparent in the adjusted values; namely, larval KGB rockfish abundance changed little between analysis periods. Annual estimates of abundance during the study period were low relative to the long-term average index of larval abundance from the Intake Cove plankton tows as indicated by the index ratios greater than one.

Larval KGB rockfishes generally occurred in the nearshore sampling area with similar seasonality to that observed at the DCPP intake structure with peak abundance occurring in May of both 1998 and 1999 (Figure 3-6). There were 5,377 KGB rockfish larvae identified from 701 samples representing 23% of the nearshore sampling area samples collected and processed from July 1997–June 1999. The mean concentrations in May of each sampling year were very similar (1998: 0.29/m^3; 1999: 0.28/m^3), indicating little change in abundance between the El Niño and subsequent La Niña years. The pattern of abundances in the nearshore sampling area differed between years with larger abundances of larvae in the sampling cells closest to shore during 1999 (Figure 3-8b). Regression analyses of the data for the two sampling periods showed declining abundances with increasing distance offshore (negative slope) for the 1999 period and almost no change with increasing distance offshore for the 1998 period (Appendix F).

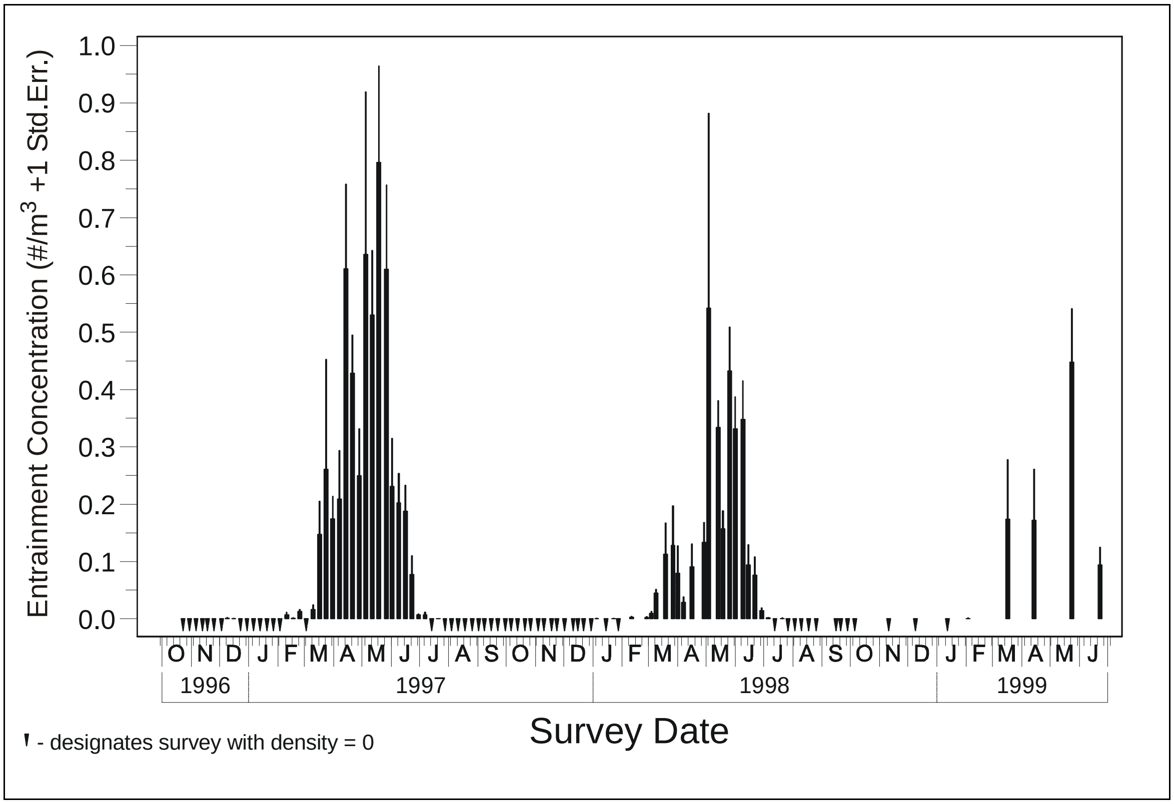


Figure 3-6. Weekly mean larval concentrations of kelp, gopher, and black-and-yellow (KGB) rockfish complex larvae at the Diablo Canyon Power Plant intake entrainment stations. Dark bars represent mean concentration and thinner bars represent one standard error.

Table 3-13. Diablo Canyon Power Plant entrainment estimates (E_T) and standard errors for kelp, gopher, and black-and-yellow (KGB) rockfish complex. E_{Adj-T} refers to the number entrained after adjustment to a long tern mean density. Note: The results for analysis periods 2 and 3 are the same because the overlap between the periods occurred during the peak larval abundances of KGB rockfish larvae.

Analysis Period	**E_T**	**SE(E_T)**	**E_{Adj-T}**	**SE(E_{Adj-T})**
1) Oct 1996 – Sept 1997	268,000,000	24,000,000	275,000,000	24,700,000
2) Oct 1997 – Sept 1998	199,000,000	25,900,000	222,000,000	28,900,000

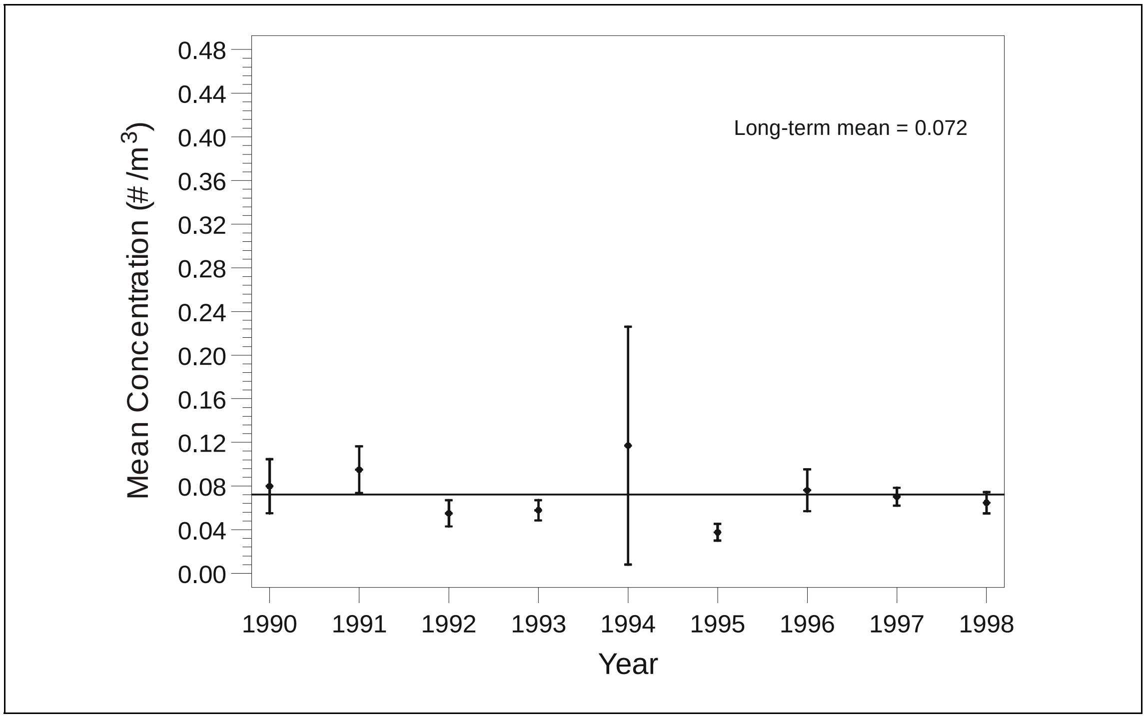


Figure 3-7. Annual mean concentration (+/- 2 standard errors) for kelp, gopher, and black-and-yellow (KGB) rockfish complex larvae collected from surface plankton tows in DCPP Intake Cove. Data were collected from December through June for every year except 1990 when only data from February through June were collected. The horizontal line is the long-term mean for all years combined.

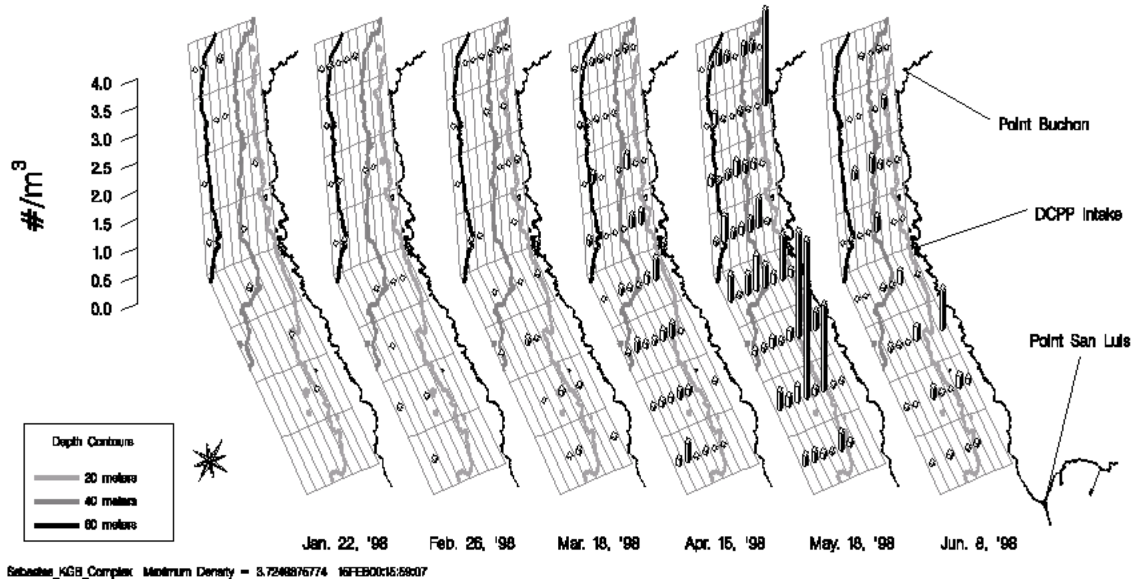
Standard lengths of all measured KGB rockfish larvae collected at the DCPP intake structure between October 1996 and June 1999 (9,926 larvae) ranged from 2.4 to 8.0 mm (mean = 4.2 mm) (Figure 3-9). The lengths of entrained KGB larvae, excluding the largest 1% and smallest 1% of all measurements, ranged from 3.3 to 5.6 mm. Similar to the KGB assessment at Morro Bay, a growth rate of 0.14 mm/d (Mary Yoklavich, NOAA / NMFS / PFEG, Santa Cruz, CA, pers. comm. 1999) was used to estimate the age of entrained larvae. Assuming that the size of the smallest 1% represents post-extrusion larvae that are aged zero days, then the estimated ages of entrained larvae ranged from zero up to ca. 16.4 d post-extrusion for the size of the largest 1% of the larvae. The estimated average age of KGB larvae entrained at DCPP was 6.4 d post-extrusion. The reported extrusion size for species in this complex ranges from 4.0–5.5 mm (Moser 1996).

Fecundity Hindcasting

The same life history parameter values used for the MBPP study (Table 3-8) were also used to calculate *FH* estimates for the KGB rockfish complex for the DCPP study. Average age at entrainment was estimated as 6.2 d. This was calculated by subtracting the value of the 1^{st} percentile value of the lengths (3.3 mm) from the mean length at entrainment (4.2 mm) and dividing by the larval growth rate for brown rockfish of 0.14 mm/d (Love and Johnson 1999; Yoklavich et al. 1996) that was also used in the MBPP study. The survival rate of the KGB larvae from size at entrainment to size at recruitment into the fishery was partitioned into six stages from parturition to recruitment using the same approach presented for the MBPP study (Table 3-14). The survival rate from extrusion to the average age at entrainment using data from blue rockfish was estimated as 0.419 ($0.419 = e^{(-0.14)(6.2)}$).

The estimated number of adult KGB rockfish females at the age of maturity whose reproductive output was been lost due to entrainment was 617 for the 1996–97 period and 497 for the 1997–98 period (Table 3-14). The similarity between the estimates was a direct result of the similarity between adjusted entrainment estimates for the two periods. Low FH estimates resulted from the relatively high fecundity of adults and young average entrainment age estimated for larvae in this complex and not including other sources of mortality such as losses due to fishing in the model. The variation in the entrainment estimate had very little effect on the model estimates relative to the variation resulting from the life history parameters.

A) January 1998 – June 1998 surveys



B) January 1999 – June 1999 surveys

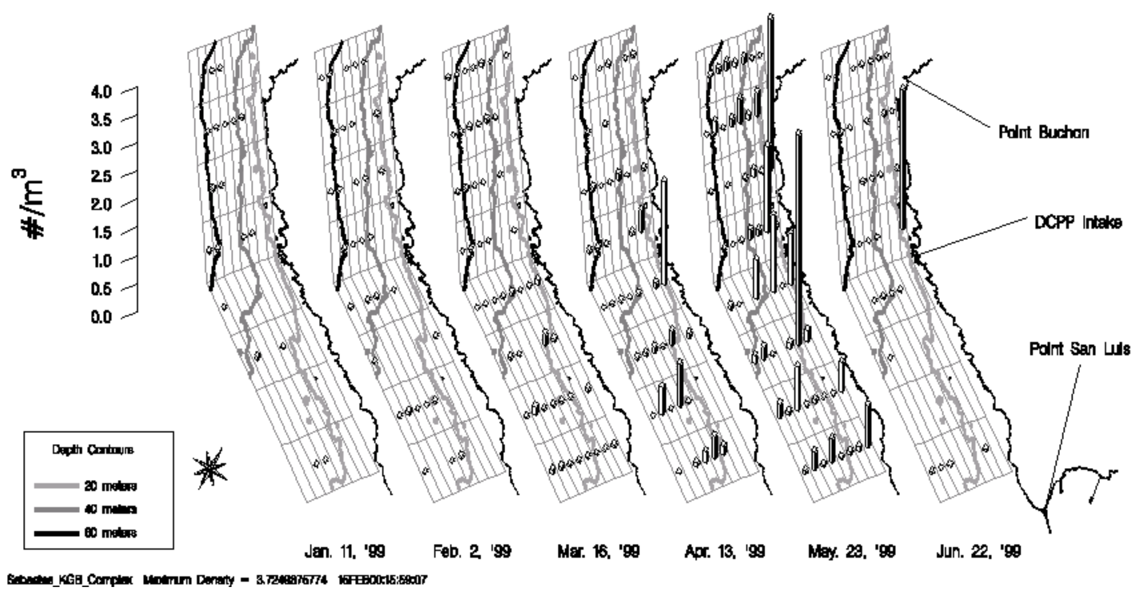


Figure 3-8. Average concentration for kelp, gopher, and black-and-yellow (KGB) rockfish complex larvae in each of the 64 nearshore stations for surveys done from A) January 1998 through June 1998, and B) January 1999 through June 1999 for Diablo Canyon Power Plant. Surveys done in other months are not shown because there were few or no KGB rockfish complex larvae collected.

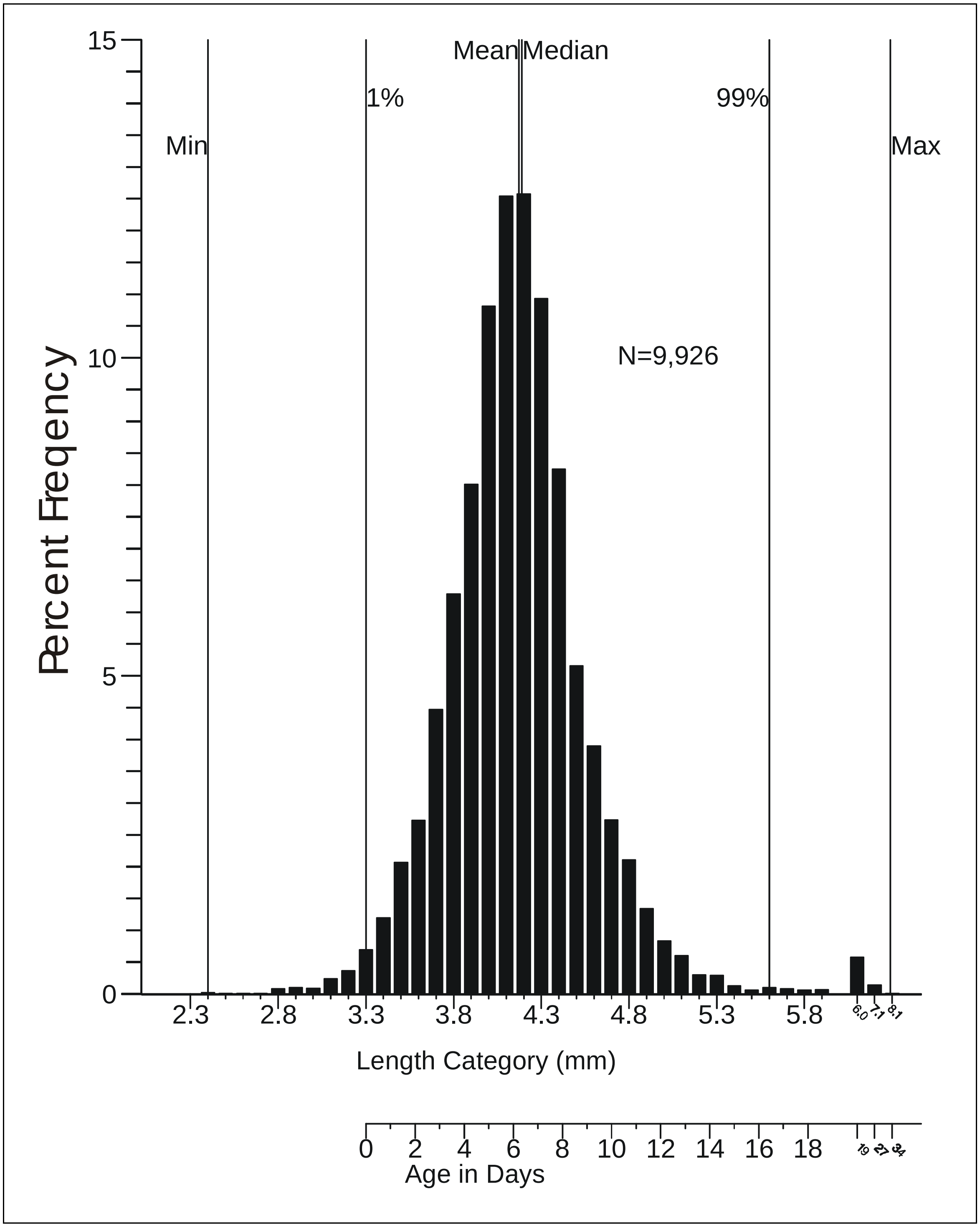


Figure 3-9. Length frequency distribution for kelp, gopher, and black-and-yellow (KGB) rockfish complex larvae measured from entrainment stations at Diablo Canyon Power Plant intake from October 1996 to June 1999. The x-scale is not continuous at larger lengths. Alternate x-scale shows age in days estimated using growth rate of 0.14 mm^{-d}.

Table 3-14. Diablo Canyon Power Plant fecundity hindcasting (*FH*) estimates for kelp, gopher, and black-and-yellow (KGB) rockfish complex for two year-long analysis periods. Upper and lower estimates represent the changes in the model estimates that result from varying the value of the corresponding parameter in the model.

Analysis Period	**Adjusted Entrainment Estimate**	**Estimate Std. Error**	**Upper *FH* Estimate**	**Lower *FH* Estimate**	***FH* Range**
1) Oct 1996–Sept 1997					
FH Estimate	617	1,470	31,500	12	31,488
Adjusted Entrainment	275,000,000	24,700,000	708	526	182
2) Oct 1997–Sept 1998					
FH Estimate	497	1,190	25,400	10	25,390
Adjusted Entrainment	222,000,000	28,900,000	603	391	212

Adult Equivalent Loss

Similar to the *FH* calculations the same life history parameter values from blue rockfish used for the MBPP study (Table 3-8) were also used to calculate *AEL* estimates for KGB rockfish at DCPP. The *AEL* estimates were extrapolated forward from the average age at entrainment of 6.2 d, the same value used in the *FH* hindcasting. Survivorship, to an assumed recruitment age of 3 yr, was apportioned into these life stages, and *AEL* was calculated assuming the entrainment of a single age class having the average age of recruitment. Survival from the average age at entrainment (6.2 d) to the age at transformation (20 d) was estimated as 0.145 ($0.145 = e^{(-0.14)(20-6.2)}$). The other stages used the survival estimates from Table 3-14.

Paralleling the *FH* results, estimates of adult equivalents lost due to larval entrainment were fairly similar among survey periods (Table 3-15). The *AEL* estimate of 1,120 adults predicted from E_{T-Adj} at DCPP during 1996–97 reflects the slightly higher abundance of KGB rockfish larvae present during this year when compared to the 1997–1998 period (*AEL*= 905). The relatively constant larval abundance and subsequent estimates of effects varied little among survey periods, indicating that recruitment for the species in this complex remained relatively constant over the two years.

Similar to the results for MBPP, the *FH* and *AEL* estimates for DCPP were very close to the theoretical relationship of $2FH \equiv AEL$, the *AEL* was only extrapolated to age three. The estimate would decrease by extrapolating to five years, the age of maturity used in the *FH* calculations.

Table 3-15. Diablo Canyon Power Plant adult equivalent loss (*AEL*) estimates for kelp, gopher, and black-and-yellow (KGB) rockfish complex. Upper and lower estimates represent the changes in the model estimates that result from varying the value of the corresponding parameter in the model.

Analysis Period	Adjusted Entrainment Estimate	Estimate Std. Error	Upper *AEL* Estimate	Lower *AEL* Estimate	*AEL* Range
1) Oct 1996–Sept 1997					
AEL Estimate	1,120	3,410	166,000	8	165,992
Annual Entrainment	275,000,000	24,700,000	1,290	958	332
2) Oct 1997–Sept 1998					
AEL Estimate	905	2,750	134,000	6	133,994
Annual Entrainment	222,000,000	28,900,000	1,100	712	388

Empirical Transport Model

The data used in computing the *ETM* estimates of P_M for KGB rockfish for the two study periods are presented in Tables 3-16 and 3-17 and in more detail in Appendices E and F. Average *PE* estimates for the two periods were similar in value and the values of f_i showed that the largest weights were applied to the *PE* values for the April and May surveys in both periods (Table 3-16). The estimate of larval duration of 16.4 days was used in the *ETM* calculations for both study periods.

The *ETM* model used for DCPP included adjustments for P_S similar to the model used at MBPP. Unlike the MBPP study, P_S was calculated using two approaches. The first approach was similar to the MBPP study, but instead of using average current speed, alongshore current displacement was used to estimate the alongshore distance that could have been traveled by KGB rockfish larvae during the day of the survey and during the 16.4 day period prior to the survey that they were susceptible to entrainment (Table 3-17). The ratio of the alongshore length of the nearshore sampling area to the alongshore current displacement was used to calculate an estimate of P_S for each survey. The second approach used the alongshore current displacement to determine the alongshore length of the source water population, but also used onshore current movement over the same period to determine the offshore distance of the source water population. During the 1997-1998 period when the pattern of abundances within the nearshore sampling area was slightly increasing with distance offshore (positive slope) the offshore extent of the extrapolated source water population was set using the onshore current displacement (Table 3-17A and Appendix F). When the pattern of abundances showed a decline with distance offshore during

1998-1999 the estimated offshore extent was the distance offshore that the extrapolated density was equal to zero (x-intercept), or the offshore extent of the sampling area (3,008 m) if the x-intercept was inside of the sampling area (Table 3-17B and Appendix F). This was typically less than the measured onshore displacement during the surveys. The P_S was calculated as the ratio of the estimated number of KGB rockfish larvae in the nearshore sampling area to the estimated number in the source water area. The average values of P_S were used in the *ETM* calculations.

The *ETM* estimates for KGB rockfish are presented with the results of the other taxa included in the assessment for the DCPP (Table 3-18). *ETM* estimates of proportional mortality (P_M) were calculated using two methods to estimate the proportion of source water sampled (P_S). One method assumed that the source water only extended alongshore and did not extend outside of the nearshore sampling area. Only this first estimate was calculated for three fishes that occur primarily as adults in the shallow nearshore. The other method assumed that the source water extended alongshore and could extend some distance outside of the nearshore sampling area. Only this estimate was calculated for two fishes that occur as adults over large oceanic areas. Both estimates were calculated for the other nine fishes. No estimate was calculated for Pacific sardine in the Analysis Period 4 because of very low abundances that year.

Estimates of P_M were relatively similar in value between periods for the estimates calculated using the alongshore displacement estimate of P_S. There was a much greater difference between periods for the estimates calculated using the P_S based on extrapolating the source water population extending both alongshore and offshore. This was a result of the difference in the pattern of abundances in the nearshore sampling area between sampling periods (Figure 3-8). The source population was extrapolated further offshore during the 1997-1998 period resulting in a larger source water population estimate, which resulted in a smaller estimate of P_S and a smaller estimate of P_M.

Results for Other Taxa

Modeling results for the other taxa selected for detailed assessment showed that, similar to the results for MBPP, demographic models could only be used for half of the fishes analyzed (Table 3-18). There was a large variation in the demographic model results among taxa that was not necessarily reflective of the differences in entrainment estimates. This was the result of the large variation in life history among the fishes analyzed. For example, although the entrainment estimates for Pacific sardine and blue rockfish were similar the demographic model results were different by greater than two orders of magnitude.

Table 3-16. Estimates used in calculating empirical transport model (*ETM*) estimates of proportional entrainment (*PE*) for kelp, gopher, and black-and-yellow (KGB) rockfish complex for Diablo Canyon Power Plant from monthly surveys conducted for two periods A) July 1997 through June 1998, and B) July 1998 through June 1999. The larval duration used in the calculations was 16.4 days. More detailed data used in the calculations are presented in Appendices E and F.

A) July 1997 – June 1998

Survey Date	PE_i	PE_i **Std. Error**	f_i	f_i **Std. Error**
21-Jul-97	0.0107	0.0151	0.0004	0.0004
25-Aug-97	0	0	0	0
29-Sep-97	0	0	0	0
20-Oct-97	0	0	0	0
17-Nov-97	0	0	0	0
10-Dec-97	0	0	0.0003	0.0003
22-Jan-98	0.0008	0.0009	0.0121	0.0053
26-Feb-98	0.0021	0.0013	0.0180	0.0038
18-Mar-98	0.0587	0.0297	0.0279	0.0050
15-Apr-98	0.0076	0.0035	0.1732	0.0214
18-May-98	0.0036	0.0008	0.6384	0.0334
8-Jun-98	0.0353	0.0084	0.1297	0.0165
	0.0167	Sum =	1.00000	

B) July 1998 – June 1999

Survey Date	PE_i	PE_i **Std. Error**	f_i	f_i **Std. Error**
21-Jul-98	0.0033	0.0035	0.0035	0.0011
26-Aug-98	0	0	0	0
16-Sep-98	0	0	0	0
6-Oct-98	0	0	0	0
11-Nov-98	0	0	0	0
9-Dec-98	0	0	0	0
12-Jan-99	0	0	0.0240	0.0053
3-Feb-99	0.0005	0.0005	0.0243	0.0045
17-Mar-99	0.0327	0.0198	0.0809	0.0108
14-Apr-99	0.0137	0.0075	0.1906	0.0328
24-May-99	0.0115	0.0026	0.5926	0.0456
23-Jun-99	0.0170	0.0125	0.0841	0.0509
	0.0131	Sum =	1.00000	

Table 3-17. Onshore and alongshore current meter displacement used in estimating proportion of source water sampled (P_S) from monthly surveys conducted for two periods A) July 1997 through June 1998, and B) July 1998 through June 1999 for kelp, gopher, and black-and-yellow (KGB) rockfish complex at the Diablo Canyon Power Plant. More detailed data included in Appendices E and F.

A) July 1997 – June 1998

Survey Date	Cumulative Alongshore Displacement (m)	Onshore Current Displacement (m)	Estimated Offshore Extent of Source Water (m)	Offshore P_S	Alongshore P_S
21-Jul-97	31,300	4,820	4,820	0.0153	0.5545
25-Aug-97	–	–	–	–	–
29-Sep-97	–	–	–	–	–
20-Oct-97	–	–	–	–	–
17-Nov-97	–	–	–	–	–
10-Dec-97	146,000	31,600	31,600	0.0000	0.1189
22-Jan-98	120,000	23,400	23,400	0.0020	0.1443
26-Feb-98	33,700	8,710	8,710	0.0693	0.5152
18-Mar-98	181,000	12,400	12,400	0.0090	0.0960
15-Apr-98	76,100	12,800	12,800	0.0404	0.2282
18-May-98	67,100	19,900	19,900	0.0334	0.2589
8-Jun-98	111,000	5,670	5,670	0.0761	0.1559
			Average =	0.0307	0.2590

B) July 1998 - June 1998

Survey Date	Cumulative Alongshore Displacement (m)	Onshore Current Displacement (m)	Estimated Offshore Extent of Source Water (m)	Offshore P_S	Alongshore P_S
21-Jul-98	76,300	11,100	3,010	0.2278	0.2278
26-Aug-98	–	–	–	–	–
16-Sep-98	–	–	–	–	–
6-Oct-98	–	–	–	–	–
11-Nov-98	–	–	–	–	–
9-Dec-98	–	–	–	–	–
12-Jan-99	46,200	24,100	3,010	0.3755	0.3755
3-Feb-99	81,900	19,700	3,010	0.2122	0.2122
17-Mar-99	36,900	8,540	4,170	0.4334	0.4709
14-Apr-99	163,000	10,200	8,000	0.0636	0.1068
24-May-99	180,000	21,800	21,000	0.0251	0.0967
23-Jun-99	158,000	5,970	4,380	0.0986	0.1100
			Average =	0.2052	0.2286

The fishes analyzed were separated into three groups based on their adult distributions: fishes that were widely distributed over large oceanic areas included northern anchovy and Pacific sardine, fishes that were primarily distributed in the shallow nearshore included smoothhead sculpin (*Orthonopias triacis*), monkeyface prickleback (*Cebidichthys violaceus*), and clinid kelpfishes (*Gibbonsia* spp.), and the rest of the fishes that were primarily nearshore, but could be found in deeper subtidal areas. The source water population used in calculating P_S was estimated using both alongshore currents and along- and off-shore extrapolation for the last group of fishes resulting in two *ETM* estimates for each analysis period. Only one *ETM* estimate for each analysis period was made for the other two groups depending on whether it was primarily nearshore, or primarily offshore. The *ETM* estimates of P_M ranged from <0.001 (0.1%) to 0.310 (31.0%) with the estimated effects being greatest for the fishes that were distributed primarily as adults in shallow nearshore areas. These fishes such as sculpins (Cottidae), monkeyface pricklebacks, and kelpfishes all had proportional mortalities due to power plant entrainment of greater than 10%. The *ETM* calculations were calculated using both estimates of P_S for snubnose sculpin because they occur slightly deeper as adults than the other nearshore fishes. The results showed that the extrapolated *ETM* estimates were approximately equal to the estimates using only alongshore current displacement because the densities for this species did not increase with distance offshore. The results for DCPP are similar to the other two studies in showing that the greatest effects occur to fishes that primarily occupy habitats in close proximity to the intake and do not occur at the same level in other areas of the source water.

Table 3-18. Results of entrainment monitoring and *FH, AEL,* and *ETM* modeling for fourteen fishes at Diablo Canyon Power Plant. The four analysis periods correspond to 1) Oct. 1996 – Sept. 1997, 2) Oct. 1997 – Sept. 1998, 3) July 1997 – June 1998, and 4) July 1998 – June 1999. Adjusted entrainment (E_{Adj-T}), *FH* and *AEL* not calculated for Analysis Period 4. Nearshore sampling of source waters began in June 1998 so *ETM* estimates of proportional mortality (P_M) was only calculated for Analysis Periods 3 and 4.

Taxon	Analysis Period	E_{Adj-T}	*FH*	*AEL*	P_M Alongshore	P_M Offshore and Alongshore
Pacific sardine	1.	8,470,000	3,170	2,630	–	–
	2.	22,600,000	8,460	7,000	–	–
	3.	22,600,000	8,460	7,000	not calculated	<0.001
	4.				not calculated	not calculated
northern anchovy	1.	136,000,000	16,100	43,200	–	–
	2.	376,000,000	44,700	120,000	–	–
	3.	377,000,000	44,700	120,000	not calculated	<0.001
	4.				not calculated	<0.001
KGB rockfish complex	1.	275,000,000	617	1,120	–	–
	2.	222,000,000	497	905	–	–
	3.	222,000,000	497	905	0.039	0.005
	4.				0.048	0.043
blue rockfish complex	1.	84,040,000	43	353	–	–
	2.	33,800,000	18	164	–	–
	3.	33,900,000	20	142	0.004	<0.001
	4.				0.028	0.002
painted greenling	1.	24,200,000	–	–	–	–
	2.	9,610,000	–	–	–	–
	3.	12,100,000	–	–	0.063	0.051
	4.				0.056	0.043
smooth-head sculpin	1.	57,700,000	–	–	–	–
	2.	115,000,000	–	–	–	–
	3.	129,000,000	–	–	0.114	not calculated
	4.				0.226	not calculated
snubnose sculpin	1.	110,000,000	–	–	–	–
	2.	83,500,000	–	–	–	–
	3.	105,000,000	–	–	0.149	0.139
	4.				0.310	0.310
cabezon	1.	51,900,000	–	–	–	–
	2.	36,300,000	–	–	–	–
	3.	36,300,000	–	–	0.011	0.009
	4,				0.015	0.008
white croaker	1.	305,000,000	5,110	14,700	–	–
	2.	440,000,000	7,380	21,300	–	–
	3.	447,000,000	7,500	21,600	0.007	<0.001
	4.				0.035	0.004
Monkey-face prickleback	1.	83,100,000	–	–	–	–
	2.	61,500,000	–	–	–	–
	3.	60,200,000	–	–	0.138	not calculated
	4.				0.118	not calculated
clinid kelpfishes	1.	181,000,000	–	–	–	–
	2.	308,000,000	–	–	–	–
	3.	458,000,000	–	–	0.189	not calculated
	4.				0.250	not calculated
blackeye goby	1.	128,000,000	12,000	75,200	–	–
	2.	109,000,000	10,300	64,100	–	–
	3.	128,000,000	12,100	75,400	0.115	0.027
	4.				0.065	0.036
sanddabs	1.	7,160,000	426	2,370	–	–
	2.	1,540,000	92	511	–	–
	3.	6,610,000	393	2,190	0.010	0.001
	4.				0.008	0.001
California halibut	1.	8,260,000	–	–	–	–
	2.	15,700,000	–	–	–	–
	3.	15,500,000	–	–	0.005	0.001
	4.				0.071	0.006

4.0 DISCUSSION

The results from these studies demonstrate the importance of a site-specific approach to assessing the effects of CWIS entrainment on marine organisms. Even though Morro Bay and San Diego Bay are both tidally influenced embayments the resulting studies, sampling, and analytical approaches were very different. And both of these studies were dramatically different from Diablo Canyon. The source waters determined to be affected by entrainment were the primary factor responsible for the differences among studies. In San Diego Bay, in the area of SBPP, the turnover in water due to tidal exchange allowed us to treat the source water population as a closed system. A larger number of stations was sampled in San Diego compared to Morro Bay because of the potential for reduced exchange among the various habitats in the San Diego source water study area. Differences in fish composition among habitats in San Diego Bay shown by Allen (1999) were also reflected in some of the differences in larval composition among stations. This resulted in site-specific effects on species such as longjaw mudsuckers which had a relatively high *ETM* estimate of P_M at SBPP. Mudsucker larvae were not particularly abundant in the source waters but were abundant in the SBPP intake canal which provided excellent habitat for adults. Similarly, effects on combtooth blennies estimated using *ETM* were lower than other fishes because they were more abundant in areas of the bay that had extensive pier pilings and other structures that provide habitat for adult blennies. The high level of site fidelity in the community composition in south San Diego Bay was likely due to the lower tidal exchange rates relative to an area such as Morro Bay. The results supported our decision to sample an extensive range of habitats in south San Diego Bay.

The source water sampling in Morro Bay was less extensive than the SBPP study, but included sampling at a nearshore station outside of the bay that was representative of water transported into the bay on flood tides. The less intensive sampling was justified by the large tidal exchange that results in rapid turnover of the water in the bay relative to a large tidal embayment such as San Diego Bay. The shallow mudflats and tidal channels in Morro Bay are drained out through the deeper navigation channel where sampling occurred. Although this may have resulted in under-sampling of larvae from certain fishes that could avoid strong tidal currents, as has been shown for longjaw mudsuckers and other species of gobies (Barlow 1963, Brothers 1975), it was probably representative of the larvae that would be transported on outgoing tides past the plant where they would be exposed to entrainment. The greatest CWIS effects using *ETM* were estimated for combtooth blennies that occur in the piers and other structures located near the plant. This was similar to the SBPP results for longjaw mudsuckers that occur in highest numbers at the entrainment station in the intake canal. These results showed the importance of sampling all habitats and the potential for increased impacts on species with habitats near plant intakes. This also indicates that potential for large impacts exist when habitats are not uniformly distributed in the source water for a CWIS and the potential for larger effects on fishes associated with habitats that may not be abundant throughout the source water.

The nearshore sampling area for DCPP was very extensive to represent the range of habitats along the exposed rocky headland where the power plant is located. The size of the sampling area was also designed to be representative of the distance north and south that larvae could be transported by alongshore currents over a 24 hour period to correspond with the *ETM* model that uses daily estimates of conditional mortality resulting from entrainment to estimate CWIS-related mortality. This extensive sampling showed similar results to SBPP and MBPP by estimating that the greatest CWIS effects using *ETM* occurred on fishes with nearshore habitats that were disproportionately affected by entrainment. In the *ETM* model species that have higher abundances in entrainment samples results in larger *PE* estimates of daily conditional mortality.

We examined the relative distribution of individual species in the sampling areas by comparing the average *PE* to the ratio of the cooling water to source water volumes. For example, in SBPP the average *PE* for CIQ gobies was 0.012 which was very close to the volumetric ratio of 0.015. In contrast, the average *PE* for longjaw mudsuckers was 0.19 which was much greater than the ratio of cooling water to source water. Although this is potentially useful for helping to determine the potential distribution of the larvae in the source water it may not be a good indicator of impacts. When the *PE* is close to the volumetric ratio the resulting impacts are directly dependent on the number of days that the larvae are exposed to entrainment. Therefore, even though the average *PE* was much greater for longjaw mudsuckers, the time (4 days) that they were exposed to entrainment was much less than CIQ gobies because they were in highest abundance in the areas directly around the CWS intake. In contrast, even though the average *PE* for CIQ goby was close to the volumetric ratio, the estimated effects of entrainment based on *ETM* were higher than the estimated effects on mudsuckers (0.215 vs. 0.171) because goby larvae were estimated to be exposed to entrainment for 23 days.

The final source water area used to adjust the *PE* estimates also affected the CWIS effects estimated using *ETM*. The MBPP results for KGB rockfish contrast with those for estuarine fishes such as gobies and blennies. Relative to fishes that are primarily estuarine inhabitants, adult KGB rockfishes are more widely distributed resulting in larger source water body populations and reduced entrainment effects. As a result the *PE* estimates were adjusted using P_S to account for the larger source water population beyond the area sampled for KGB rockfishes. All of the results for DCPP were adjusted to account for the onshore and alongshore currents that can transport larvae over hundreds of kilometers, resulting in very low estimated effects for species, such as northern anchovy, that have widely distributed source populations.

The source water sampling for all three of these studies was done to satisfy the requirements of the *ETM*. Source water sampling would not have been required if the assessments were done using only more traditional demographic modeling approaches. The source water sampling was necessary because the *ETM* directly links mortality to a source population. As a consequence, the habitat occupied by that source population can be described and ecosystem losses can be mitigated. The area of production foregone (APF) is one approach for estimating the amount of habitat that would need to be replaced to compensate for the larval production lost due to entrainment.

Area of Production Foregone (APF) models can be used to understand the scale of loss resulting from an impact and the extent of mitigation that could yield compensation for the loss. It is based on the idea that losses from environmental impacts can usually only be estimated from a group of species and that the true impact results from the sum of direct and indirect losses attributable to the impact. The use of APF allows for the estimation of both the direct and indirect consequences of an impact and provides a currency (i.e., habitat acreage) that may be useful for understanding the extent of compensation required to offset an impact.

Probably the most controversial issue in APF assessment is how it treats the few taxa actually analyzed in the assessment. In most assessments, including Habitat Replacement Cost (HRC) (Strange et al. 2002), estimates of loss of taxa are implicitly considered to be without error. In APF, each estimate is considered to be prone to (sometimes) massive error (indeed, estimates of confidence intervals in ETM calculations often cross through zero). In APF models the assumption is that each taxon represent a sample and that the mean of the samples is representative of the true loss rate. For example, assume 5 taxa and the ETM calculations indicate that for an estuarine system of 2000 acres the loss rates for the 5 taxa are 5, 10, 3, 22 and 15 percent. In APF the estimate of loss would be the average of the 5 values or 11 percent. Because APF considers taxa to be simply independent replicates useful for calculating the expected impact, the choice of taxa for analysis may differ from HRC assessments. In APF the concern is more that each taxon is representative of other taxa that are either unsampled (most invertebrates, plants and holoplankton) or not analyzed (the vast majority of fish). In APF, the average loss across taxa then represents the average loss across all entrained organisms. This is a fundamental difference between APF and economic based models like HRC. The underlying statistical-philosophic basis of APF addresses one of the most problematic issues in impact estimation: the typical inability to estimate impact for unevaluated taxa.

In APF, the next step is to take the average ETM loss rate and turn it into an ecological currency, which then can be used to understand the impact and form a basis for mitigation. This can be quite a simple step. Loss is turned into habitat from which production is foregone. This is calculated as the area of habitat that would need to be added to the system to make up the lost resources. In the example above, the estimate was that 11% of organisms at risk in a 2000-acre estuary were lost to entrainment. The estimate of APF then would simply be 2,000 acres x 11% or 220 acres. Therefore the creation of 220 acres of new estuarine habitat would compensate for the losses due to entrainment. This does not mean that all biological resources were lost from an area of 220 acres, which is a common misunderstanding. Instead it means that if 220 acres of new habitat were created then all losses, calculated and not calculated, would likely be compensated for. Here again is an important feature of APF. The currency of impact (acres needed to compensate) includes all impacts, even indirect ones. One common criticism of the approach of focusing more detailed analysis to only a limited number of taxa is that not only are other taxa directly affected by entrainment not assessed, but that there is also no provision for estimation of indirect impacts (often food web considerations). APF addresses this concern by expressing impact in terms of habitat and assuming that indirect impacts are addressed by the complete compensation of all directly lost resources.

In the given example, APF would predict that the creation of 220 acres of new habitat would compensate for all impacts due to entrainment. What sort of habitat should be created? Again the statistical-philosophic basis of APF contributes to the answer. Because taxa in APF are simply independent replicates that yield a mean loss rate, habitat is not directed by taxa. Instead the approach assumes that habitat should be created that represents the habitat for the populations at risk. If the habitat in the estuary was 60% subtidal eelgrass beds, 15% mudflats and 25% vegetated intertidal marsh, then these same percentages should be maintained in the created habitat. Doing so would ensure that impacts on all affected taxa would be addressed.

The logic of the example would seem to imply that this methodology would only be useful if there were habitat creation opportunities. However even if there are not local opportunities, the approach is useful for other reasons:

1) Opportunities may exist in other locations (such as another nearby estuary);

2) Area of Production Foregone can be useful in understanding the scale and relative importance of the impact, which helps with permitting decisions, and in establishing a cost-basis for the impact; and

3) Often there are alternative mitigation strategies that could be implemented whose scale would be determined by APF. An example would be the size of the creation of an artificial reef or the area of a marine reserve designated as mitigation for entrainment losses.

In the most general model APF is estimated from the product of P_M and the source water area for each taxa analyzed. In the example above the source water area was the same for all taxa as it was the area of the estuary. Clearly, the approach becomes more difficult on the open coast where the source water areas differ across taxa. The task is simplified by the proportional relationship between P_M and the size of the source water population used in calculating P_S. As the size of the source water area increases relative to the sampling area, P_S decreases resulting in a proportional decrease in P_M. If the habitat in the larger source water can be assumed to be distributed in the same relative proportions as the area sampled then you only need to use the areas of various habitats in the sampled area to estimate APF by using the uncorrected P_M. This greatly simplifies the application of APF and also reduces the need to rely on limited current data information to extrapolate beyond the areas sampled. In practice, when many taxa are impacted, each having varying habitat requirements, APF estimation becomes a matter of restoration using an estimate such as

$$\frac{\sum_{i=1}^{N} \frac{1}{P_{S_i}} P_{M_i}}{N},$$

for I = 1 to N taxa.

One of the advantages of the *ETM* model over more traditional demographic approaches towards CWIS assessment is the reduced need for life history data. As the results show, the necessary life history information on reproduction and age-specific mortality for the *FH* and *AEL* models was only available for a limited number of fishes. The life history information was collected from data in the scientific literature, but the level of uncertainty surrounding published demographic parameters was rarely reported. The likelihood is that the uncertainty associated with the information was very large. This needs to be considered when interpreting results from *FH* and *AEL* models, because the accuracy of estimated entrainment effects will depend on the accuracy of age-specific mortality and fecundity estimates. This limits the utility of these modeling approaches especially on the Pacific coast of California where fishes in highest abundance in entrainment samples are small, forage species with limited life history information. We were fortunate that the work of Brothers (1975) provided us with demographic information on CIQ gobies, the most abundant larvae collected in two of the studies.

Unlike demographic models the only life history information required by *ETM*, which it shares with *FH* and *AEL*, is an estimate of the duration of the period of time the larvae are vulnerable to entrainment, estimated in these studies by the age of the larvae entrained. This was estimated in our studies using larval lengths measured from the samples and larval growth rates obtained or derived from the scientific literature. The average length was used to estimate the average age at entrainment (average length – length at 1st percentile) and the maximum length based on the length at the 99th percentile was used to estimate the maximum number of days that the larvae were exposed to entrainment. It is possible that these estimates were biased. Other reported data (e.g., Moser 1996) for various species suggested that hatching lengths could be either smaller or larger than the size estimated from the samples, and indicated that the smallest observed larvae represented either natural variation in hatch lengths within the population or shrinkage following preservation (Theilacker 1980). The possibility remains that all larvae from the observed minimum length to the greatest reported hatching length (or to some other size) could have just hatched, leading to overestimation of larval age.

The extensive weekly sampling at DCPP over more than two years resulted in measurements of almost 10,000 KGB rockfish larvae from entrainment samples. Despite this large data set, we did not have a high level of confidence that these data necessarily provided a more accurate estimate of size at extrusion. The reported size of KGB rockfish at extrusion is 4.0-5.5 mm (Moser 1996) indicating that the average size at entrainment, 4.2 mm, could be a more accurate minimum size for estimating age at entrainment than the much smaller value used in the calculations. Although the minimum and average sizes were different than reported in the literature this shouldn't present a problem in estimating the number of days of exposure to entrainment as long as the growth rate used in the calculations is valid for that size of larvae. The uncertainty regarding the estimation of the period of exposure to entrainment has resulted in reporting of *ETM* results using larval durations based on the mean and maximum lengths at MBPP and DCPP. This uncertainty can easily be resolved by aging entrained larvae using otoliths. Removing the uncertainty associated with the age of the entrained larvae may justify the additional costs associated with this approach.

The duration that larvae may be subject to entrainment is affected by growth and behavior of the larvae, but also by the hydrodynamic characteristics of the source waters. In closed systems such as south San Diego Bay or freshwater lakes biological factors are probably more important than hydrodynamic factors. In open systems both biological and physical factors affect the length of time that larvae are subject to entrainment. For power plants located in coastal areas, such as DCPP, the effects of currents and larval growth both need to be considered in determining the size of the source population potentially affected by entrainment, but in estuarine areas such as Morro Bay hydrodynamic forces have a much greater effect on exposure to entrainment. The large tidal exchange ratio in Morro Bay results in huge exports of larvae out of the bay and into nearshore waters. Brothers (1975) showed that tidal exchange in Mission Bay, California resulted in much higher larval mortality rates than his calculated values for CIQ gobies. He hypothesized that larval behavior similar to that observed in longjaw mudsucker (Barlow 1963) resulted in the higher observed survival rates. Barlow described that longjaw mudsucker post-larvae are found close to the bottom. The location of MBPP near the harbor entrance of Morro Bay probably results in reduced effects on estuarine fish populations because the large majority of entrained larvae would be exported out to sea. The source water calculations for MBPP did not account for the strong effects of tidal exchange on entrainment exposure which was used to argue that mean larval lengths should have been used in calculating larval exposure to entrainment instead of the length of the 99th percentile. More sophisticated models incorporating hydrodynamic factors should be considered for estuarine systems similar to Morro Bay where hydrodynamic forces strongly affect the period of time that larvae are exposed to entrainment. This could have been done by increasing the source water volume to account for tidal outflow which transport larvae out of the bay into the ocean over the same number of days that the larvae are exposed to entrainment. This would also require that the nearshore area be included in the calculation of the source water population estimate because the larvae transported out of the bay would still be subject to entrainment.

The sampling frequency may be another source of bias associated with our estimate of the age of the larvae being entrained. The potential for biased sampling would be more prevalent in fishes that do not have prolonged spawning periods such as KGB rockfishes or on the East Coast where spawning occurs more seasonally. It would be less of a potential problem in fishes such as CIQ goby that have larvae that are present almost year-round. Entrainment sampling occurring on a monthly or less frequent basis could miss certain periods when certain age classes are present. Although more frequent sampling may not be required in the source water this may argue for more frequent weekly or bi-weekly entrainment sampling.

The frequency for source water sampling also needs to be considered for species with limited spawning periods. This should be one of the considerations in selecting taxa for detailed assessment since species with limited spawning periods will have few estimates of *PE* decreasing the confidence in the *ETM* estimates for those taxa. Unfortunately, the current sampling approach may also result in the selection of taxa that have prolonged spawning durations. This can be avoided if the period of spawning for important taxa can be accounted for in the study design.

In an entrainment assessment being prepared for the Potrero Power Plant in San Francisco Bay, the source water sampling frequency was increased during the spawning season for Pacific herring (*Clupea pallasii*) which was identified as an important species during the study design (Tenera Environmental, unpublished data). If this is not accounted for in the sampling and selection of species for analysis it may result in biased estimates for certain species. This is especially problematical if a species is collected relatively infrequently and in low numbers, but is included in the assessment because of its commercial or recreational value. Examples from these studies include Pacific herring at MBPP and California halibut (*Paralichthys californicus*) at DCPP. Both of these fishes represented less than 1.0% of the total larvae collected during entrainment sampling but were included in the assessments (Tables 2-4, 3-6, and 3-12). In both cases the results of the demographic modeling were important in placing the results for these species in context. In the case of Pacific herring at MBPP the *ETM* estimate of entrainment mortality of 16% represented the estimated loss of 532 adults calculated using the *FH* method (Table 3-11). No demographic estimates were available for California halibut at DCPP (Table 3-18). This problem did not occur at SBPP where the assessment was limited to the most abundant fishes regardless of their commercial or recreational value.

The approach used at SBPP for selecting taxa for analysis is acceptable if the taxa used in the assessment represent the range of habitats and fishes found in the source water potentially impacted by entrainment. If the list of taxa represent a reasonable sample from the fishes in the source water then the P_M estimates for the fishes can be averaged to obtain an estimate of the expected entrainment impacts on other fish and invertebrate larvae, zooplankton, and phytoplankton not included in the assessment. As the examples in the previous paragraph demonstrate, no single estimate of P_M may be particularly reliable, and therefore the use of the average P_M may be more appropriate as a estimator of average losses to the population. As previously discussed, the average value can be also used in calculating APF estimates for scaling restoration projects that could be used to compensate for entrainment losses.

Using averages for APF does not imply that there is an average mortality within the area estimated by the APF, but rather that averages are useful for estimating the amount of habitat affected. In order to view mortality spatially, it may be useful to allocate the mortality estimate over the area of the source population. A first approximation would be to allocate mortality in a linear or Gaussian fashion across the range of the source population. This was the approach used to estimate the cumulative effects of CWIS at all of the power plants in southern California (MBC and Tenera 2005). In this way mortality is equal to zero at the periphery of the source population, the furthest distances from the power plant intake. In addition, the source population is subject to stochastic and variable deterministic processes with a result of a changing source population area. Using current measurements, and numerical or physical modeling can be used to make further refinements.

The simple volumetric approach for estimating cumulative effects (MBC and Tenera 2005) can be expanded using more accurate estimates of P_M for a range of species. This would involve combining source water population, oceanographic, and hydrographic data from individual power plants. Cumulative effects result when the source water populations for the various power plants overlap. The *ETM* is easily adjusted to calculate cumulative effects by expanding the estimates of the source water and entrainment populations (Eq. 18) to include all of the power plants being considered.

The time period that larvae are exposed to entrainment needs to be adjusted for fishes with planktonic egg stages. This was not considered in these studies because the fishes analyzed for entrainment effects were mostly species that did not have a planktonic egg stage. Therefore the durations used in the *ETM* modeling for anchovies, croakers, and flatfishes should have been increased by the average number of days that the eggs for these fishes were potentially exposed to entrainment. Since it would not be feasible to age eggs collected from entrainment samples this adjustment would need to rely on estimates of egg duration from the scientific literature. This requires the assumption that the estimate of *PE* applies to both egg and larval stages and that mortality on passage through the cooling system is 100% for both egg and larval stages. If there is concern that egg stages are less abundant in the source waters than larval stages, separate *PE* estimates could be calculated for egg and larval stages using an approach similar to the original *ETM* concept presented by Boreman et al. (1978 and 1981) which conceptualized an *ETM* model incorporating separate *PE* estimates and durations for each life stage. This approach will be difficult to implement for most fishes because fish eggs can only be identified for a few species on the west coast. Therefore, the most conservative approach would be to assume that fish eggs are entrained in the same relative proportions as fish larvae and account for the egg planktonic duration in the assessment models. For organisms with available life history information, estimates of larval and egg survival can be used to estimate the number of eggs that would have been entrained from abundances of larvae in the samples.

One often proposed method to estimate egg entrainment is to assume a 1:1 eggs to larvae entrainment ratio. However, egg mortality may be significantly different than larval mortality. For example, the estimates of instantaneous natural mortality (M) rates for northern anchovy were 0.191 d^{-1} for eggs and 0.114 d^{-1} for larvae. One million eggs would become 512,477 larvae at the end of 3.5 days, the estimated duration of entrainment for eggs. At the end of a larval duration of 70 days, there would be 175 fish assuming negative exponential survival. The assumption of exponential survival and stable age distribution of eggs and larvae over the 3.5 and 70 day periods can be used to estimate the numbers of all ages by integration as follows:

$$N = \int_0^t N_0 e^{-Mt} dt = \left. \frac{N_0 e^{-Mt}}{-M} \right|_0^t .$$

Separate integration of eggs and larvae results in a 0.568:1 estimated entrainment ratio of eggs to larvae, thus showing a higher risk to larvae due to the prolonged susceptibility.

The focus of our discussion on *ETM* results reflects our belief that entrainment effects from CWIS are best assessed using this approach. Although we focus on *ETM*, the multiple modeling approaches used in these studies was valuable for several reasons. First of all, the demographic models provide valuable context for assessing effects on commercially and recreationally valuable species that also allows for comparison with *ETM*. For example, DCPP estimates of *AEL* for KGB rockfishes were compared to harvest data assuming 100% catchability of adult equivalents and assuming no compensatory mortality. These assumptions likely result in overestimating fishery values (e.g., price per kilogram). Given these conditions, an estimated economic loss to the local fishery could be based on an average weight of 1.0 kg for a 3-yr old KGB rockfish recruiting to the live-fish fishery. The annual average *AEL* estimate of 1,013 rockfishes translates to a potential direct economic loss of $7,749 based on the average price of $7.65/kg. This value represented approximately 2% of the ex-vessel revenue attributed to KGB complex rockfishes landed at ports in the Morro Bay area in 1999 (PSMFC PacFin Database). Similar conversions to fishery value can be performed using *FH* estimates.

This type of conversion also allows for indirect comparison of demographic model results with *ETM* by similar conversion of *ETM* losses into fishery value. To continue our example using the DCPP results for KGB rockfishes, we assumed that the probable effect of entrainment losses at DCPP on fisheries was likely localized to the ports within the Morro Bay area since most fishes in this complex demonstrate high site fidelity (Lea et al. 1999). In addition, extension of effects based on alongshore currents and larval duration indicate that the area potentially affected was only three to seven times the size of the nearshore sampling area, which was likely within the range of fishers from either Port San Luis or Morro Bay. The estimate of entrainment mortality (P_M) was between 4–5% for this area. Applying this range of proportional reduction to the local catch from the Morro Bay area in 1999 yielded estimated dollar losses to the Morro Bay area fishery of approximately $20,000. In this example the fishery value estimates using *ETM* and *AEL* are reasonably close. The same type of indirect comparison could be done for species without any fishery value by converting *ETM* estimates of P_M to APF. The estimate of APF could be used with data on abundances to obtain estimates of adult populations that could be compared with demographic model results.

The demographic modeling approaches and conversions to fishery value using either demographic or *ETM* model results ignore any potential effects of compensation. We took this approach because there remain conflicting opinions whether larval mortality is compensated in some fashion. One side of the argument is that if compensation occurs, the estimates of *FH*, *AEL* and P_M will overestimate the number of adults lost and ecosystem losses (Saila et al. 1997). The response is that it is difficult to determine if compensation occurs at all (Rose et al. 2001, Nisbet et al. 1996). Additionally, if population mortality is density independent or weakly dependent, then the recruited population size will fluctuate in response to either changes in larval abundances or mortality. In the case of large density dependent mortality, little change due to changes in recruitment might be observed in local population sizes (Cayley et al. 1996). Field experiments on west coast species of fishes have been equivocal (e.g. Stephens et al. 1986) and recent studies on bocaccio (*Sebastes paucispinis*) showed no evidence of compensation in the stock-recruitment relationship (Tolimieri and Levin 2005). Currently, the USEPA and the California Energy Commission consider that compensation does not reduce impacts from entrainment and impingement on adult populations.

Results from demographic models are also necessary for combining estimates from entrainment and impingement unless independent data on adult fish populations are available for comparison with impingement losses. Impingement studies are designed to collect data on juveniles and adult fishes that are used to develop estimates of annual impingement. An *AEL* model is then used to extrapolate the number of impinged fishes either backward or forward to the numbers of adults of a certain age. By using the average age of reproductively mature females in the extrapolation these results can be combined with *FH* or *AEL* entrainment estimates to obtain estimates of the combined effects of impingement and entrainment. This approach assumes that the *FH* and *AEL* entrainment estimates are extrapolated to the same age used in the impingement estimates. Combined assessments can only be done on the few fishes with life history data available for estimating *FH*, *AEL* or one of the other demographic models. Fortunately, the total impingement losses at these three plants were relatively low due to the CWIS designs and species with the highest impingement estimates were not entrained in high abundances (Tenera Environmental 2000, 2001, 2004). This is not always the case and combining impingement and entrainment estimates into comprehensive CWIS assessments remains problematic for most species due to incomplete life history data.

Another approach for combining results from impingement and entrainment would involve using the numbers of impinged individuals for a species to estimate the relative losses to the population. The impingement mortality and entrainment mortality rate estimated by *ETM* can be converted to survival and multiplied to estimate cumulative CWIS effects. This approach involves the assumption that there is no compensatory mechanisms acting on the population between larval and adult stages such that entrainment losses estimated by *ETM* represent losses to the adult population. It also assumes that impingement and entrainment losses apply to the same stock. Although this is reasonable for a closed system such as south San Diego Bay, it would be much more difficult in an open system. In addition, there are few species with adequate data on adult stocks that could be used in this approach.

Finally, demographic model results provide a direct comparison with *ETM* results for both fishery and non-fishery species. It is obviously preferable to present data as both percentages relative to a source population using *ETM* and as absolute numbers of fishes using one or both demographic models. This helps ensure that P_M estimates are properly interpreted and instances where a large P_M that equates to only a few adults fishes are not misinterpreted. Ensuring the species included in the assessment were adequately sampled is the best way to avoid this type of problem. Unfortunately, these types of comparison are only possible for the limited number of fishes on the west coast with published life history data. This approach is also complicated by the uncertainty related to the levels of any compensatory, depensatory, or behavioral mechanisms that may have been operating on the subject populations when the life history data were collected. The availability and uncertainty associated with life history information continue to be the greatest limitations to the use of demographic models for CWIS assessment.

Despite these limitations, the USEPA made extensive use of demographic models in the assessments used in the rule making for 316(b). This was necessary because of the need to determine the economic costs associated with implementing certain technologies that could be used to help meet performance standards for impingement (80-95%) and entrainment (60-90%) reduction mandated in the new 316(b) rule. These methods will continue to be used due to the availability of an option for site-specific compliance. This option involves a cost-benefit analysis that compares the costs of technological or operational measures for achieving the performance standards against environmental benefits calculated using benefits valuation methods. As a result of this requirement there is active research being done to increase the availability of life history data for Pacific coast fishes.

4.1 GUIDELINES FOR ENTRAINMENT IMPACT ASSESSMENT

The three studies presented in this paper make it clear that it is not feasible to use a prescriptive approach to entrainment assessment design. Based on our experiences with these and other studies, we provide some general considerations that might be helpful in the design, sampling, and analysis of entrainment impact assessments. These comments are presented in the hopes that others may benefit from our experiences in conducting CWIS entrainment assessments.

Considerations for Study Design

1. Determine potential species that could be affected by entrainment using historical data on entrainment for the power plant, if available, and data from surrounding waters. Insure that sampling will account for any endangered, threatened, or other listed species that could potentially be affected by entrainment.
2. Determine the source water areas potentially affected by entrainment including the distribution of habitats that might be differentially affected by CWIS entrainment. Different habitats may require use of different sampling gear and methods.
3. We have used oblique tows with bongo and wheeled bongo frames that sample the entire water column for both entrainment and source water because the intake structures for these plants were assumed to withdraw water from the entire water column. Power plants with intakes that withdraw water from a discrete depth in the water column may require the use of pumps or closing nets for entrainment sampling at discrete water depths where water withdrawal occurs. Hydrodynamic studies should be done to verify the intake flow field for sampling at discrete depths. We have not used pumps to sample inside of power plant cooling water systems because of potential bias due to predation by biofouling organisms.
4. Determine appropriate sampling frequency based on species composition and important species that might have short spawning seasons. This could include adjusting sampling frequency seasonally based on presence of certain species. Sampling of entrainment can be done more frequently than source water sampling to provide more accurate estimates of length frequencies of entrained larvae and may also be desirable to provide more accurate estimates for calculating baseline conditions for compliance with new 316(b) rules.
5. These studies were generally conducted over a one-year period except in the case of DCPP where one of the strongest ENSO events of that century occurred during the first year of sampling. The relative effects of entrainment estimated by the *ETM* model should be much less subject to interannual variation than absolute estimates using *FH*, *AEL* or other demographic models. Therefore if source water sampling is done in conjunction with entrainment sampling one year is a reasonable period of sampling for these studies.
6. Use hydrodynamics of source waters to determine appropriate sampling area. In a closed system this may be the entire source water. In an open

system, ocean or tidal currents should be used to determine the appropriate sampling area for estimating daily entrainment mortality (PE) for the larger source water population.

Ad hoc rule 1: Since *PE* is estimated as a daily mortality the sampling area should include the area potentially affected during a 24 h period. This area is a pragmatic way to arrive at a first stage estimate of daily mortality and hence survival. The use of a current meter positioned near the intake but outside the influence of its flow allows the estimation of advection in the nearby source water. The current meter approach can be combined with estimates of larval dispersion (Largier 2003) for an understanding of the magnitude of source water population affected.

Ad hoc rule 2: The *PE* is applied to a larger source population that is potentially affected in the time period of a larval duration. (Another option would be to use the range of the stock.) In an open system, the estimation of P_M includes extrapolating the population of the sampling area to the larger source water population over a larval duration. It is difficult to say that the single current meter accurately reflects the advection of the source water population to the intake. In addition, a single current meter says very little about diffusion processes. Be sure that appropriate physical data are collected during the study to model hydrodynamics and determine size of source population.

7. The uncertainties associated with estimating larval durations, and hydrodynamics used in estimating the size of the source water populations make estimating variance for *ETM* problematic. One approach we have used is to base the variance calculations solely on the sampling variances used in estimating the variance of *PE*. A similar approach would use the CV from the source water sampling (which includes both entrainment and source water data) to estimate the variance for *ETM* or use a Monte Carlo approach using the upper and lower confidence limit values for the *PE* values. These approaches have been considered because of the large unrealistic error terms derived using the Delta method that incorporates all of the multiple intercorrelated sources of error in the model.

Considerations for Sampling and Processing

1. We have used sample volumes of 30-60 m^3 per sample for these and other studies but this volume should be adjusted for the larval concentrations in the source waters. The appropriate sample volume is best determined by preliminary sampling using the gear proposed for the study.
2. Be sure that mesh size used for net sampling is appropriate for taxa that might be the focus of detailed analysis. We have used 335 µm mesh nets

because we have observed fish larvae being extruded through 505 µm mesh nets. Much smaller sized mesh would be needed to sample invertebrate larvae effectively.

3. Although we generally combine the subsamples from the two bongo nets for analysis, preserving one of them directly in 70-80% ethanol allows for genetic analyses to be conducted and analysis of otoliths to determine age and growth rates. Larval fishes are generally easier to identify when initially preserved in 5-10% formalin.
4. If ageing using larval otoliths is not done, be sure that length frequencies measured from entrainment samples are realistic based on available life history. We applied general rules for using the length data for determining mean, minimum, and maximum ages, but would recommend developing criteria based on the length frequency distribution for each species.
5. Be sure to account for egg stages that would be subject to entrainment if fish eggs are not sorted and identified from the samples.

Considerations for Analysis

1. Use multiple modeling approaches to validate results and provide additional data for determining effects at the adult population level.
2. Similar to the approach of using multiple models to provide additional data for determining effects at the adult population level, the *ETM* results can be converted into another currency using APF. This approach is probably most appropriate for scaling restoration projects that could be used to help offset losses due to entrainment.
3. Although *FH* and *AEL* models can be hindcast or extrapolated to the same age they will not necessarily provide the same estimate unless the data used in the two models are derived from a life table assuming a stable age distribution.
4. *FH* and *AEL* are estimates of the number of adults at a specific age. To estimate the number of adult females in the population, N_F, the average fecundity can be used instead of *TLF*. The *AEL* analog is extrapolation to all adult fish ages - *AEL'*. A comparison can be made using the relation $AEL'=2N_F$. This age of entry into the adult population may need to be adjusted to the average age of fishery catch if comparisons are being made with fishery data. The use of *AEL* and *FH* (Horst 1975 and Goodyear 1978), aligning at fishery age, is one method of estimating losses in terms of adult animals.
5. Another estimate would use production foregone or total biomass that would have been produced by entrained or impinged animals, had they not been entrained or impinged (Rago 1984). Production foregone includes all biomass lost through all forms of mortality had the animals survived entrainment or impingement. This measure is most often used for forage species and represents ecosystem losses, e.g. to other trophic

levels. Age-1 equivalent loss is a measure similar to *AEL* and *FH* that is most commonly used for harvested species. The USEPA (2002) used age-1 equivalents to evaluate power plant losses “because methods are unavailable for valuing fish eggs and larvae.” They conservatively estimated fish landings value using the number of age-1 individuals, as the average fishery age is older in most cases. However the USEPA believed the method may underestimate the true value of reducing impingement and entrainment because life history data were not available for most species. If survival rates from the age of entrainment until adulthood are accurate, *FH* and *AEL* underestimate the numbers of lost adults because they are extrapolated to a single age, e.g. age of maturity in the case of *FH*. An improved approach to *FH* will be to use the average annual fecundity to estimate the equivalent number of females N_F removed from the standing stock of adults. Similarly, *AEL* can be extrapolated to all adult ages and summed to estimate the number of adult equivalents *AEL'* and these measures can then be compared with fishery losses. However, the accuracy of these kinds of estimates is subject to the accuracy of the underlying survival and fecundity estimates.

6. Another estimate of the number of equivalent adults lost by larval entrainment is to use the mortality estimate from the *ETM* procedure and apply it to a survey of the standing stock. This accuracy of this estimate is subject to the accuracy of the estimate of the source population affected. This method may result in improvements when there is little confidence in survival estimates or when there is conjecture about compensatory processes that may negate the underlying models of *AEL* and *FH*.

4.2 CONCLUSION

As should be clear from this report, we feel that CWIS impacts are best evaluated using empirically based source water body information and the *ETM* model, and not using demographic models based on life history information derived from various sources with varying, or unknown, levels of confidence. Although demographic models are useful for providing context for *ETM* estimates there is no reason to base an assessment solely on demographic modeling results with the availability of approaches such as the *ETM* that provide estimates based on empirically derived estimates. In contrast to demographic models, uncertainty associated with *ETM* model estimates can be controlled through changes to the sampling design for the entrainment and source water sampling. The CEC and CCC have all required the *ETM* approach in recent studies. Hopefully the information in this paper will assist others in the design and analysis of CWIS assessments that meet the requirements of both 316(b) and regulatory requirements of other agencies.

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APPENDIX A

VARIANCE EQUATIONS FOR IMPACT ASSESSMENT MODELS

A1. Fecundity Hindcasting (*FH*)

The variance of *FH* was approximated by the Delta method (Appendix E2) (Seber 1982):

$$Var(FH) = (FH)^2 \left[CV^2(E_T) + \sum_{j=1}^{n} CV^2(S_j) + CV^2(\bar{F}) + \left(\frac{Var(A_L) + Var(A_M)}{(A_L - A_m)^2} \right) \right]$$

where

$CV(E_T)$= CV of estimated entrainment,
$CV(S_j)$ = CV of estimated survival of eggs and larvae up to entrainment,
$CV(\bar{F})$ = CV of estimated average annual fecundity,
A_M = age at maturation, and
A_L = age at maturity.

The behavior of the estimator for *FH* appears log-linear, suggesting that an approximate confidence interval can be based on the assumptions that ln(*FH*) is normally distributed and uses the pivotal quantity

$$Z = \frac{\ln FH - \ln FH}{\sqrt{\frac{Var(FH)}{FH^2}}}.$$

A 90% confidence interval for *FH* was estimated by solving for *FH* and setting Z equal to

+/-1.645, i.e.

$$FH \cdot e^{-1.645\sqrt{\frac{Var(FH)}{FH^2}}} \quad \text{to} \quad FH \cdot e^{+1.645\sqrt{\frac{Var(FH)}{FH^2}}}.$$

A2. Adult Equivalent Loss (*AEL*)

The *AEL* approach uses estimates of the abundance of entrained or impinged organisms to forecast the loss of equivalent numbers of adults. 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:

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

where

n = number of age classes,
E_j = estimated number of larvae lost in age class j, and
S_j = survival rate for the jth age class to adulthood (Goodyear 1978).

Age-specific survival rates from larval stage to recruitment into the fishery (through juvenile and early adult stages) must be included in this assessment method. For some commercial species, survival rates are known for adults in the fishery; but for most species, age-specific larval survivorship has not been well described.

Survivorship to recruitment, to an adult age, was apportioned into several age stages, and *AEL* was calculated using the total entrainment as

$$AEL = E_T \prod_{j=1}^{n} S_j \ ,$$

where

n = number of age classes from entrainment to recruitment and
S_j = survival rate from the beginning to end of the jth age class.

The variance of *AEL* can be estimated using a Taylor series approximation (Delta method of Seber 1982) as

$$Var(AEL) = AEL^2 \left(CV^2(E_T) + \sum_{j=1}^{n} CV^2(S_j) \right).$$

A3. Proportional Entrainment and *ETM*

The Empirical Transport Model (*ETM*) calculations provide an estimate of the probability of mortality due to power plant entrainment. The values used in calculating proportional entrainment (*PE*) are population estimates based on the respective larval densities and volumes of the cooling water system flow and source water areas. On any one sampling day, the conditional entrainment mortality can be expressed as

$$PE_i = \frac{\text{abundance of entrained larvae}_i}{\text{abundance of larvae in source population}_i}$$
$$= \text{probability of entrainment in } i\text{th time period } \left(i = 1, \ldots, N\right).$$

In turn, the daily probability can be estimated and expressed as

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

where

E_i = estimated abundance of larvae entrained in the *i*th time period $\left(i = 1, \ldots, N\right)$;

R_i = estimated abundance of larvae at risk of entrainment from the source population in the *i*th time period $\left(i = 1, \ldots, N\right)$.

The variance for the period estimate of *PE* can be expressed as

$$Var\left(PE_i\right) = Var\left(\frac{E_i}{R_i}\middle| E_i, R_i\right).$$

Assuming zero covariance between the entrainment and source and using the delta method (Seber 1982), the variance of an estimator formed from a quotient (like PE_i) can be effectively approximated by

$$Var\left(\frac{A}{B}\right) \approx Var(A)\left(\frac{\partial\left[\frac{A}{B}\right]}{\partial A}\right)^2 + Var(B)\left(\frac{\partial\left[\frac{A}{B}\right]}{\partial B}\right)^2.$$

The delta method approximation of $Var(PE_i)$ is shown as

$$Var\left(PE_i\right) = Var\left(\frac{E_i}{V_S \cdot \rho_{Si}}\right)$$

which by the Delta method can be approximated by

$$Var\left(PE_i\right) \approx Var\left(E_i\right)\left(\frac{1}{V_S \cdot \overline{\rho_{S_i}}}\right)^2 + Var\left(V_S \cdot \bar{\rho}_{S_i}\right)\left(\frac{-E_i}{V_S \cdot \left(\bar{\rho}_{S_i}\right)^2}\right)^2$$

and is equivalent to

$$= PE_i^2\left[CV\left(E_i\right)^2 + CV\left(V_S \cdot \bar{\rho}_{S_i}\right)^2\right]$$

where

$$R_i = V_S \cdot \overline{\rho}_{S_{ij}} \text{ and}$$

$$CV\left(\theta\right) = \frac{Var\left(\theta\right)}{\theta^2}.$$

APPENDIX B. Mean larval fish concentrations (larvae per 1000 m^3) by station for monthly surveys from February 2001 through January 2002 in San Diego Bay.

		Stations									
Taxon	**Common Name**	**SB1**	**SB2**	**SB3**	**SB4**	**SB5**	**SB6**	**SB7**	**SB8**	**SB9**	**Mean**
CIQ goby complex	gobies	2,095.9	1,549.6	2,391.7	2,914.0	3,003.0	4,109.9	3,995.8	2,743.1	2,400.4	**2,800.4**
Anchoa spp.	bay anchovies	556.5	476.4	231.4	159.6	938.9	1,327.7	1,042.7	520.4	73.3	**591.9**
Hypsoblennius spp.	combtooth blennies	27.2	45.7	140.8	81.6	210.8	84.6	575.7	94.4	453.6	**190.5**
Atherinopsidae	silversides	18.2	57.1	6.0	42.2	11.4	22.4	5.3	58.5	18.2	**26.6**
Syngnathus spp.	pipefishes	12.5	13.7	8.3	4.5	16.0	8.1	12.8	6.9	9.2	**10.2**
Gillichthys mirabilis	longjaw mudsucker	27.1	4.3	11.5	3.1	15.9	1.5	12.2	0.7	1.2	**8.6**
Engraulis mordax	northern anchovy	0.4	0.8	0.9	-	6.9	0.8	18.6	15.1	11.1	**6.1**
Hypsopsetta guttulata	diamond turbot	0.4	0.8	1.9	2.1	5.9	2.6	10.7	11.8	18.4	**6.1**
Acanthogobius flavimanus	yellowfin goby	2.4	3.5	0.6	12.0	2.9	15.1	1.0	1.9	2.0	**4.6**
Paralabrax spp.	sand basses	-	0.2	0.6	-	12.2	1.1	17.6	1.7	6.9	**4.5**
Labrisomidae	labrisomid kelpfishes	-	1.4	2.5	4.8	2.0	1.1	10.1	9.0	5.5	**4.0**
Genyonemus lineatus	white croaker	0.5	1.0	1.8	2.3	6.3	5.3	6.7	4.3	4.8	**3.7**
Sciaenidae	croakers	0.7	0.4	1.0	0.2	5.1	0.3	10.1	0.2	4.2	**2.5**
Cheilotrema saturnum	black croaker	0.2	0.3	0.5	0.8	4.1	3.0	3.9	0.8	3.8	**1.9**
Paralichthys californicus	California halibut	0.1	0.5	0.2	0.2	0.5	0.7	2.0	0.4	2.4	**0.8**
Gibbonsia spp.	clinid kelpfishes	-	-	0.2	1.8	0.8	0.5	-	0.7	0.8	**0.5**
Trachurus symmetricus	jack mackerel	-	-	-	-	-	-	-	-	3.5	**0.4**
Serranidae	sea basses	-	-	-	-	-	-	-	0.9	1.5	**0.3**
Lepidogobius lepidus	bay goby	0.1	-	0.3	0.4	0.2	-	0.5	0.2	0.4	**0.2**
Roncador stearnsi	spotfin croaker	-	-	0.4	-	0.6	-	0.4	0.4	0.2	**0.2**
Menticirrhus undulatus	California corbina	-	-	-	-	0.9	-	0.5	-	0.1	**0.2**
Citharichthys stigmaeus	speckled sanddab	-	-	-	0.4	-	-	-	0.2	1.0	**0.2**
Clupeiformes	herrings and anchovies	-	-	-	-	-	1.2	-	-	0.2	**0.2**
Odontopyxis trispinosa	pygmy poacher	0.3	-	-	0.6	-	0.3	-	-	0.2	**0.2**
Gobiesox spp.	clingfishes	0.2	-	-	0.3	-	-	-	0.6	-	**0.1**
Hippocampus ingens	Pacific seahorse	-	-	0.3	-	-	0.3	-	0.4	-	**0.1**
Clinocottus analis	wooly sculpin	-	-	-	-	-	-	0.7	-	0.2	**0.1**
Typhlogobius californiensis	blind goby	0.1	-	-	-	0.3	-	0.3	-	0.2	**0.1**
Strongylura exilis	California needlefish	0.9	-	-	-	-	-	-	-	-	**0.1**
Ruscarius creaseri	roughcheek sculpin	0.3	-	0.3	-	-	-	-	-	0.2	**0.1**
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	0.2	-	-	0.3	0.3	-	**0.1**
Artedius spp.	sculpins	-	-	-	-	0.3	-	-	-	0.2	**0.1**
Hyporhamphus rosae	California halfbeak	0.4	0.2	-	-	-	-	-	-	-	**0.1**
Paralichthyidae	lefteye flounders & sanddabs	-	-	-	-	-	0.3	-	0.2	-	**0.1**
Cottidae	sculpins	-	-	-	-	0.2	-	-	0.2	-	**0.1**
Oligocottus spp.	sculpins	-	-	-	-	-	-	0.2	0.2	-	**0.1**
Pleuronichthys ritteri	spotted turbot	-	-	-	-	-	-	-	0.4	-	**0.1**
Atractoscion nobilis	white seabass	-	-	-	-	0.2	-	-	0.2	-	**<0.1**
Porichthys myriaster	specklefin midshipman	-	-	-	-	-	0.3	-	-	-	**<0.1**
Clupeidae	herrings	-	-	-	-	-	-	0.3	-	-	**<0.1**
Nannobrachium spp.	lanternfishes	-	-	-	-	-	-	0.2	-	-	**<0.1**
Gobiesox rhessodon	California clingfish	-	-	-	-	-	0.2	-	-	-	**<0.1**
Sebastes spp.	rockfishes	-	-	-	-	-	-	0.2	-	-	**<0.1**
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	0.2	**<0.1**
	Station Total	**2,744.3**	**2,155.7**	**2,801.3**	**3,231.0**	**4,245.4**	**5,587.0**	**5,728.8**	**3,474.2**	**3,024.3**	

APPENDIX C. Estimates of CIQ goby larvae at South Bay Power Plant entrainment and source water stations from monthly surveys conducted from February 2001 through January 2002 used in calculating empirical transport model (*ETM*) estimates of proportional entrainment (*PE*) and annual estimate of proportional mortality (P_M). The daily cooling water intake volume used in calculating the entrainment estimates was 2,275,244 m^3, and the volume of the source water used in calculating the source water population estimates was 149,612,092 m^3. The number of days that the larvae were exposed to entrainment was estimated at 22.86 days.

Survey Date	Entrainment Concentration (#/m^3)	Estimated Number Entrained	Source Water Concentration (#/m^3)	Estimated Number in the Source Water	*PE* Estimate	Days in Survey Period	Estimate of Source Water Population for Period	Proportion of Source Population for Period (*f*)	$=f_i(1-PE_i)^d$
28-Feb-01	2.143	4,877,000	5.712	8.546E+08	0.0057	41	3.504E+10	0.2165	0.1900
29-Mar-01	1.069	2,433,000	3.643	5.451E+08	0.0045	29	1.581E+10	0.0977	0.0882
17-Apr-01	1.997	4,544,000	2.794	4.180E+08	0.0109	19	7.942E+09	0.0491	0.0382
16-May-01	2.036	4,633,000	1.770	2.649E+08	0.0175	29	7.682E+09	0.0475	0.0317
14-Jun-01	3.747	8,525,000	2.311	3.458E+08	0.0247	29	1.003E+10	0.0620	0.0350
26-Jul-01	4.047	9,208,000	2.740	4.100E+08	0.0225	42	1.722E+10	0.1064	0.0633
23-Aug-01	0.648	1,475,000	2.609	3.904E+08	0.0038	28	1.093E+10	0.0675	0.0619
25-Sep-01	1.057	2,406,000	2.307	3.452E+08	0.0070	33	1.139E+10	0.0704	0.0600
23-Oct-01	1.254	2,852,000	2.553	3.820E+08	0.0075	28	1.070E+10	0.0661	0.0557
27-Nov-01	1.655	3,764,000	2.390	3.576E+08	0.0105	35	1.252E+10	0.0773	0.0607
20-Dec-01	1.861	4,233,000	2.745	4.107E+08	0.0103	23	9.446E+09	0.0584	0.0461
17-Jan-02	3.554	8,087,000	3.132	4.686E+08	0.0173	28	1.312E+10	0.0811	0.0545
				Average =	0.0118			P_M=	0.2147

APPENDIX D. Estimates of KGB rockfish larvae at MBPP entrainment and source water stations from monthly surveys conducted from January 2000 through December 2000 used in calculating empirical transport model (*ETM*) estimates of proportional entrainment (*PE*) and annual estimate of proportional mortality (P_M). The daily cooling water intake volume used in calculating the entrainment estimates was 1,619,190 m^3, and the volume of the source water used in calculating the source water population estimates was 15,686,663 m^3. Bay volume = 20,915,551 m^3. The larval duration used in the calculations was 11.28 days.

Survey Date	Estimated Number Entrained	Estimated Number in the Bay	Bay *PE*	Estimated Number in the Offshore Area	Offshore *PE*	Total *PE*	Source Water Population for Period	Proportion of Source Population for Period (*f*)	$=f_i(1-PE_iP_S)^d$
17-Jan-00	5,500	17,800	0.3097	0	–	0.3097	17,800	0.0099	0.0073
28-Feb-00	2,180	20,700	0.1052	22,100	0.0988	0.0509	42,800	0.0239	0.0227
27-Mar-00	0	6,550	–	186,000	–	–	192,000	0.1076	0.1076
24-Apr-00	38,100	715,000	0.0533	576,000	0.0661	0.0295	1,291,000	0.7218	0.7010
15-May-00	4,460	11,800	0.3785	202,000	0.0220	0.0208	214,000	0.1197	0.1173
12-Jun-00	0	14,900	–	15,000	–	–	30,300	0.0169	0.0169
10-Jul-00	0	0	–	0	–	–	0	–	–
8-Aug-00	0	0	–	0	–	–	0	–	–
5-Sep-00	0	0	–	0	–	–	0	–	–
2-Oct-00	0	0	–	0	–	–	0	–	–
27-Nov-00	0	0	–	0	–	–	0	–	–
18-Dec-00	0	0	–	0	–	–	0	–	–
			$\bar{x}$ = 0.0705		$\bar{x}$ = 0.0156	$\bar{x}$ = 0.0342			P_M = 0.0271

APPENDIX E. Estimates used in calculating empirical transport model (*ETM*) estimates of proportional entrainment (*PE*) for kelp, gopher, and black-and-yellow (KGB) rockfish complex for Diablo Canyon Power Plant. Entrainment estimates and estimates from the nearshore sampling area from monthly surveys conducted for two periods A) July 1997 through June 1998, and B) July 1998 through June 1999. The daily cooling water intake volume used in calculating the entrainment estimates was 9,312,114 m^3, and the volume of the sampled source water used in calculating the nearshore population estimates was 1,738,817,356 m^3. The larval duration used in the calculations was 16.4 days.

A) July 1997 – June 1998

Survey Date	Start Date Based on Larval Duration	Estimated Number Entrained	Entrainment Std. Error	Estimated Population in Nearshore Sampling Area	Nearshore Population Std. Error	PE_i	PE_i Std. Error	f_i	f_i Std. Error
21-Jul-97	5-Jul-97	2,770	2,770	258,000	255,000	0.0107	0.0151	0.0004	0.0004
25-Aug-97	9-Aug-97	0	–	0	–	–	–	–	–
29-Sep-97	13-Sep-97	0	–	0	–	–	–	–	–
20-Oct-97	4-Oct-97	0	–	0	–	–	–	–	–
17-Nov-97	1-Nov-97	0	–	0	–	–	–	–	–
10-Dec-97	24-Nov-97	0	–	216,000	216,000	–	–	0.0003	0.0003
22-Jan-98	6-Jan-98	6,280	6,280	7,775,000	3,345,000	0.0008	0.0009	0.0121	0.0053
26-Feb-98	10-Feb-98	23,900	13,900	11,534,000	2,267,000	0.0021	0.0013	0.0180	0.0038
18-Mar-98	2-Mar-98	1,051,000	503,000	17,903,000	2,903,000	0.0587	0.0297	0.0279	0.0050
15-Apr-98	30-Mar-98	847,000	376,000	111,247,000	12,360,000	0.0076	0.0035	0.1732	0.0214
18-May-98	2-May-98	1,468,000	288,000	409,996,000	51,937,000	0.0036	0.0008	0.6384	0.0334
8-Jun-98	23-May-98	2,940,000	622,000	83,336,000	9,213,000	0.0353	0.0084	0.1297	0.0165
					Mean =	0.0167	Sum =	1.0000	

B) July 1998 – June 1999

Survey Date	Start Date Based on Larval Duration	Estimated Number Entrained	Entrainment Std. Error	Estimated Population in Nearshore Sampling Area	Nearshore Population Std. Error	PE_i	PE_i Std. Error	f_i	f_i Std. Error
21-Jul-98	5-Jul-98	7,000	7,000	2,118,000	636,000	0.0033	0.0035	0.0035	0.0011
26-Aug-98	10-Aug-98	0	–	0	–	–	–	–	–
16-Sep-98	31-Aug-98	0	–	0	–	–	–	–	–
6-Oct-98	20-Sep-98	0	–	0	–	–	–	–	–
11-Nov-98	26-Oct-98	0	–	0	–	–	–	–	–
9-Dec-98	23-Nov-98	0	–	0	–	–	–	–	–
12-Jan-99	27-Dec-98	0	–	14,709,000	3,038,000	–	–	0.0240	0.0053
3-Feb-99	18-Jan-99	6,830	6,830	14,905,000	2,462,000	0.0005	0.0005	0.0243	0.0045
17-Mar-99	1-Mar-99	1,621,000	967,000	49,607,000	5,491,000	0.0327	0.0198	0.0809	0.0108
14-Apr-99	29-Mar-99	1,601,000	825,000	116,783,000	22,089,000	0.0137	0.0075	0.1906	0.0328
24-May-99	8-May-99	4,168,000	868,000	363,131,000	33,925,000	0.0115	0.0026	0.5926	0.0456
23-Jun-99	7-Jun-99	877,000	287,000	51,558,000	33,815,000	0.0170	0.0125	0.0841	0.0509
					Mean =	0.0131	Sum =	1.0000	

APPENDIX F. Regression estimates, onshore and alongshore current meter displacement, source water estimates, and estimates of the proportion of source water sampled (P_S) from monthly surveys conducted for two periods A) July 1997 through June 1998, and B) July 1998 through June 1999 for kelp, gopher, and black-and-yellow (KGB) rockfish complex at the Diablo Canyon Power Plant. The common slope used in calculating source water estimates was 0.000117 for the 1997-1998 period and -0.000367 for the 1998-1999 period. The ratio of the length of the nearshore sampling area (17,373 m) to the alongshore current displacement was used to calculate P_S for each survey (alongshore P_S). The regression coefficients and onshore and alongshore current displacement were used to calculate an estimate of the population in the source water for each survey. The ratio of the estimated population in the nearshore sampling area to the estimated population in the source water was used to calculate an estimate of P_S for each survey (offshore P_S).

A) July 1997 - June 1998

Survey Date	Y-Intercept	X-Intercept	Cumulative Alongshore Displacement (m)	Onshore Current Displacement (m)	Estimated Offshore Extent of Source Water (m)	Extrapolated Number Beyond Nearshore Sampling Area	Total Extrapolated Offshore Source Population	Total Extrapolated Alongshore Source Population	Offshore P_S	Alongshore P_S
21-Jul-97	-0.171	1,460	31,300	4,820	4,820	16,382,000	16,848,234	466,000	0.0153	0.5545
25-Aug-97	–	–	–	–	–	–	0	0	–	–
29-Sep-97	–	–	–	–	–	–	0	0	–	–
20-Oct-97	–	–	–	–	–	–	0	0	–	–
17-Nov-97	–	–	–	–	–	–	0	0	–	–
10-Dec-97	-0.172	1,470	146,000	31,600	31,600	7,772,826,000	7,774,642,009	1,816,000	<0.0001	0.1189
22-Jan-98	-0.015	125	120,000	23,400	23,400	3,753,412,000	3,807,288,976	53,877,000	0.0020	0.1443
26-Feb-98	0.064	-545	33,700	8,710	8,710	144,140,000	166,528,437	22,388,000	0.0693	0.5152
18-Mar-98	0.165	-1,410	181,000	12,400	12,400	1,801,789,000	1,988,251,728	186,463,000	0.0090	0.0960
15-Apr-98	2.115	-18,000	76,100	12,800	12,800	2,264,580,000	2,752,044,506	487,464,000	0.0404	0.2282
18-May-98	8.127	-69,400	67,100	19,900	19,900	10,706,927,000	12,290,666,879	1,583,740,000	0.0334	0.2589
8-Jun-98	1.376	-11,700	111,000	5,670	5,670	559,792,000	1,094,442,999	534,651,000	0.0761	0.1559
								Mean =	0.0307	0.2590

B) July 1998 - June 1999

Survey Date	Y-Intercept	X-Intercept	Cumulative Alongshore Displacement (m)	Onshore Current Displacement (m)	Estimated Offshore Extent of Source Water (m)	Extrapolated Number Beyond Nearshore Sampling Area	Total Extrapolated Offshore Source Population	Total Extrapolated Alongshore Source Population	Offshore P_S	Alongshore P_S
21-Jul-98	0.596	1,620	76,300	11,100	3,010	0	9,299,000	9,299,000	0.2278	0.2278
26-Aug-98	–	–	–	–	–	–	0	0	–	–
16-Sep-98	–	–	–	–	–	–	0	0	–	–
6-Oct-98	–	–	–	–	–	–	0	0	–	–
11-Nov-98	–	–	–	–	–	–	0	0	–	–
9-Dec-98	–	–	–	–	–	–	0	0	–	–
12-Jan-99	0.859	2,340	46,200	24,100	3,010	0	39,166,000	39,166,000	0.3755	0.3755
3-Feb-99	0.859	2,340	81,900	19,700	3,010	0	70,254,000	70,254,000	0.2122	0.2122
17-Mar-99	1.529	4,169	36,900	8,540	4,170	9,113,397	114,452,000	105,339,000	0.4334	0.4709
14-Apr-99	2.936	8,003	163,000	10,200	8,000	744,108,728	1,837,168,000	1,093,059,000	0.0636	0.1068
24-May-99	7.716	21,036	180,000	21,800	21,000	10,709,111,477	14,464,376,000	3,755,264,000	0.0251	0.0967
23-Jun-99	1.605	4,376	158,000	5,970	4,380	54,169,916	522,822,000	468,652,000	0.0986	0.1100
								Mean =	0.2052	0.2286

Edmund G. Brown, Jr.
Governor

VARIATION IN ENTRAINMENT IMPACT ESTIMATIONS BASED ON DIFFERENT MEASURES OF ACCEPTABLE UNCERTAINTY

PIER FINAL PROJECT REPORT

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California Energy Commission
Public Interest Energy Research Program

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August 2011
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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Variation in Entrainment Impact Estimation Based on Different Measures of Acceptable Uncertainty is the final report for the Environmental Effects of Cooling Water Intake Structures Project (Contract Number 500-04-025), conducted by the University of California, Santa Cruz. The information from this project contributes to PIER's Energy-Related Environmental Research Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/.

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Abstract

A significant number of California’s coastal power plants use once-through cooling. This technology diverts huge amounts of water from a water body into the power plant’s cooling system before being discharged back. Millions of small aquatic organisms that are carried along in this water flow are killed as they pass through the power plant; this impact is referred to as entrainment. Power plant operators are required to assess and, if appropriate, mitigate or compensate for entrainment impacts. To determine the size and type of projects, such as wetland restoration, that could compensate for these losses, a method known as the Area of Production Foregone is used. This method has been used in most, if not all, recent power plant entrainment studies in California. The Area of Production Foregone is an estimate of the area of habitat that, if provided, would produce the larvae lost due to entrainment and therefore compensate for the impact. This calculation is based upon another model that estimates the portion of a population lost to entrainment in comparison to the overall population in the water body affected by the cooling water intake. As the number of studies using this approach have increased, two major statistical issues remain unresolved: (1) how to estimate and incorporate statistical error into estimation of Area of Production Foregone and (2) the effect of sample size (number of species used in the assessment) on estimation of Area of Production Foregone. This study found: (1) explicit incorporation of statistical error may lead to an increase in the area of restoration or creation required for compensation; and (2) the number of species sampled dramatically affects the estimation of Area of Production Foregone, but only when the required likelihood of complete compensation is greater than 50 percent. This report documents ways to improve the use and accuracy of this method and therefore benefits California by ensuring appropriate mitigation when entrainment impacts occur.

Keywords: Once-through cooling, Area of Production Foregone, Empirical Transport Model, Habitat Production Foregone, entrainment.

Executive Summary

Introduction

Nineteen power plants in California, representing more than 19,000 megawatts of capacity and located along the state's coast, bays and estuaries, use once-through cooling technology to condense steam used in producing electricity. Once-through cooling technology requires the diversion of millions of gallons of water per day from a water body. This water is then circulated through the power plant's cooling system and then discharged back to marine water bodies.

Power plants in California using this cooling technology are subject to provisions of the U.S. Clean Water Act. Specifically, Section 316(b) of the act requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available to protect aquatic organisms from being killed or injured. Cooling water intake structures impact aquatic organisms by either impingement or entrainment. Impingement is where larger organisms are pinned against screens located at the entrance to the cooling water intake structure. Entrainment is where organisms that are small enough pass through the screens are carried by the water into the power plant's cooling systems where they are subjected to thermal, physical, or chemical stresses.

While assessment of impingement impacts can easily be determined through monitoring, the assessment of entrainment impacts presents special challenges. These include that fact that entrained organisms, which include fish and invertebrate larvae, are difficult not only to sample, but also to identify to an informative level. The distribution and variability of these populations in local waters may also be difficult to determine. Finally, there is great difficulty in scaling such losses such that the currency of impact is interpretable and useful when assessing mitigation options.

Project Objectives

The recent history of assessing the impact from entraining small marine organism by power plants has relied heavily on the use of the Empirical Transport Model. The Empirical Transport Model estimates the portion of a population that will be lost to entrainment by determining both the number of larvae from that population that will be entrained as well as the size of the larval populations found in the source water body. The source water body is the area where larvae are at risk of being entrained and is based primarily upon biological and oceanographic factors. Recent determinations using Empirical Transport models have calculated the average mortality across target species and used this number as the best estimate of mortality for all entrained organisms.

Using this information, the Area of Production Foregone (APF) can be calculated. The Area of Production Foregone, also known as Habitat Production Foregone, is an estimate of the area of habitat that, if provided, would produce enough larvae to compensate for those larvae lost due to entrainment. This has usually been based on species specific APF values that were used to generate a mean APF across species. More recently, APF estimation has incorporated the use of statistical error by developing confidence limits in APF calculation. These help provide an approach for addressing the specific question: what is the likelihood the calculated APF is large enough to provide, if used as a basis for mitigation, full compensation for the impact?

Empirical Transport Model and Area of Production estimates are based upon values derived from a limited number of target species and then used as the best estimate for all entrainable species. Target species are selected based on their abundance and the ease of collecting and identifying their larval stages. Because of this, a limited number of fish and, occasionally, crab species have been used for entrainment. The assumption, thus far untested, is that target species are reasonable representatives for the other species not targeted.

The goals of this project are to evaluate the effect of (1) incorporating statistical error in estimating Areas of Production Foregone and (2) the number of species in estimating Area of Production Foregone.

Project Outcomes

There were two major results of this study. First, as expected, explicit incorporation of statistical error leads to an increase in the area required for restoration or creation. As an example, increasing the level of confidence that the mean falls within the specified range from 50 percent to 95 percent increases the required area about 50 percent (across all studies). Using a more conservative increase from 50 to 80 percent produced, on average, an increase in area of about 25 percent. Assuming a direct relationship between area and cost, this means that the cost of increasing the likelihood of attaining full compensation from 50 to 80 percent would add an additional 25 percent to the cost of the mitigation project.
Second, the number of species sampled dramatically affects the estimate of the Area of Production Foregone, but only when the confidence limit is greater than 50 percent. The lack of change for the 50 percent confidence limit is because the expected mean does not change as a function of sample size. Instead, statistical error increases, which, when using confidence limits other than 50 percent, will affect estimates of the Area of Production Foregone. This result points to an important policy implication: if policy mandates that the 50 percent confidence limit for the Area of Production Foregone value (mean) be used to assess impacts and as a measure of compensatory mitigation, sample size is theoretically unimportant, because the expected mean does not vary with number of species assessed. The key implication of this result is that minimizing cost during sampling and assessment may be countered by the increased cost of compensatory mitigation (for example, habitat creation or restoration) due to inadequate sampling, which typically leads to greater statistical error.

Benefits to California

The California State Water Resources Control Board recently adopted a policy for assessing and mitigating the effects of power plants using once-through cooling technology. This policy identifies the use of the Habitat Production Foregone (referred to in this report as the Area of Production Foregone) as the appropriate method to show how power plant operators have achieved reductions in power plant entrainment impacts. Furthermore, other state agencies, such as the California Energy Commission and the California Coastal Commission, have used this method to identify the type and size of wetland restoration needed to address the entrainment impacts of power plants using once-through cooling. This report documents ways to improve the use and accuracy of this method and therefore benefits California by ensuring appropriate mitigation when entrainment impacts occur.

Unless otherwise noted, all tables and figures in this report were generated by the authors for this study.

1.0 Introduction

Nineteen power plants in California, representing over 19,000 MW of capacity and located along the state's coast, bays and estuaries, use once-through cooling technology to condense steam used in producing electricity. Once-through cooling technology requires the diversion through the power plant cooling system and then discharge of millions of gallons of water per day.

Power plants in California using this cooling technology are subject to provisions of the Clean Water Act. Specifically, Section 316(b) of the act requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available to protect aquatic organisms from being killed or injured by impingement (being pinned against screens at the entrance to the cooling water intake structure) or entrainment (being small enough to pass through the screens and drawn into cooling water systems and subjected to thermal, physical or chemical stresses).

While assessment of impingement impacts can easily be determined through monitoring, assessment of entrainment impacts presents special challenges. These challenges include that fact that entrained organisms, which include fish eggs and fish and invertebrate larvae, are difficult not only to sample but also to identify to an informative level. The distribution and variability of these populations in local waters are often difficult to determine. There is also great difficulty in scaling such losses such that the currency of impact is interpretable and useful when assessing mitigation options.

The recent history of assessing the impact from entraining small marine organism by the intake of cooling water by power plants has relied heavily on the use of the Empirical Transport Model (ETM). The ETM estimates the portion of a larval population that will be lost to entrainment by determining both the amount of larvae from that population that will be entrained as well as the size of the larval populations found in the source water body. The source water body is the area where larvae are at risk of being entrained and is determined by biological and oceanographic factors. Recent determinations using ET models have calculated the average mortality across target species and used this as the best estimate of mortality for all entrained organisms.

Often ET models have been used in conjunction with demographic models that translate larval losses to adults using either hindcast (Fecundity Hindcast, [FH]) or forecast modeling (Adult Equivalent Loss, [AEL]). However the utility of the FH and AEL models has been hampered by the need for species specific life history information that is lacking for many species entrained in California. These models also suffer from an attribute that is rarely talked about but is fundamentally important and which separates these models from ETM models. Results in FH and AEL models are specific to the species modeled whereas those in ETM models are applicable across species.

To understand this it is helpful to use an example. Assume that an entrainment assessment has been conducted and that all three models were used. FH modeling will estimate the number of adult females that are required to produce the entrained larvae. AEL models will estimate the number of adults that would have resulted from the lost larvae. ETM models will estimate the percent of larvae at risk that were killed due to entrainment (called proportional mortality [P_M]) and the area of the population at risk (called source water body [SWB]). Also assume that the total number of species that were used in modeling was 10. While this is a large number for most 316(b) studies, this is a tiny fraction of the species actually entrained and lost. Hence, the utility of the models must be related to the degree that the model is useful as a proxy for other species not included in the models.

This condition is essential but has never been evaluated. Both FH and AEL models will end up producing numbers of lost adults. Because of the filter of life history, particularly fecundity and early survivorship, there is no expectation that these numbers also estimate species not modeled. By contrast, ETM estimates simply yield the proportional loss of larvae and source water body. The species specific product of P_M and SWB gives the Area of Production Foregone (APF), which is an estimate of the area of habitat that if provided would produce the larvae lost due to entrainment. Importantly, APF estimates should be and have been much more robust to life history variation than either FH or AEL estimates. Hence, it is expected that some estimator of replicate measures of APF (e.g. mean, median, 95% confidence interval) may be a proxy for other species entrained but not directly modeled. Typically, mean APF has been used, but recently the 80% confidence limit was used in a case before the California Coastal Commission (Poseidon Resources [Channelside] 2008). Explicit incorporation of statistical uncertainty (that leads to confidence limits) into APF evaluation has been constrained because of the lack of assessment of the effect of such incorporation and also because the method of incorporation of uncertainty (henceforth called error) has not been vetted.

As noted, the basis of ETM for impact assessment of entrainment is target species, which are used to estimate the general effect on entrainable organisms. Such species are selected based on their abundance, their ease of collection and on the ability to determine their identity based on larval characteristics (Steinbeck et al. 2007). Because of limitation in all these criteria, the vast majority of target organisms in ETM estimation have been a select group of fish species (note, certain species of crabs are also sometimes used). Recent determinations using ET models have calculated the average proportional mortality across target species and used this as the best estimate of proportional mortality for all entrained organisms. The major, thus far untested assumption is that target species are proxies for other species not targeted. Figure 1 schematically represents target organisms as a fraction of species entrained.

The goals of this project were to evaluate the effect of (1) incorporation of statistical error in estimation of APF and (2) sample size (number of species for which APF is assessed) on estimation of APF. For the first goal, both resampling theory and traditional parametric approaches were utilized, while resampling theory was the basis of the approach to address the second goal.

Fundamentals of the Empirical Transport Model (ETM)

A detailed description of the ETM can be found in Steinbeck et al (2007). The following is derivative of that paper. Results of empirical transport modeling provide an estimate of the conditional probability of mortality (P_M) associated with entrainment. P_M requires an estimate of proportional entrainment (P_E) as an input, which is an estimate of the daily entrainment mortality on larval populations in that body of water subject to entrainment, called the source water body (SWB). Empirical transport modeling has been used extensively in recent entrainment studies in California (Steinbeck et al. 2007) and elsewhere (e.g. at the Salem Nuclear Generating Station in Delaware Bay, New Jersey and at other power stations along the east coast of the United States (Boreman et al. 1978, 1981; PSE&G 1993). ETM derivations have also been developed (MacCall et al. 1983) and used to assess impacts at the San Onofre Nuclear Generating Station (SONGS; Parker and DeMartini 1989).

The basic form of the ETM incorporated many time-, space-, and age-specific estimates of mortality as well as information regarding spawning periodicity and larval duration (Boreman et al. 1978, 1981). Much of this type of information is unknown for species entrained in California, Hence, a variation of ETM has been developed for use for coastal once through cooling (OTC) systems in California. The essence of the approach is the compounding of P_E over time, which allows estimation of P_M using assumptions about species-specific larval life histories, specifically the length of time in days that the larvae are in the water column and exposed to entrainment.

On any sampling day *i*, P_E can be expressed as follows:

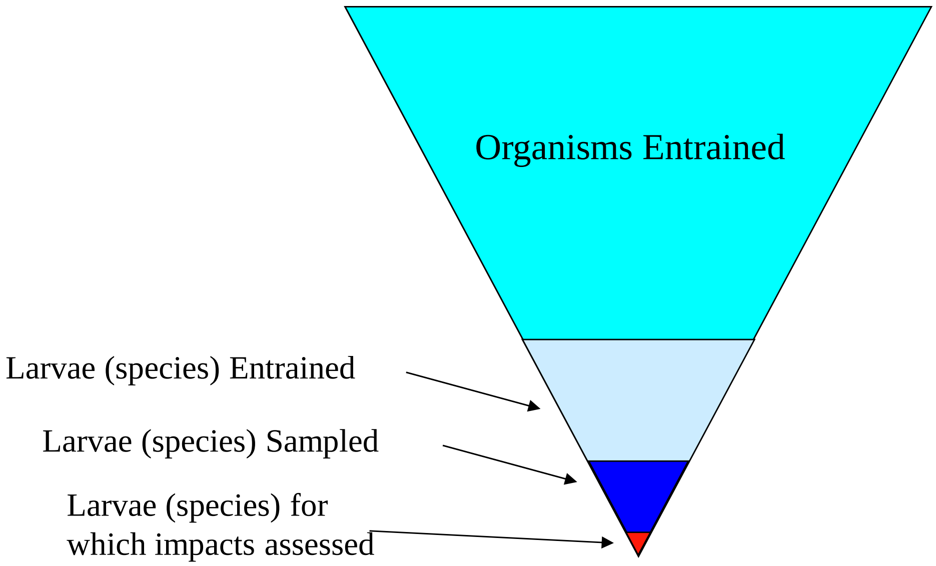

Figure 1. The inverse triangle of entrainment assessment.

$$P_{E\,i} = \frac{E_i}{N_i} \qquad (1)$$

where

E_i = total numbers of larvae of species entrained during a day during the i^{th} survey; and

N_i = numbers of larvae at risk of entrainment, i.e., abundance of larvae in the sampled source water during a day during the i^{th} survey.

Survival over one day = $1\text{-}P_{Ei}$, therefore survival over the number of days (d) that the larvae are vulnerable to entrainment = $(1\text{-}P_{Ei})^d$. Here d is determined based on a derived age distribution of entrained individuals. The derivation is based on the measured size frequency distribution of entrained individuals. Many values of d could be used, but the most common are average age and the constrained maximum (Steinbeck et al. 2007) age of entrained individuals. The difference between these two estimates can have profound effects on the estimate of impact (see below). Methods for estimating E_i and N_i can be found in Steinbeck et al. (2007).

Regardless of whether the species has a single spawning period per year or multiple overlapping spawning, the estimate of total larval entrainment mortality can be expressed as the following:

$$P_M = 1 - \sum_{i=1}^{n} f_i (1 - P_S P_{Ei})^d \qquad (2)$$

Where:

P_{Ei} = estimate of the proportional entrainment for the i_{th} survey
P_S = ratio (sampled source water / SWB)
f_i = proportion of total annual larvae hatched during i_{th} survey
d =estimated number of days larvae vulnerable to entrainment

To establish independent survey estimates, it was assumed that each new survey represented a new, distinct cohort of larvae that was subject to entrainment. Each of the surveys was weighted using the proportion of the total population at risk during the i_{th} survey (f_i) calculated as follows:

$$f_i = \frac{N_i}{N_T} \qquad (3)$$

Where:

N_i = the source population spawned during the i^{th} survey
N_T = the sum of the N_i 's for the entire study period.

As noted above, the number of days that the larvae of a specific taxon were exposed to the mortality estimated by P_E, can be estimated using length data from a representative number of larvae from the entrainment samples. Typically, a point estimate of larval exposure has been used in the calculations (mean or maximum). These point estimates are constrained by using the values between the 1st and upper 99th percentiles of the length measurements for each entrained larval taxon. The constrained range is used to eliminate potential outlier measurements in the length data. Each measurement can then be divided by a species-specific estimate of the larval growth rate obtained from the scientific literature to produce an age frequency distribution. Maximum larval duration is calculated as the number of days between the 1st and 99th percentile. The second estimate uses an estimate of d calculated using the difference in length between the 1st percentile and the 50th percentile and is used to represent the mean number of days that the larvae were exposed to entrainment.

The term P_S represents the ratio of the area or volume of sampled source water to a larger area or volume containing the population of inference (Parker and DeMartini 1989). This allows for sampling of an area smaller than the likely source water body (SWB). If an estimate of the larval population in the larger area is available, the value of P_S can be computed directly.

There are two extreme versions of estimation of the SWB. These are noted for simplicity – the actual estimation is often more complex (Steinbeck et al. 2007). When an intake is withdrawing water exclusively from a contained water body, such as an estuary, the assumed SWB is often that water body for all species entrained. Note that even in these cases, there is often an addition to the SWB that represents tidal flux. For intakes withdrawing water from the open ocean, SWB is calculated separately for each assessed species. This calculation is based on the value of d and an estimate of net current velocity over the period of larval vulnerability. Hence P_S is then calculated as:

$$P_S = \frac{L_G}{L_P} \qquad (4)$$

Where:

L_G = length of sampling area

L_P = length of alongshore current displacement based on the period (d) of larval vulnerability for a taxon

Estimation of Area of Production Foregone and Consideration of Error in its Estimation

For a more detailed treatment of this topic see Strange et al. (2004) and Steinbeck et al. (2007). One problem associated with the use of ETM approaches is in the estimation of impact and potential mitigation opportunities. This is because the currency of ETM is proportional mortality (P_M), which is not an intuitive currency for impact assessment. Calculation of the area of production foregone (APF) is one approach for estimating impact and for giving guidance to compensation strategies because it yields the amount of habitat that would need to be replaced to compensate for the larval production lost due to entrainment.

Area of Production Foregone models can be used to understand the scale of loss resulting from entrainment and the extent of mitigation that could yield compensation for the loss. The basis of APF calculations with respect to entrainment rests on the assumptions that (1) P_M information collected on a group of species having varied life history characteristics can be used to estimate to impact to all entrained species and, (2) the currency of APF (habitat acreage) is useful in understanding both direct and indirect impacts resulting from entrainment, which is essential for understanding the extent of compensation required to offset the loss.

Because APF considers taxa to be simply independent replicates useful for calculating the expected impact, the choice of taxa for analysis may differ from Habitat Replacement Cost (HRC) assessments (Steinbeck et al. 2007). For APF, the concern is that each taxon is representative of others that were either unsampled (most species including invertebrates, plants and holoplankton) or not assessed for impact (most fish species, see Figure 1). The core assumption of APF with respect to estimating impact is that the average loss across assessed taxa is the single best point estimator of the loss across all entrained organisms. This fundamental statistical-philosophic assumption of APF addresses one of the most problematic issues in impact estimation: the typical inability to estimate impact for unevaluated taxa. The calculation of APF is quite simple mathematically and in concept. Conceptually, it is an estimate of the area of habitat that would be required to replace all resources affected by the impact. Hence, for entrainment, it can be considered to be the area of habitat that would have to be added to replace lost larval resources. As an example, assume that for gobies the estimate was that 11% of larvae at risk in a 2000-acre estuary were lost to entrainment. The estimate of APF then would simply be 2,000 acres (the Source Water Body = SWB) x 11% (P_M) or 220 acres. Therefore the creation of 220 acres of new estuarine habitat would compensate for the losses of goby larvae due to entrainment. This does not mean that all biological resources were lost from an area of 220 acres, which is a common misunderstanding.

Instead it means that if 220 acres of new habitat were created then losses to gobies would be compensated for.

Mathematically then APF is the product of P_M and SWB. This calculation is done separately for each species i.

$$APF_i = P_{M_i}(SWB_i) \qquad (5)$$

Clearly the goal should not be to assess impacts to individual species. Rather it should be to estimate all direct and indirect impacts to the system and to provide guidance as to the mitigation that would be compensatory. Indeed one criticism of many assessment methodologies (e.g. Habitat Equivalency Analysis = HEA) is that there is a focus on only a limited number of taxa (Figure 1) of all that are directly affected by entrainment and that there is also no provision for estimation of indirect impacts (often food web considerations). APF, as discussed, addresses this concern by expressing impact in terms of habitat and assuming that indirect impacts are mitigated for by the complete compensation of all directly lost resources. The idea is that the addition of the right amount of habitat would lead to compensatory production of larvae and would also compensate for indirect effects resulting from the larval losses. For example, if one indirect consequence of larval losses was the loss of a food resource for seabirds, the replacement of those lost larvae should mitigate the impact to seabirds. Hence the task is to determine the right amount of habitat.

The most obvious approach, as noted, and one that is consistent with the underlying assumptions of APF is to use species specific APF values to calculate a point estimate of overall effect. The main assumptions of this approach are:

1) Species specific APF values represent random samples from a population of APF values (the family of all possible species specific APF values)
2) Each species specific APF is the mean value of a series of samples and hence has associated measurement error.

Based on these assumptions, the mean (across species) should represent the single best estimate of the impact due to entrainment.

$$\overline{APF} = \sum_{i=1}^{n} APF_i \qquad (6)$$

Because species in APF are simply independent replicates that yield a mean loss rate, habitat restored or created should not be directed by species. Instead the habitat monetized or created should represent the habitat for the populations at risk. That is, if the habitat in the SWB estuary was 60% subtidal eelgrass beds, 15% mudflats and 25% vegetated intertidal marsh, the same percentages should be maintained in the created habitat. Doing so would ensure that impacts on all affected species would be addressed. Probably the most controversial issue in APF assessment is how measurement error is accommodated, although such accommodation is part of national policy recommendations (EPA 2006). In most assessments, including Habitat Replacement Cost (HRC) (Strange et al. 2002), estimates of loss of taxa are implicitly considered to be without error. In APF, each species specific estimate is considered to be prone to (sometimes) massive error (indeed, estimates of confidence intervals in ETM calculations often cross through zero). Because of the uncertainty as to how error should be calculated and used in the calculation of estimates of compensatory mitigation, the goals of this project were to evaluate the effect of:

1) Incorporation of statistical uncertainty in estimation of APF – specifically how incorporation of error affects estimates of the likelihood that proposed mitigation acreage will be compensatory.
2) Sample size (number of species for which APF is assessed) on estimation of APF. Here the idea was to test how sensitive APF estimates are to sample size. The results of this portion of the study inform future sampling design.
3)

To address these goals, information (PM, the standard errors of PM, SWB) was collected from entrainment assessments at seven power plants (Figure 2). All assessments included empirical transport modeling and were done consistently with recent 316(b) determinations.

Sources of data are shown in Table 1 below. Note that for some power plants, data sources were corrected addendums to published studies.

Incorporation of statistical uncertainty in estimation of APF: Approach

The goal of this portion of the project was to estimate confidence limits for APF values. Such calculations would inform two questions (that mathematically are equivalent):

1) What is our confidence that the calculated APF accurately describes the impact?
2) What is the likelihood that restoration or creation of a given amount of area of habitat will lead to complete compensation for an impact?

This second question assumes that the measures used to compensate actually work. This assumption should not be left untested – instead there should always be an evaluation of the compensation measures.

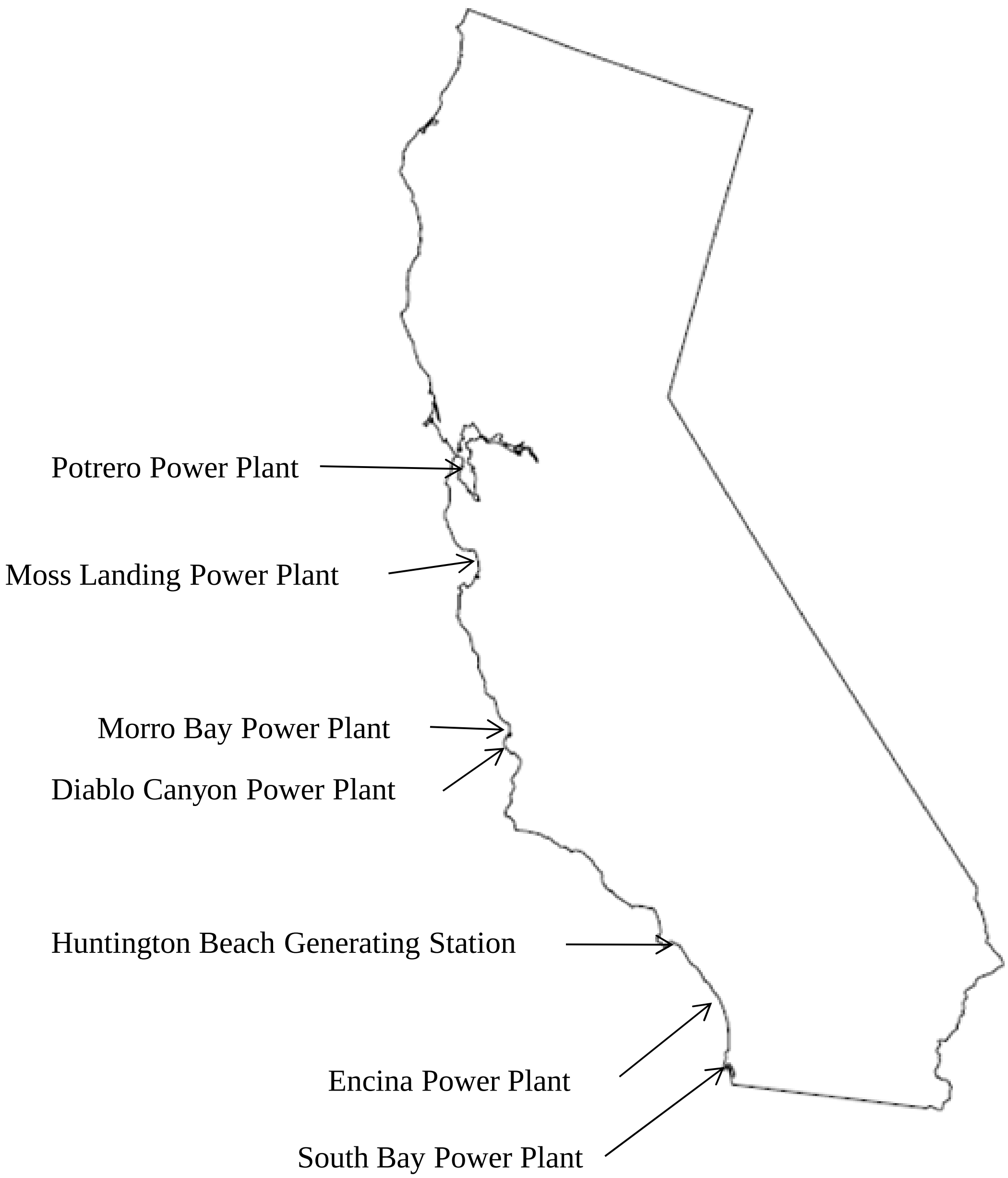

Figure 2. Location of power plants used in this study.

Power Plant	Data Source
South Bay	316(b) demonstration report to San Diego Regional Water Quality Control Board. May, 2004
Encina	316(b) demonstration report to San Diego Regional Water Quality Control Board. January 2008
Huntington Beach	AES Huntington Beach LLC Generating Station impingement and entrainment study. California Energy Commission. April 2005
Diablo Canyon	Addendum to 316(b) demonstration report. Document E9-055.0 to San Luis Obispo Regional Water Quality Control Board. March, 2000
Morro bay	Addendum to 316(b) demonstration report "Morro Bay Power Plant Modernization Project" to San Luis Obispo Regional Water Quality Control Board. July, 2001
Moss Landing	316(b) demonstration report to San Luis Obispo Regional Water Quality Control Board. April, 2000
Potrero	Final Staff Assessment: Potrero Power Plant Unit 7 Project. California Energy Commission. February 2002.

Table 1. Sources of data used in this study.

Two approaches were used to address these questions. First, based on the idea that species specific APF values are random samples from a distribution of values, confidence limits (or intervals) can be calculated using traditional parametric approaches or using resampling methods. There are substantial concerns about the use of parametric approaches (MacKinnon et al. 2004) when the underlying shape of the distribution in question is unknown or known and non-normal. APF values are synthetic not directly measured terms, and even the theoretical shape of the distribution of such values is unknown, hence both parametric and resampling methods were used and compared.

For each (treatment) combination of Power Plant, sample year, larval duration (mean or maximum period of vulnerability) and habitat (open coast or estuarine), $\overline{APF}$ (equation 6) and the standard error of APF (SE_{APF}) was calculated. These were used to generate confidence values based on a normal inverse function (Z inverse).

Generation of confidence limits for the same combinations was also calculated using resampling methods (Simon 1997). Resampling was performed with replacement and a series of 1000 means were generated for each treatment combination. Confidence limits (1, 5, 10, 20, 25, 50, 75, 80, 90, 95, 99) were determined based on the distribution of resampled means. As a reminder, the value at the 50th percentile should approximate the arithmetic mean.

Results from the two methods were compared using ordinary least squares regression for area estimated using confidence values ranging from the 50th to 99th percentiles (50, 75, 80, 90, 95, 99). The lower values (confidence values <50th percentile) were not used as they are inversely symmetric to higher values and would inflate replication.

The second approach was based on the standard errors calculated for each species P_M. See Appendix A. By assuming that the SWB was measured without error (which is probably ok for estuarine species and not ok for coastal species), confidence values for APF could be generated from the product of $P_{M(CV)}$ and

SWB, where $P_{M(CV)}$ is the P_M at a given confidence value. The underlying assumption here was that species specific APF values reflect the impact to that species and are not simply a sample from a distribution of independent measurements of the overall impact. The logic of this approach then is that the impact and confidence interval is species specific and that the net effect should reflect that logic. For example, the mean value of the 80th percentile could be calculated across species for South Bay, estuarine habitat, year one, maximum larval duration. Because parametric and resampling methodologies yielded the same results in the calculations discussed above, only the confidence limits based on the normal distribution were used. Mathematically then for any given confidence value the resulting APF would be:

$$\overline{APF_{CV}} = \sum_{i=1}^{n} APF_{CVi} \qquad (7)$$

Where:

$\overline{APF_{CV}}$ = Mean APF value across species for a given confidence value

APF_{CVi} = APF value for species i for a given confidence value

Incorporation of statistical uncertainty in estimation of APF: Results

Parametric and resampling estimation of area corresponding to similar confidence levels produced very similar results; the equation of the line comparing the two has a slope of 1 and an r^2 of .999. The results for each combination of Power Plant, sample year, larval duration (mean or maximum period of vulnerability) and habitat (open coast or estuarine) are shown in the series of Figures 1a – 1g in Appendix B. While the increase in area varied with each treatment combination, increasing likelihood of compensation resulted in an (exponential) increase in the APF estimate (Figure 3).

Using species specific confidence levels produced dramatically greater number of acres than was found using the approach using species specific APF values as replicates (Figures 2a-2g in Appendix B).

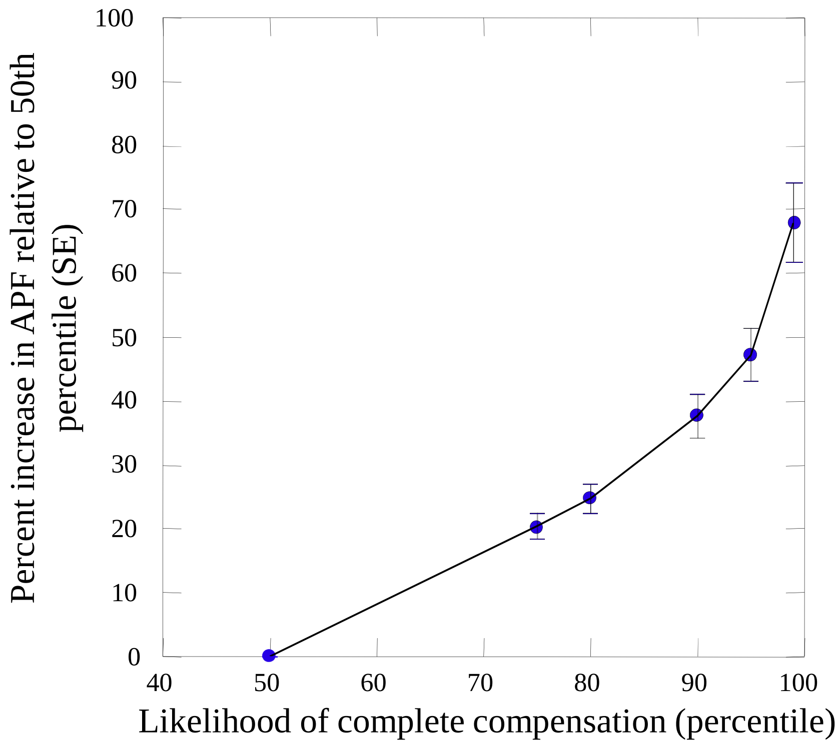

Figure 3. Effect of increasing likelihood of complete compensation on percent increase in APF.

The effect of sample size (number of species for which APF is assessed) on estimation of APF: Approach

Data from Diablo Canyon, in year one of the study, using maximum larval duration was used to assess the effect of replication on estimation of the confidence values for APF. For this treatment combination, P_M and SWB were originally calculated for 12 species and the corresponding APF values were determined as a result of this project (Appendix A). These 12 APF values were subjected to resampling in lots of 12, 11, 10, 9, 8, 7, 6, 5, 4, 3 replicates. During each run of a given level of replication, 1000 means were generated and the distribution of those means was used to determine APF values for a series of confidence values (50, 75,80, 90, 95, 99th percentile).

The effect of sample size (number of species for which APF is assessed) on estimation of APF: Results

The number of species sampled (level of replication) had a huge effect on the area required to attain a given confidence level for all levels above 50%, which is the mean (Figure 4). Using the 80% confidence level as an example, the estimated APF ranged from 3000 hectares (at 3 replicate species) to 2450 hectares (12 replicate species). Using the same line (80th percentile), one can also see that relative to the mean (50th percentile), increasing replication from 3 to 12 species decreased the area required by about 30%.

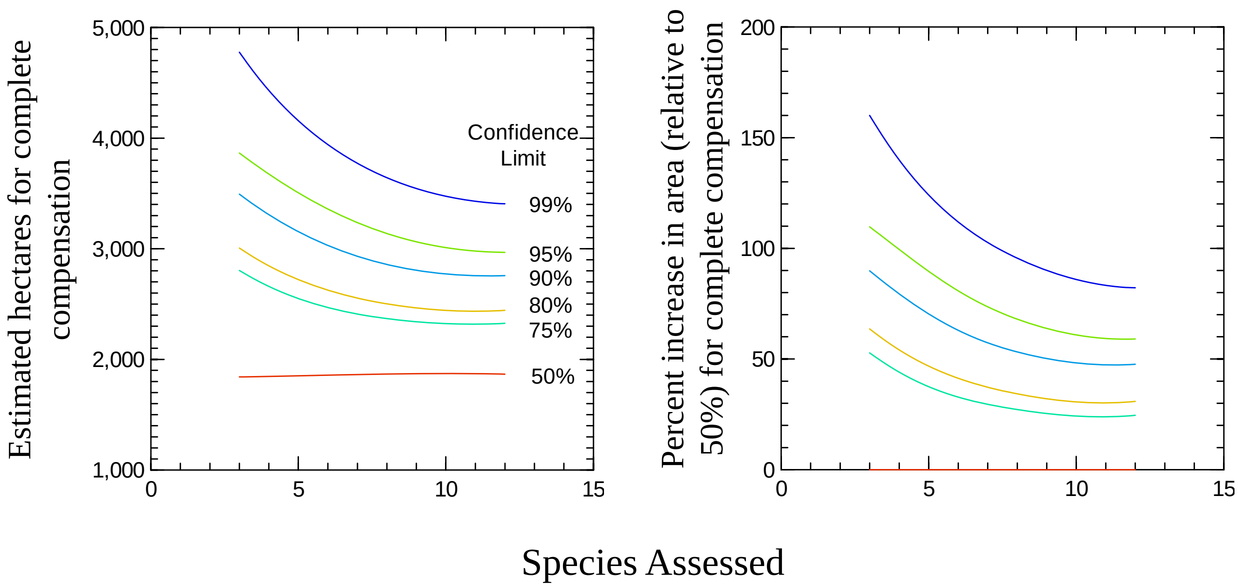

Figure 4: Effect of replication of species assessed on estimated APF.

Synthesis

Area of production foregone (APF, often also called Habitat Production Foregone; HPF) has been used in most if not all recent power plant entrainment studies in the state of California that adhered to 316(b) type assessment methods. In addition it has also been used to assess entrainment in impact studies of desalinization facilities that are co-located with power plants

(Poseidon Resources [Channelside] 2008). Far from being an unchanging approach, it has evolved considerably over the last ten years. While the derived ETM/APF approach was first used in the 316(b) assessment at Diablo Canyon (2000), the first finalized study utilizing APF was that at Moss Landing (Steinbeck et al. 2007, Moss Landing 316(b), 2000). In that assessment ETM was utilized but APF was calculated based on mean larval duration of vulnerability. In subsequent determinations at other power plants, either both mean and maximum larval durations or only maximum values were used for assessment (Appendix A). This evolution reflected the attained understanding that the true period of larval vulnerability was better estimated using maximum larval duration. Other changes in the use of APF have come in the way the SWB has been calculated for both open coast (see Diablo Canyon 316(b) and the use of an offshore gradient approach) and estuarine habitats (see Morro Bay 316(b) and the use of tidal flux). The point is that the use of APF is evolving as we understand both its constraints and the assumptions (often implicit) of the mathematics underlying its calculation.

There has also been an evolution in thinking about the most problematic general issue in impact assessment - how to account for error? In particular, an essential question is how to use confidence values to give a context to assessment of impact. In the specific case of APF, the general approach has been to use species specific APF values in the calculation of the mean APF, which is then used both as a currency of impact and also as a target value for compensatory mitigation. It is rarely if ever noted that the mean APF (from sample APF values) is (making assumption of normality) also the 50% confidence limit for the distribution of possible true population means. In non-statistical terms, this means that the true impact will be greater than or equal to the mean APF 50% of the time and equivalently that the likelihood of complete compensation from the creation of restoration of area equal to the mean APF is 50%. Two important points need to be made here. First, this argument is one about the amount of area; there is the assumption that the restoration or habitat creation actually works as designed. Second, probabilistically, half the possible population means (true impacts) are above and half below the 50th percentile (mean APF). Hence, if the true impact is above the mean APF there will be incomplete compensation, but not none at all. This last point seems obvious, but given the continued misinterpretation about APF (the wrong idea that APF means that existing habitat has been lost), it is important to be clear about the meaning of mathematical / statistical concepts.

Incorporation of confidence levels could have a profound effect on the estimation of habitat (restored or created) required to attain complete compensation for an impact. Ultimately, the confidence level desired is a policy decision that should balance the cost (financial and to society) of underestimating the area required for compensation with the cost (primarily financial) to the permittee or applicant. The results of this study provide guidance to the increase in area associated with increasing confidence that the effort will result in complete compensation. This is in turn should give insight into the trade off in costs noted above.

Conclusions

Parametric and resampling methods yield similar confidence values. Here single species APF values were considered to be independent replicate samples of the overall impact. In every combination of power plant, sample year, larval duration and habitat confidence levels (shown as likelihoods) calculated using parametric and resampling methods yielded similar results (See Appendix B). More importantly, increasing likelihoods of complete compensation were associated with increasing area of restoration or creation. The increase in area varied with treatment combination but the overall relationship revealed an exponential pattern (Figure 3). Increasing the likelihood from 50% to 95%, which is the traditional value used in inferential statistics, increased the required area about 50% (across all studies). Using a more conservative increase from 50-80% produced, on average, an increase in area of about 25%. Assuming a direct relationship between area and cost, this means that the cost of increasing the likelihood of attaining full compensation from 50 to 80% would add an additional 25% to the cost of the mitigation project.

The results of this part of the study can be used to inform other questions. As discussed, early ETM studies used the mean larval duration as the estimate of the period of larval vulnerability instead of maximum larval duration, which is currently used. The ETM study conducted at Diablo Canyon Power Plant was the most thorough investigation of entrainment impacts on the west coast and allows for a robust comparison of the effect of assumed period of larval vulnerability from mean to maximum larval duration. This change fundamentally affected estimated APF values (Figure 5). At all likelihood (of complete compensation) values greater than 50%, the area needed, under the assumption of maximum larval duration, was more than twice that needed under the assumption of mean larval duration.

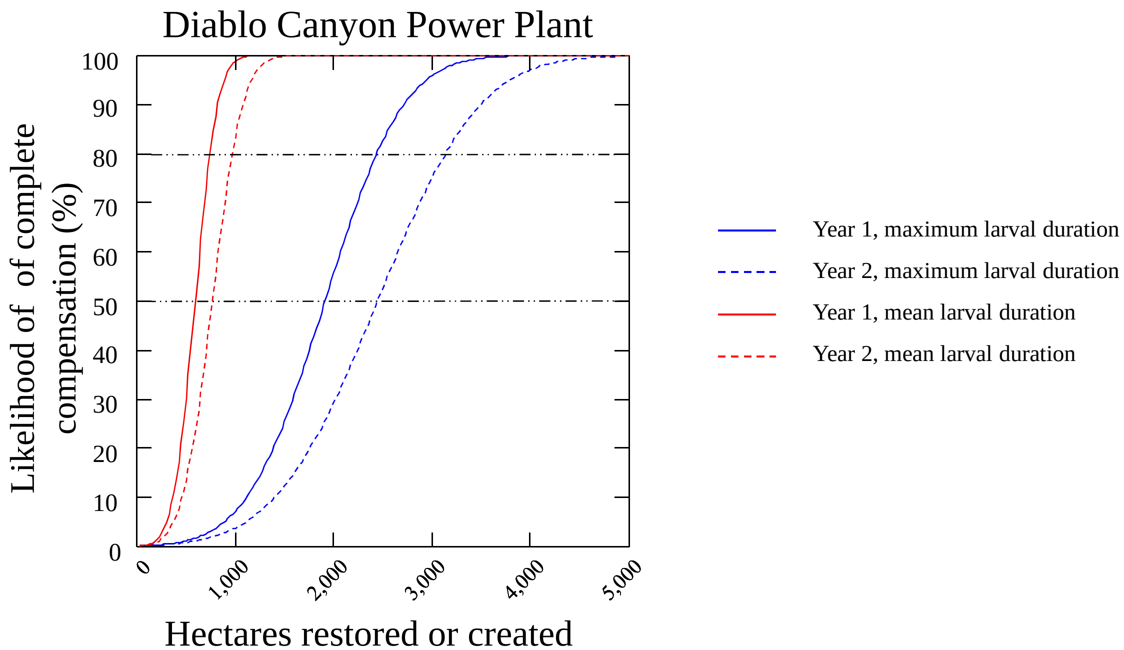

Figure 5: Probability of complete compensation as a function of area restored or created. APF estimates (using parametric approach) based from two years of sampling and two methods of estimating period of larval vulnerability

Species specific confidence values yield APF estimates much larger than those generated under the assumption that species specific APF values are replicate samples. Because standard errors were calculated for each P_M value, it was possible to calculate confidence values for each species. Using the logic discussed above and equation 7, species specific and mean confidence values were calculated. The impact of species specific estimation was large (Appendix B: Figures 2a – 2g). In all cases where the likelihood of complete compensation was greater than 50% this method yielded larger areas than that using mean confidence values; often there was a doubling of area.

The statistical-philosophical basis of this method of incorporation of measurement error is that the calculation of P_M and APF values for each species accurately describes (after error is accounted for) the impact to the species. Hence, APF values are not considered to be independent replicate samples of the overall impact of entrainment across all species be they assessed or not. Under this logic, the goal would be to ensure that the area restored or created was sufficient to compensate for the losses to each species at a given confidence level. While appealing, there are problems with this approach. First, measurement errors associated with P_M are often massive, and likely inappropriate for the task of generation of confidence values. Second, there is no provision for estimation of the impact for species not assessed (which are the vast majority of species). Third, and most fundamental, estimation of confidence values based on species specific error rates is counter to the logic of the calculation of mean APF. That is, the replication for the estimation of mean APF is the species specific APF values (not error rates), therefore the error must be based on the same replication (see Quinn and Keough 2003).

The number of species sampled dramatically affects estimation of APF (Figure 5). This clearly is not an unexpected result and is completely consistent with sampling theory (Quinn and Keough 2003, Zar 1996). Resampling the data for species sampled at Diablo Canyon, year 1, maximum larval duration showed that for all confidence levels above 50% the estimated area required to compensate for entrainment impact decreased as a function of number of species assessed. The lack of change for the 50% confidence limit is because the expected mean does not change as a function of sample size. Instead error changes, which affects the estimates of area at confidence limits different from 50%. Intuitively this is the result of the distribution of expected means broadening at low sample size. This points to an important policy implication. If policy mandates that the 50% confidence limit for the APF value (~mean) be used to assess impacts and as a measure of compensatory mitigation, sample size is theoretically unimportant, because the expected mean does not vary with number of species assessed. Note that the actual mean APF may vary across sample size. Indeed at smaller sample sizes there will be much more variability in the mean if sampled repeatedly. This would lead to a greater probability of under or over estimating the impact than would occur at higher sample size. By contrast to the situation where policy mandates use of the 50% confidence limit for APF, if policy or regulation requires incorporation of confidence values higher than 50% (e.g. Poseidon case where 80% level was used), then sample size becomes even more important. This is because the likely mitigation requirement will decrease with increasing sample size. The key implication of this result is that minimizing cost during sampling and assessment may be countered by the increased cost of habitat creation or restoration due to inadequate sampling.

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Appendix A
Data from Seven Power Plants

Table APA-1 Data from Seven Power Plants

Powerplant	Year	Habitat	Species	larval duration	Pm	Pm (SE)	offshore (km)	SWB (Hectares)	APF (Hectares)
South Bay	1	Estuarine	anchovies	maximum	0.1050	0.3132		3032.66	318.43
South Bay	1	Estuarine	CIQ goby complex	maximum	0.2150	0.4294		3032.66	652.02
South Bay	1	Estuarine	combtooth blennies	maximum	0.0310	0.1774		3032.66	94.01
South Bay	1	Estuarine	longjaw mudsucker	maximum	0.1710	0.3925		3032.66	518.59
South Bay	1	Estuarine	silversides	maximum	0.1460	0.3734		3032.66	442.77
South Bay	2	Estuarine	anchovies	maximum	0.0790	0.2814		3032.66	239.58
South Bay	2	Estuarine	CIQ goby complex	maximum	0.2670	0.4739		3032.66	809.72
South Bay	2	Estuarine	combtooth blennies	maximum	0.0340	0.1849		3032.66	103.11
South Bay	2	Estuarine	longjaw mudsucker	maximum	0.5020	0.5368		3032.66	1522.40
South Bay	2	Estuarine	silversides	maximum	0.1490	0.4121		3032.66	451.87
Encina	1	Coastal	California halibut	maximum	0.0015	0.0024	3	11117.30	16.79
Encina	1	Coastal	northern anchovy	maximum	0.0017	0.0026	3	6299.80	10.39
Encina	1	Coastal	queenfish	maximum	0.0037	0.0049	3	8217.14	29.99
Encina	1	Coastal	spotfin croaker	maximum	0.0063	0.0153	3	5558.65	35.24
Encina	1	Coastal	white croaker	maximum	0.0014	0.0028	3	13499.58	18.63
Encina	1	Estuarine	blennies	maximum	0.0864	0.1347		123.00	10.55
Encina	1	Estuarine	Garibaldi	maximum	0.0648	0.1397		123.00	7.92
Encina	1	Estuarine	gobies	maximum	0.2160	0.3084		123.00	26.39
Huntington Beach	1	Coastal	black croaker	maximum	0.0010	0.0007	4.44	8620.58	8.62
Huntington Beach	1	Coastal	blennies	maximum	0.0080	0.0054	4.44	5687.81	45.50
Huntington Beach	1	Coastal	California halibut	maximum	0.0030	0.0020	4.44	13730.72	41.19
Huntington Beach	1	Coastal	diamond turbot	maximum	0.0060	0.0040	4.44	7509.68	45.06
Huntington Beach	1	Coastal	northern anchovy	maximum	0.0120	0.0080	4.44	31993.92	383.93
Huntington Beach	1	Coastal	queenfish	maximum	0.0060	0.0040	4.44	37726.16	226.36
Huntington Beach	1	Coastal	rock crab megalops	maximum	0.0110	0.0074	4.44	11775.54	129.53
Huntington Beach	1	Coastal	spotfin croaker	maximum	0.0030	0.0020	4.44	7509.68	22.53
Huntington Beach	1	Coastal	white croaker	maximum	0.0070	0.0047	4.44	21240.41	148.68
Diablo Canyon	1	Coastal	blackeye goby	maximum	0.1151	0.0832	3	8560.80	985.69
Diablo Canyon	1	Coastal	blue rockfish complex	maximum	0.0041	0.0479	3	14146.20	58.14
Diablo Canyon	1	Coastal	cabezon	maximum	0.0111	0.1371	3	12058.20	134.21
Diablo Canyon	1	Coastal	California halibut	maximum	0.0047	0.0901	3	21088.80	98.27
Diablo Canyon	1	Coastal	clinid kelpfishes	maximum	0.1894	0.1218	3	29962.80	5674.65
Diablo Canyon	1	Coastal	KGB rockfishes	maximum	0.0388	0.0495	3	20149.20	781.59
Diablo Canyon	1	Coastal	monkeyface prickleback	maximum	0.1377	0.0726	3	31894.20	4390.56
Diablo Canyon	1	Coastal	painted greenling	maximum	0.0629	0.0920	3	26465.40	1664.67
Diablo Canyon	1	Coastal	sanddabs	maximum	0.0103	0.0583	3	12371.40	127.67
Diablo Canyon	1	Coastal	smoothhead sculpin	maximum	0.1139	0.0843	3	36122.40	4115.06
Diablo Canyon	1	Coastal	snubnose sculpin	maximum	0.1494	0.0967	3	31737.60	4741.91
Diablo Canyon	1	Coastal	white croaker	maximum	0.0070	0.0368	3	23437.80	163.60
Diablo Canyon	1	Coastal	blackeye goby	mean	0.0885	0.0774	3	4802.40	425.16
Diablo Canyon	1	Coastal	blue rockfish complex	mean	0.0028	0.0479	3	9657.00	26.75
Diablo Canyon	1	Coastal	cabezon	mean	0.0068	0.1373	3	10179.00	69.12
Diablo Canyon	1	Coastal	California halibut	mean	0.0029	0.0902	3	9291.60	26.95
Diablo Canyon	1	Coastal	clinid kelpfishes	mean	0.1498	0.1248	3	11745.00	1759.40
Diablo Canyon	1	Coastal	KGB rockfishes	mean	0.0242	0.0442	3	12423.60	300.53
Diablo Canyon	1	Coastal	monkeyface prickleback	mean	0.1056	0.0710	3	12319.20	1300.29
Diablo Canyon	1	Coastal	painted greenling	mean	0.0478	0.0920	3	14616.00	698.64
Diablo Canyon	1	Coastal	sanddabs	mean	0.0088	0.0581	3	9239.40	81.49
Diablo Canyon	1	Coastal	smoothhead sculpin	mean	0.0862	0.0767	3	12580.20	1084.16
Diablo Canyon	1	Coastal	snubnose sculpin	mean	0.1045	0.0961	3	12423.60	1297.89
Diablo Canyon	1	Coastal	white croaker	mean	0.0047	0.0368	3	11170.80	52.84
Diablo Canyon	2	Coastal	blackeye goby	maximum	0.0652	0.0576	3	6577.20	429.03
Diablo Canyon	2	Coastal	blue rockfish complex	maximum	0.0277	0.0372	3	15816.60	437.80
Diablo Canyon	2	Coastal	cabezon	maximum	0.0152	0.0651	3	9970.20	151.25
Diablo Canyon	2	Coastal	California halibut	maximum	0.0712	0.0793	3	16547.40	1177.84
Diablo Canyon	2	Coastal	clinid kelpfishes	maximum	0.2497	0.1132	3	22863.60	5709.96
Diablo Canyon	2	Coastal	KGB rockfishes	maximum	0.0480	0.0793	3	22863.60	1098.37
Diablo Canyon	2	Coastal	monkeyface prickleback	maximum	0.1176	0.0894	3	31737.60	3731.39
Diablo Canyon	2	Coastal	painted greenling	maximum	0.0558	0.0666	3	23176.80	1293.96
Diablo Canyon	2	Coastal	sanddabs	maximum	0.0080	0.0749	3	14302.80	113.99
Diablo Canyon	2	Coastal	smoothhead sculpin	maximum	0.2257	0.1133	3	26569.80	5997.34
Diablo Canyon	2	Coastal	snubnose sculpin	maximum	0.3102	0.1383	3	27405.00	8500.48
Diablo Canyon	2	Coastal	white croaker	maximum	0.0347	0.0349	3	20358.00	707.03
Diablo Canyon	2	Coastal	blackeye goby	mean	0.0412	0.0445	3	4489.20	185.00
Diablo Canyon	2	Coastal	blue rockfish complex	mean	0.0293	0.0400	3	6942.60	203.21
Diablo Canyon	2	Coastal	cabezon	mean	0.0117	0.0650	3	6525.00	76.15
Diablo Canyon	2	Coastal	California halibut	mean	0.0606	0.0847	3	5637.60	341.69
Diablo Canyon	2	Coastal	clinid kelpfishes	mean	0.1797	0.1314	3	10022.40	1800.72
Diablo Canyon	2	Coastal	KGB rockfishes	mean	0.0472	0.0798	3	8769.60	413.49
Diablo Canyon	2	Coastal	monkeyface prickleback	mean	0.1153	0.1025	3	9135.00	1053.08
Diablo Canyon	2	Coastal	painted greenling	mean	0.0369	0.0632	3	14824.80	546.89
Diablo Canyon	2	Coastal	sanddabs	mean	0.0101	0.0751	3	7151.40	72.01
Diablo Canyon	2	Coastal	smoothhead sculpin	mean	0.1562	0.1303	3	10544.40	1647.14
Diablo Canyon	2	Coastal	snubnose sculpin	mean	0.1851	0.1091	3	14302.80	2647.59
Diablo Canyon	2	Coastal	white croaker	mean	0.0280	0.0364	3	8091.00	226.87

Data from Seven Power Plants (cont.)

Powerplant	Year	Habitat	Species	larval duration	Pm	Pm (SE)	offshore (km)	SWB (Hectares)	APF (Hectares)
Morro Bay	1	Coastal	cabezon	mean	0.0249	0.5373	3	17151.30	427.07
Morro Bay	1	Coastal	KGB rockfishes	mean	0.0271	0.5733	3	15988.50	433.29
Morro Bay	1	Coastal	northern lampfish	mean	0.0253	0.8518	3	20930.40	529.54
Morro Bay	1	Coastal	Pacific staghorn sculpin	mean	0.0513	1.1220	3	45058.50	2311.50
Morro Bay	1	Coastal	white croaker	mean	0.0434	1.0526	3	20058.30	870.53
Morro Bay	1	Estuarine	combtooth blennies	maximum	0.7371	0.6012	3	930.58	685.93
Morro Bay	1	Estuarine	gobies	maximum	0.4333	0.5551	3	930.58	403.22
Morro Bay	1	Estuarine	jacksmelt	maximum	0.4392	0.5451	3	930.58	408.71
Morro Bay	1	Estuarine	Pacific herring	maximum	0.2544	0.4510	3	930.58	236.74
Morro Bay	1	Estuarine	shadow goby	maximum	0.0643	0.2625	3	930.58	59.84
Morro Bay	1	Estuarine	combtooth blennies	mean	0.4972	0.6114	3	930.58	462.68
Morro Bay	1	Estuarine	gobies	mean	0.1158	0.3357	3	930.58	107.76
Morro Bay	1	Estuarine	jacksmelt	mean	0.2172	0.4348	3	930.58	202.12
Morro Bay	1	Estuarine	Pacific herring	mean	0.1642	0.3927	3	930.58	152.80
Morro Bay	1	Estuarine	shadow goby	mean	0.0283	0.1923	3	930.58	26.34
Moss Landing	1	Estuarine	bay goby	mean	0.2144	0.0406		1213.80	260.26
Moss Landing	1	Estuarine	blackeye goby	mean	0.0749	0.0476		1213.80	90.89
Moss Landing	1	Estuarine	combtooth blennies	mean	0.1820	0.0786		1213.80	220.85
Moss Landing	1	Estuarine	gobies	mean	0.1069	0.0067		1213.80	129.76
Moss Landing	1	Estuarine	longjaw mudsucker	mean	0.0894	0.0216		1213.80	108.56
Moss Landing	1	Estuarine	Pacific herring	mean	0.1337	0.0168		1213.80	162.30
Moss Landing	1	Estuarine	Pacific staghorn sculpin	mean	0.1179	0.0198		1213.80	143.09
Moss Landing	1	Estuarine	white croaker	mean	0.1291	0.0242		1213.80	156.73
Potrero	1	Estuarine	bay goby	maximum	0.0025	0.0013		39670.22	99.57
Potrero	1	Estuarine	California halibut	maximum	0.0076	0.0066		39670.22	303.08
Potrero	1	Estuarine	gobies	maximum	0.0048	0.0017		39670.22	191.61
Potrero	1	Estuarine	northern anchovy	maximum	0.0029	0.0020		39670.22	115.44
Potrero	1	Estuarine	Pacific herring	maximum	0.0035	0.0104		39670.22	139.64
Potrero	1	Estuarine	white croaker	maximum	0.0049	0.0037		39670.22	195.57
Potrero	1	Estuarine	yellowfin goby	maximum	0.0017	0.0009		39670.22	67.44
Potrero	1	Estuarine	bay goby	mean	0.0011	0.0005		39670.22	44.43
Potrero	1	Estuarine	California halibut	mean	0.0024	0.0021		39670.22	95.21
Potrero	1	Estuarine	gobies	mean	0.0011	0.0004		39670.22	41.65
Potrero	1	Estuarine	northern anchovy	mean	0.0005	0.0004		39670.22	21.03
Potrero	1	Estuarine	Pacific herring	mean	0.0011	0.0032		39670.22	42.45
Potrero	1	Estuarine	white croaker	mean	0.0011	0.0008		39670.22	44.03
Potrero	1	Estuarine	yellowfin goby	mean	0.0009	0.0005		39670.22	36.50

APPENDIX B
Power Plant Specific Figures

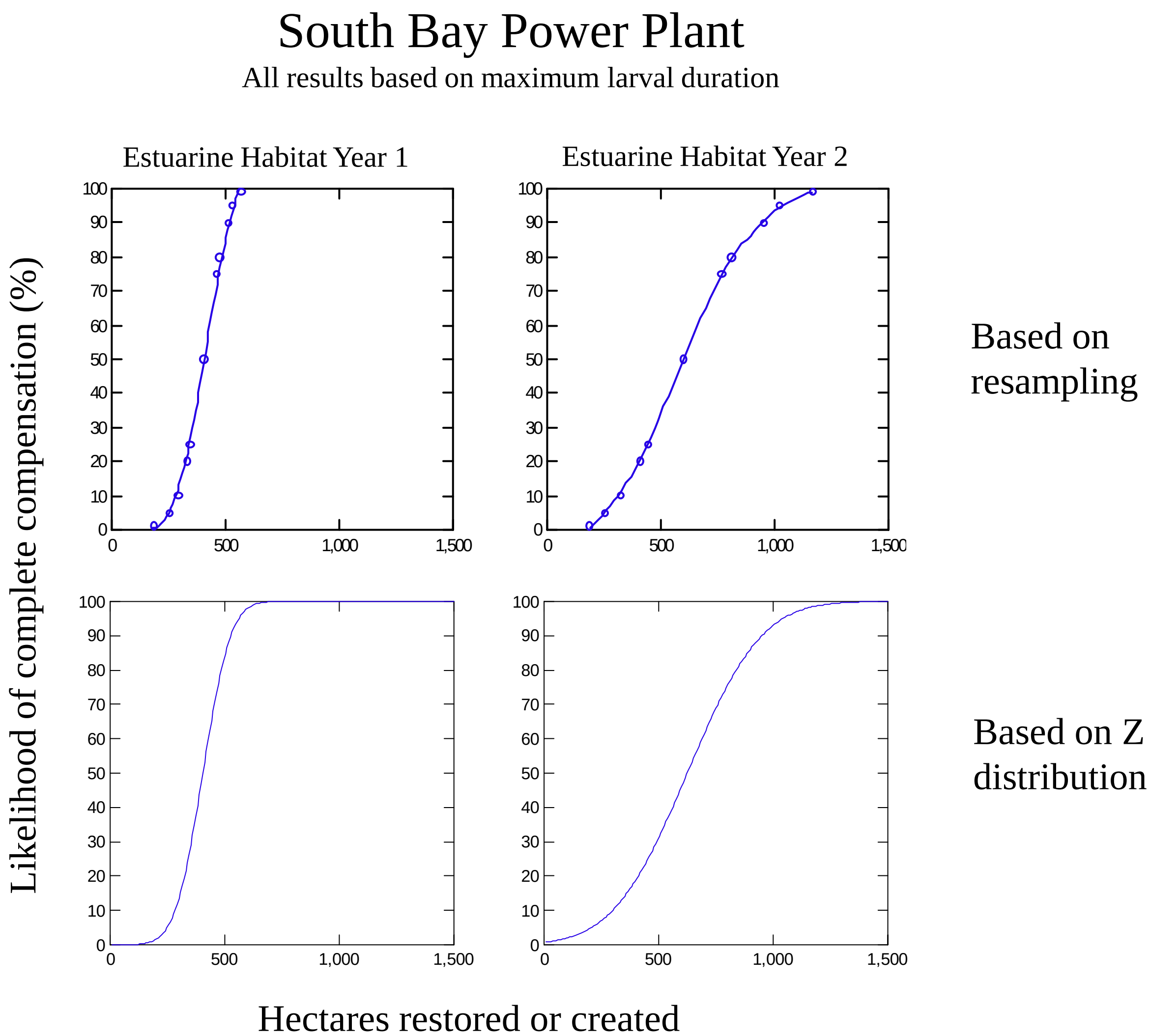

Figure 1a. Hectares restored or created at South Bay Power Plant.

APA-1

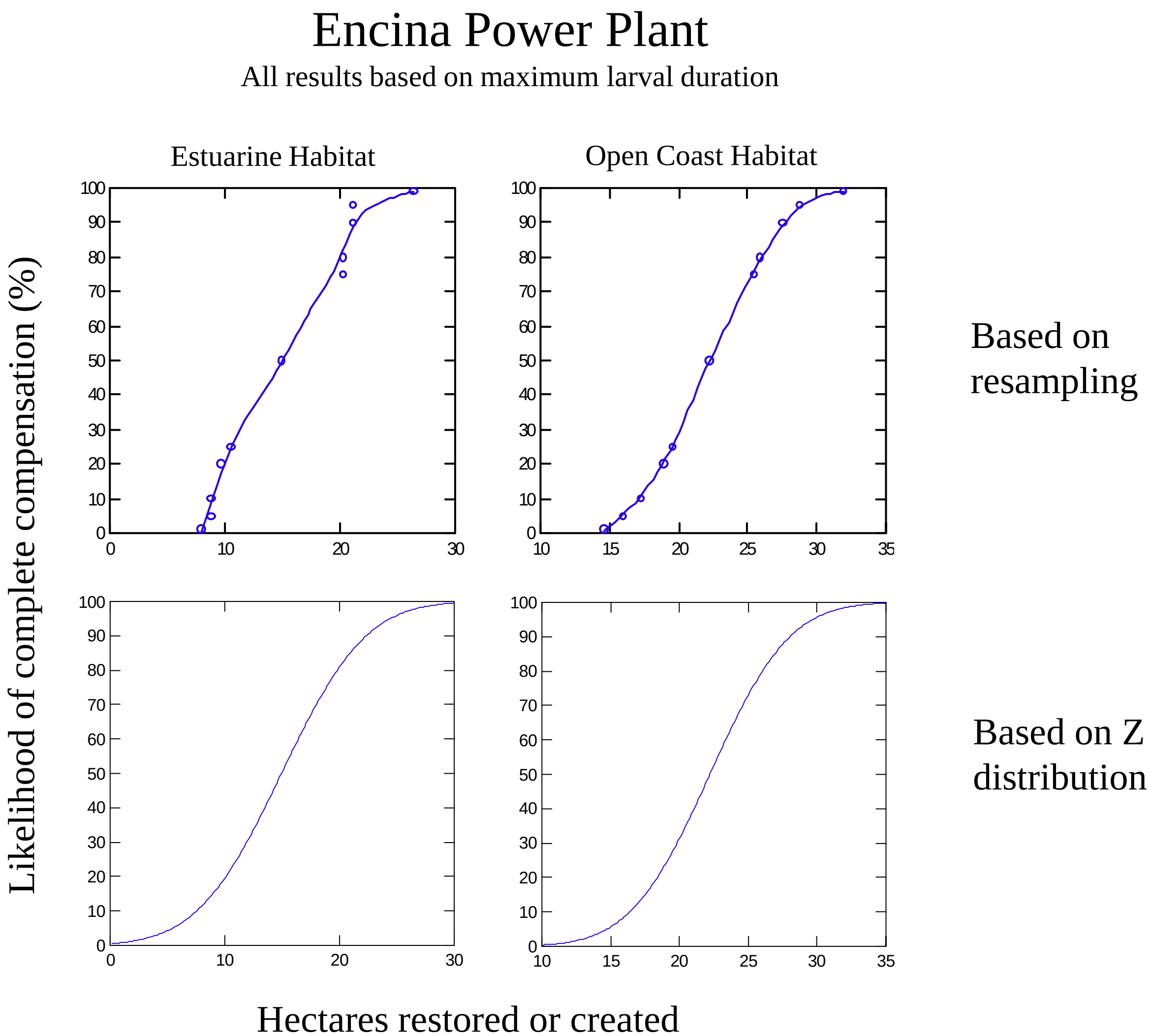

Figure 1b. Hectares restored or created at Encina Power Plan**t.**

APA-1

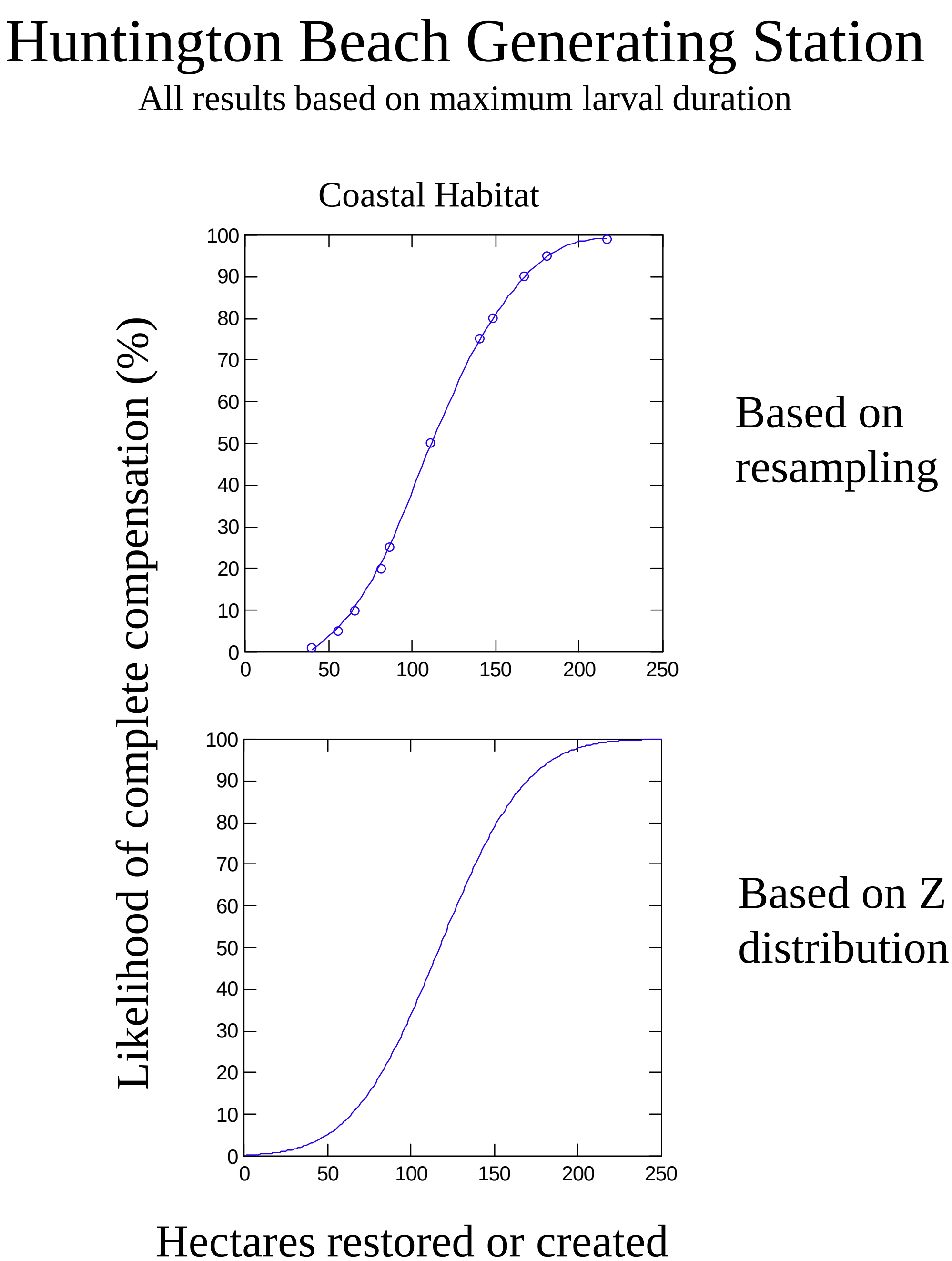

Figure 1c. Hectares restored or created at Huntington Beach Generating Station.

APA-1

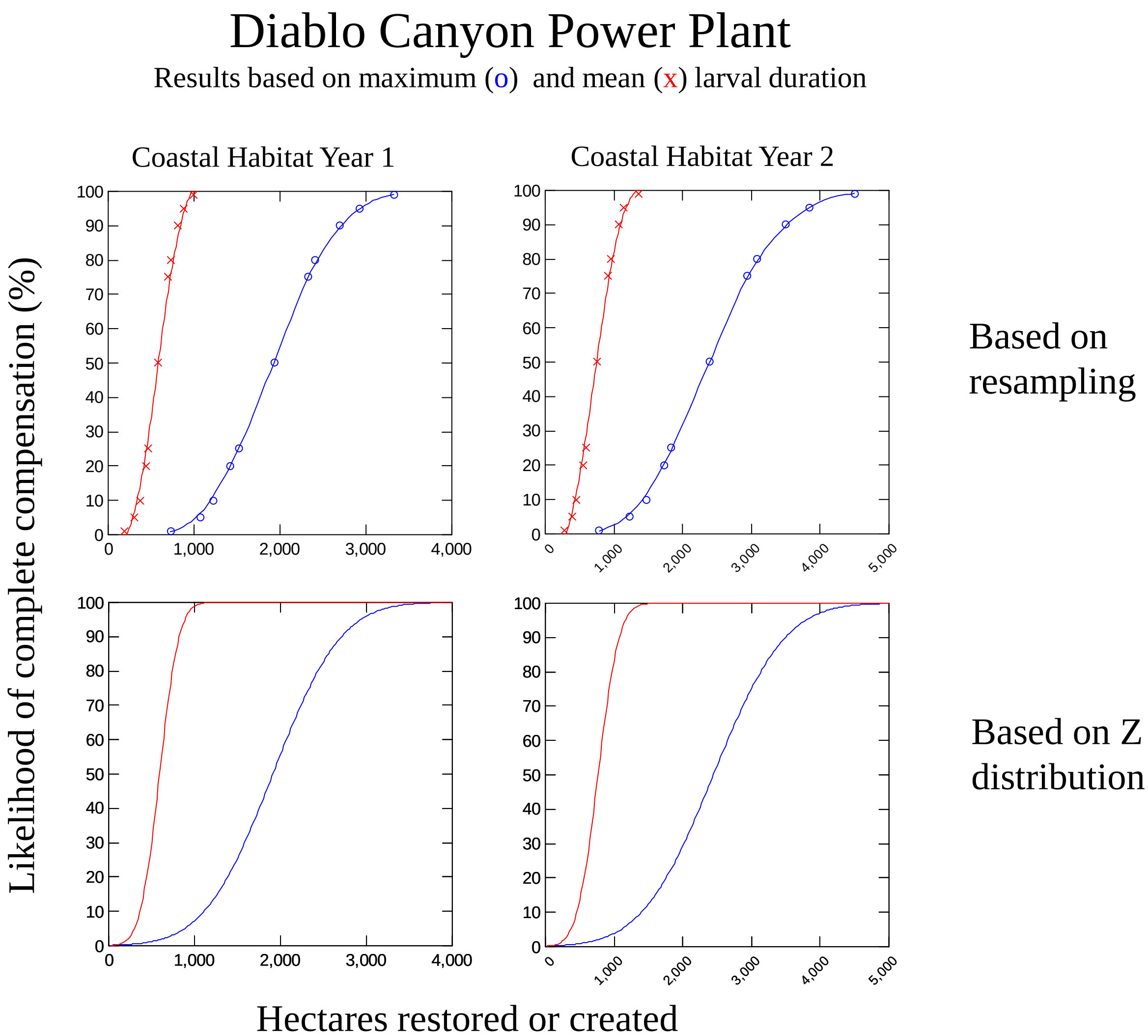

Figure 1d. Hectares restored or created at Diablo Canyon Power Plant.

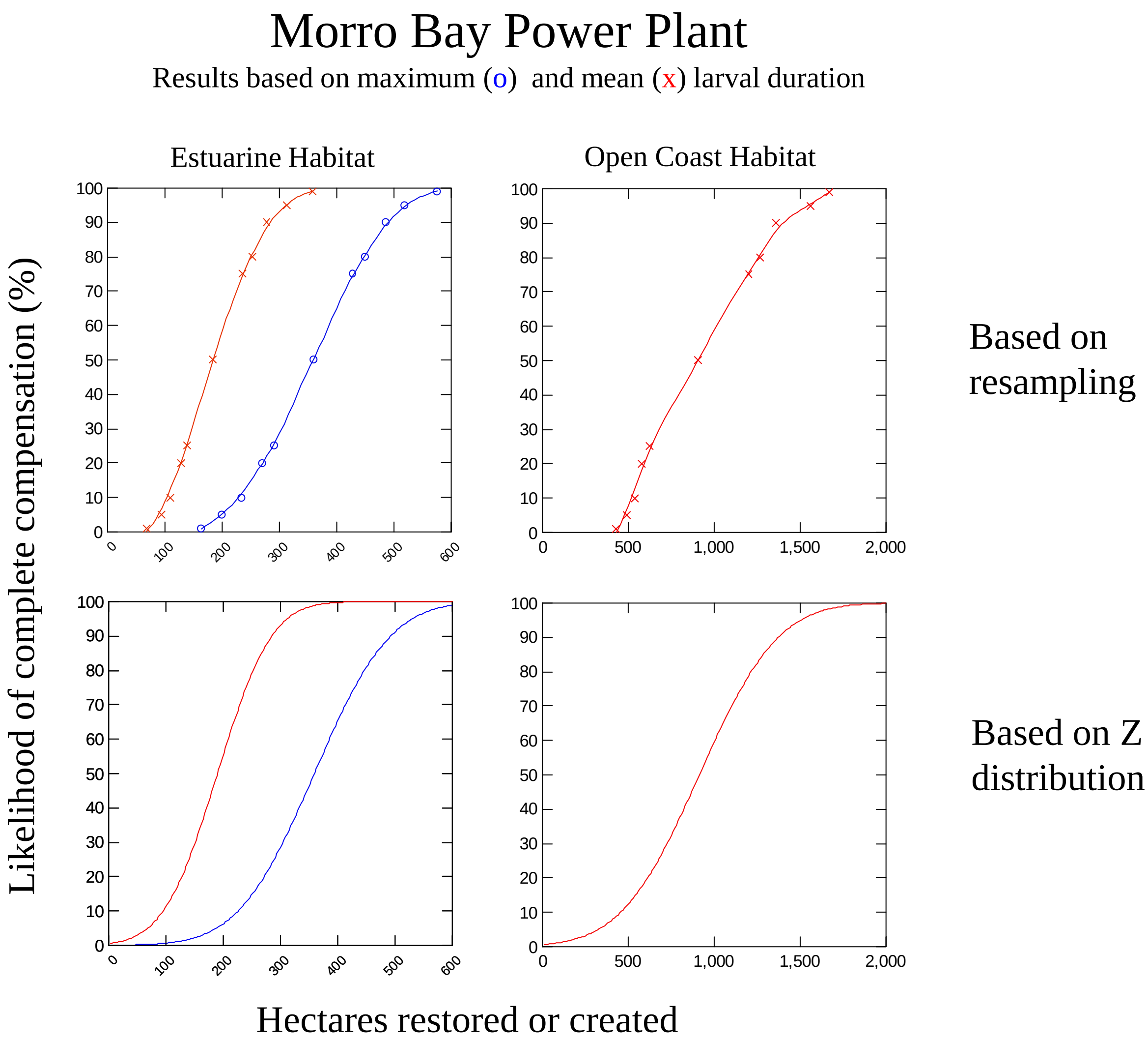

Figure 1e. Hectares restored or created at Morro Bay Power Plant.

APA-1

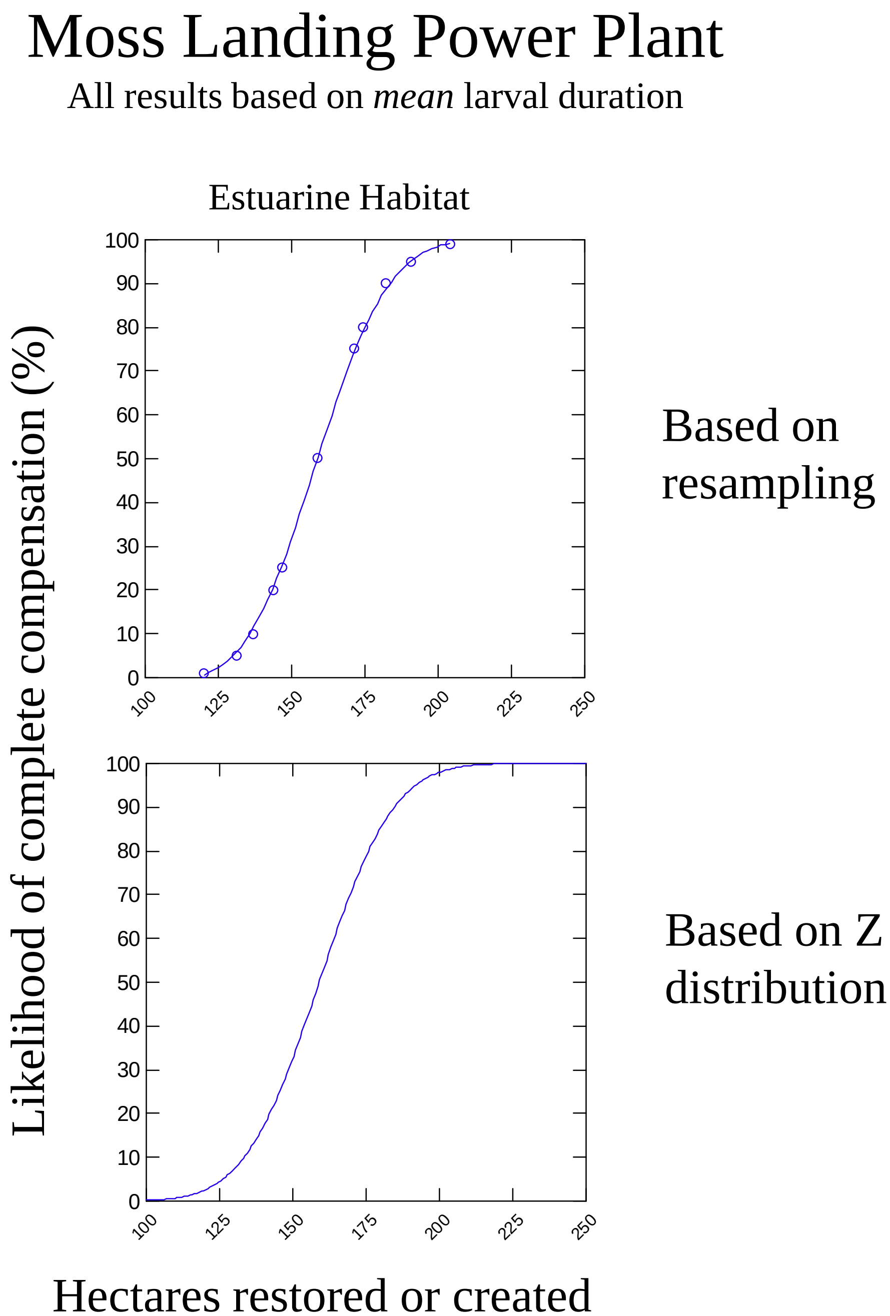

Figure 1f. Hectares restored or created at Moss Landing Power Plant.

APA-1

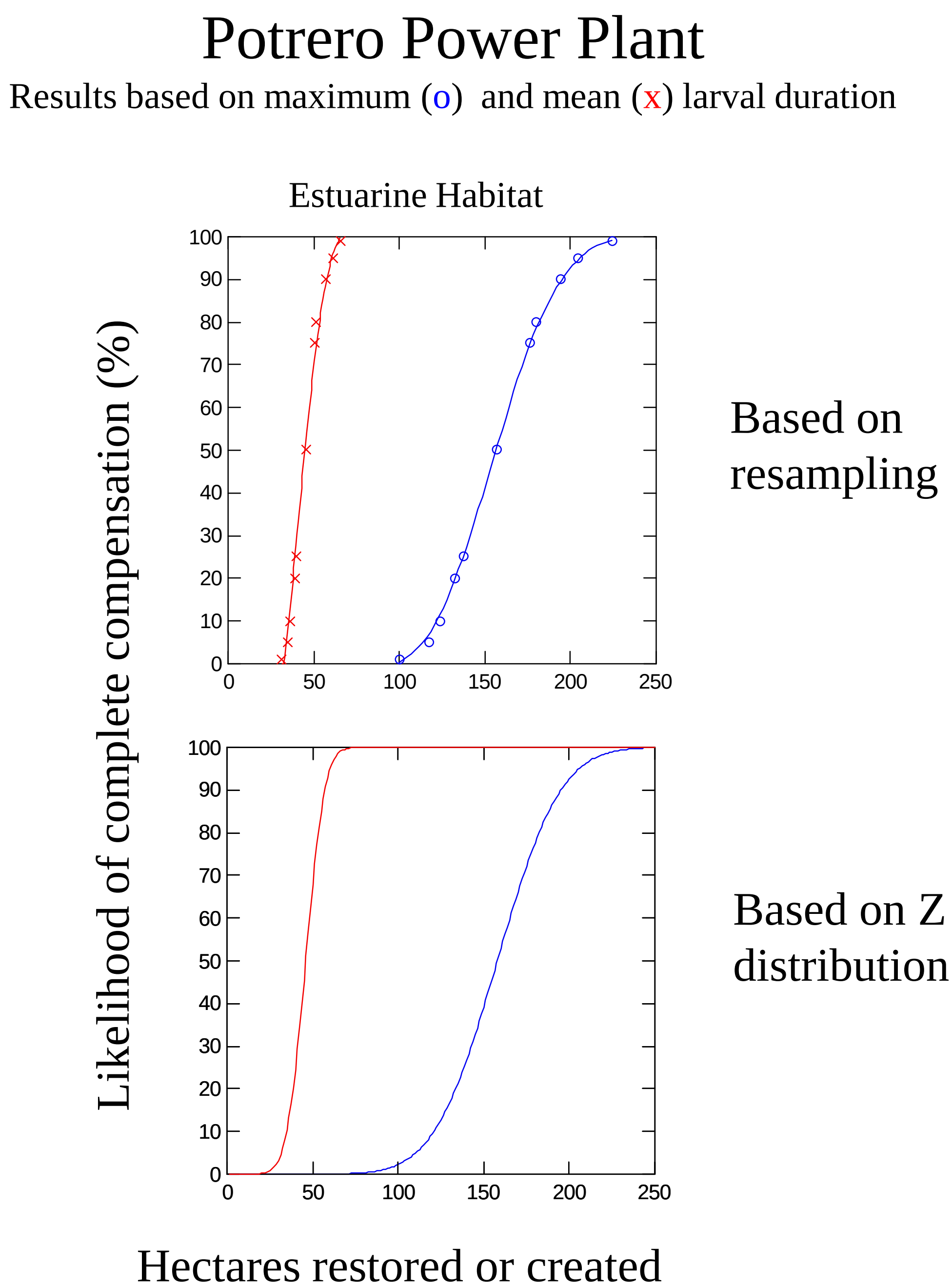

Figure 1g. Hectares restored or created Potrero Power Plant

APA-1

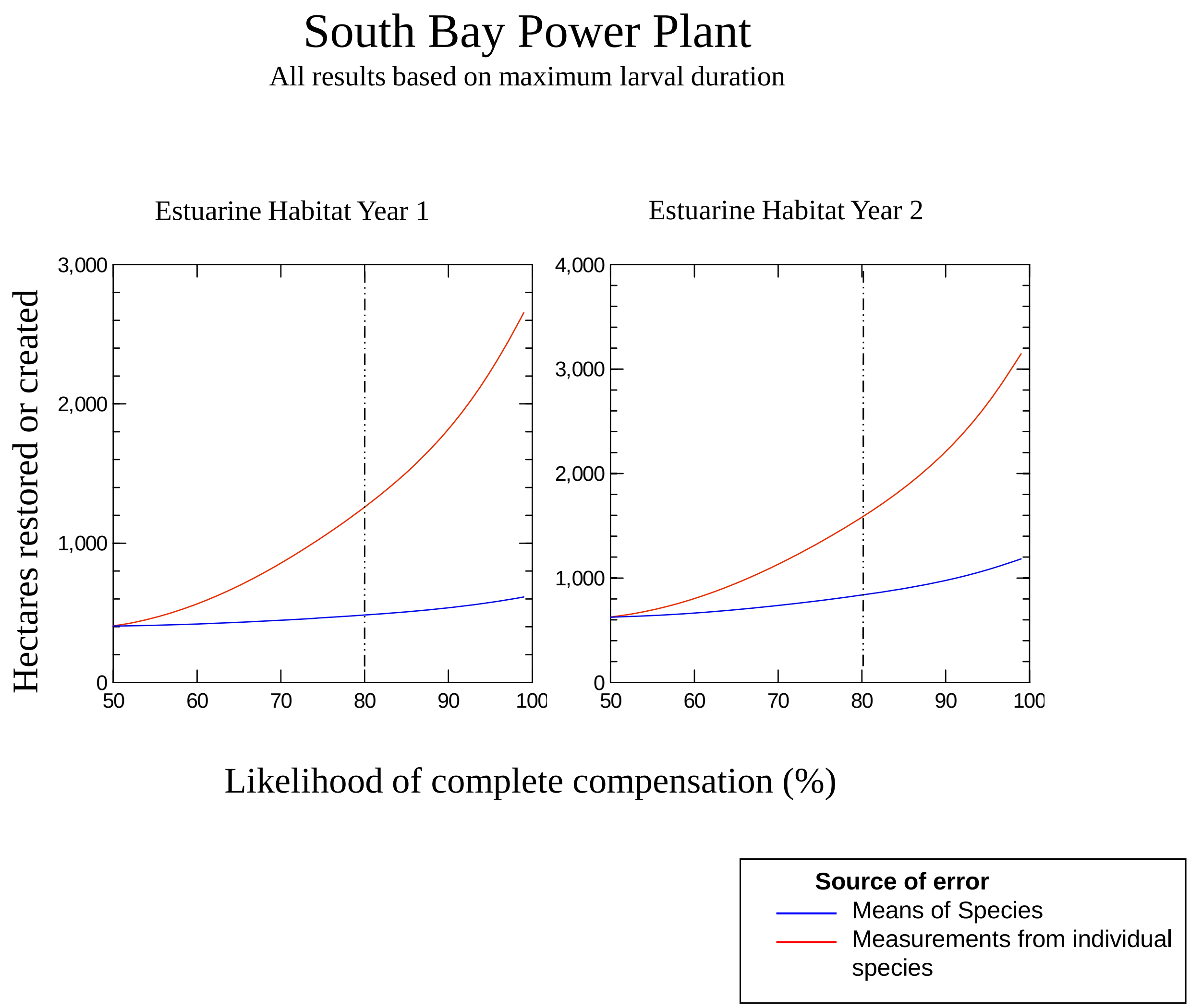

Figure 2a. Likelihood of complete compensation (%) South Bay Power Plant.

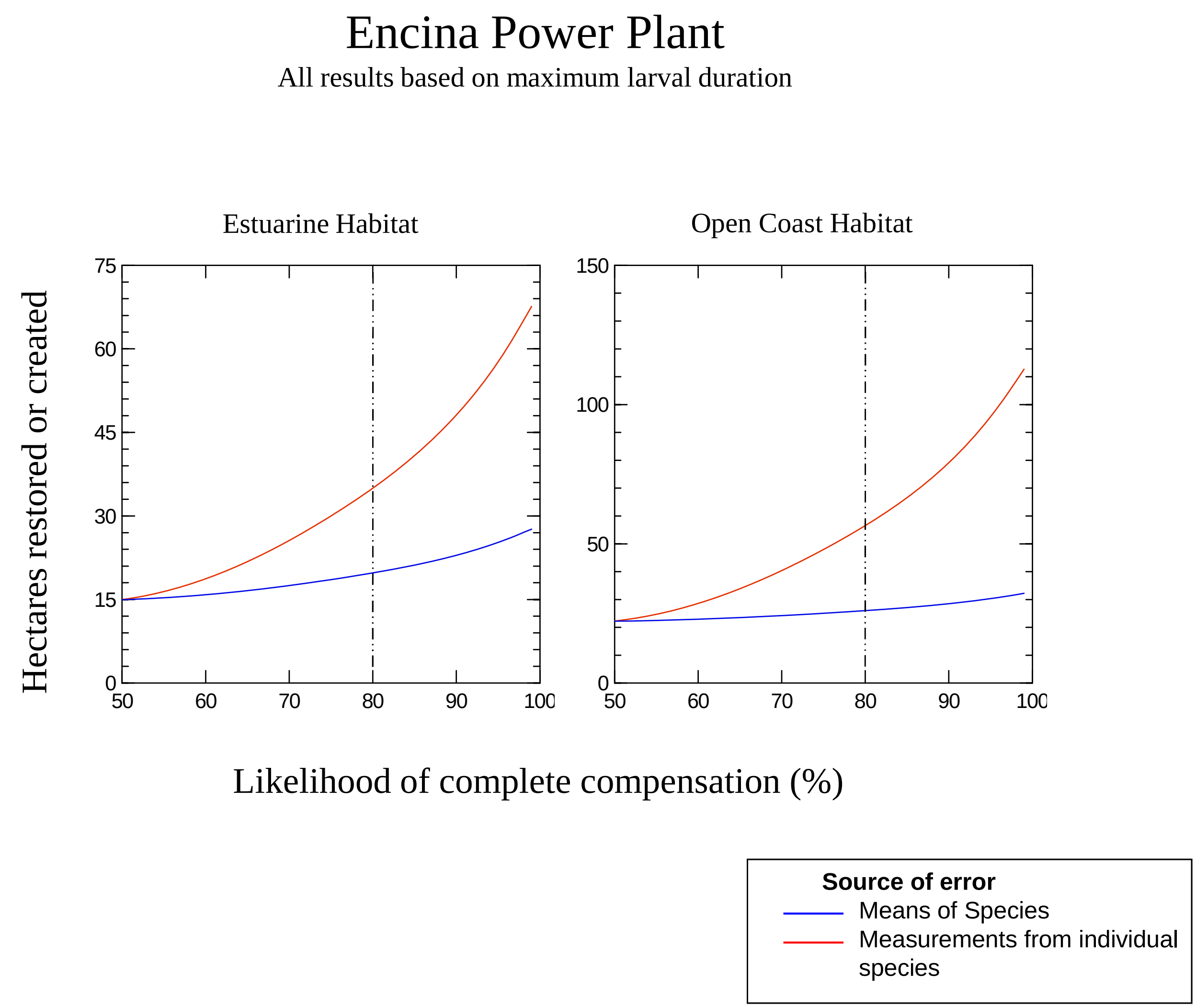

Figure 2b. Likelihood of complete compensation (%) Encina Power Plant.

APA-1

Huntington Beach Generating Station

All results based on maximum larval duration

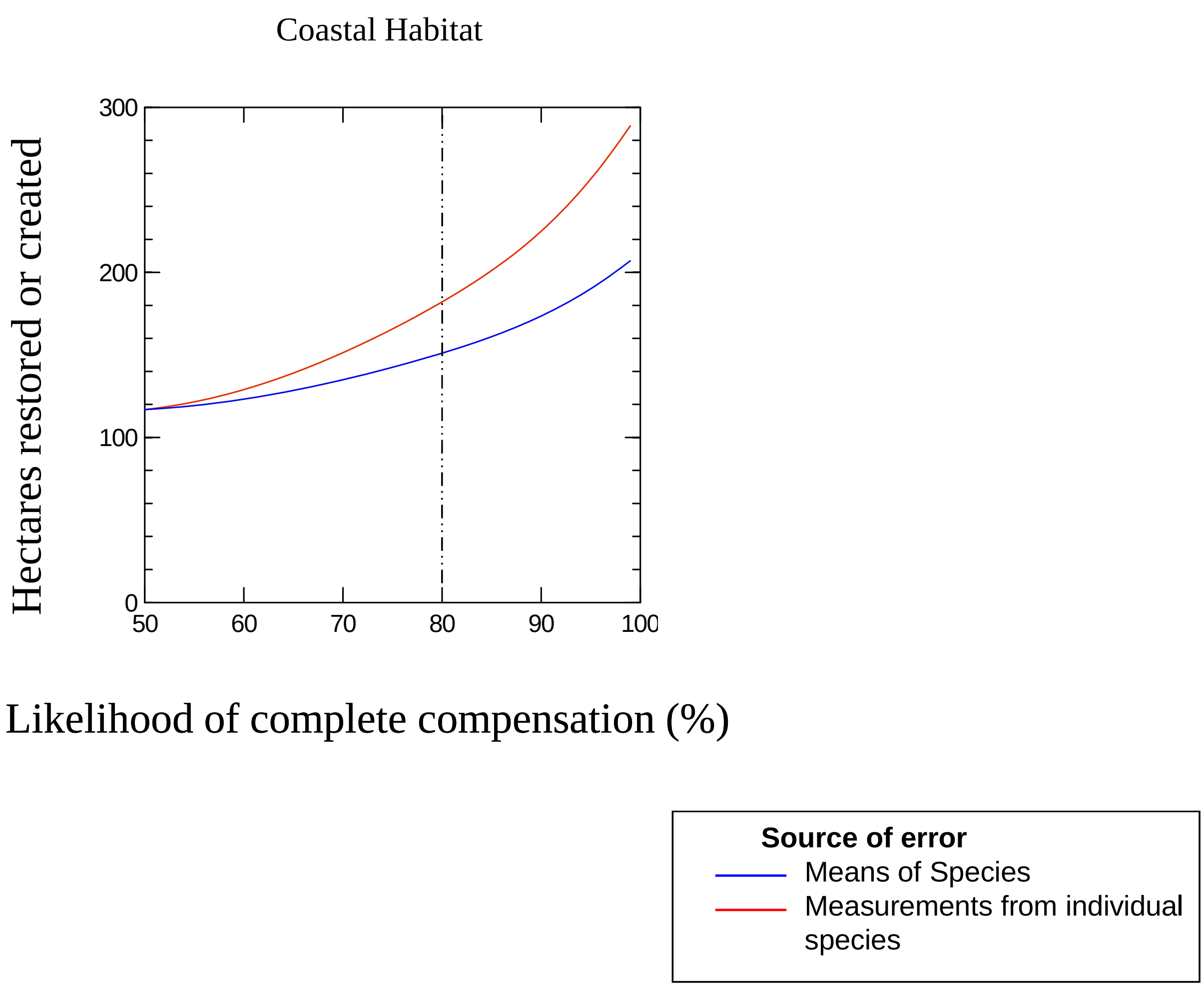

Figure 2c. Likelihood of complete compensation (%) Huntington Beach Generating Station.

APA-1

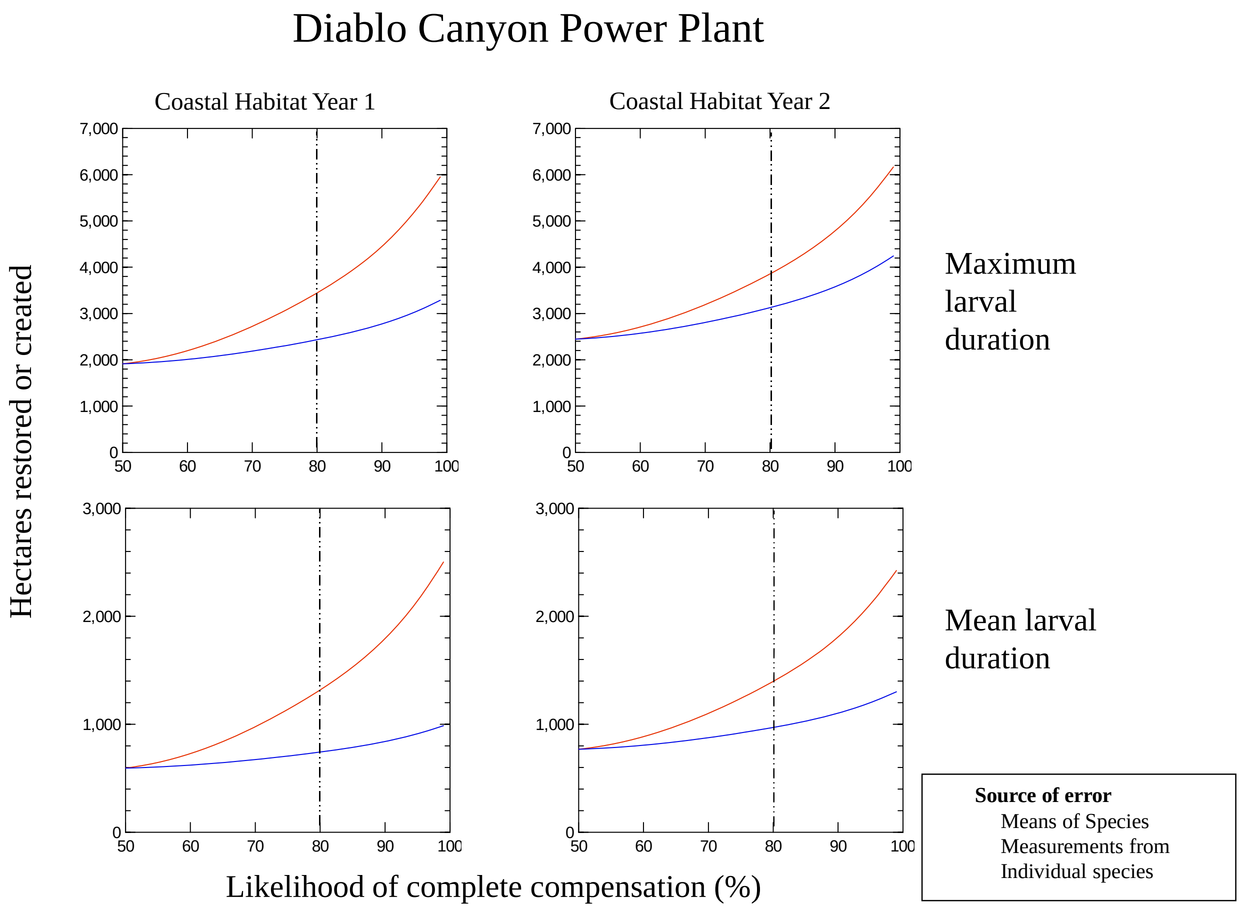

Figure 2d. Likelihood of complete compensation (%) Diablo Canyon Power Plant.

APA-1

Morro Bay Power Plant

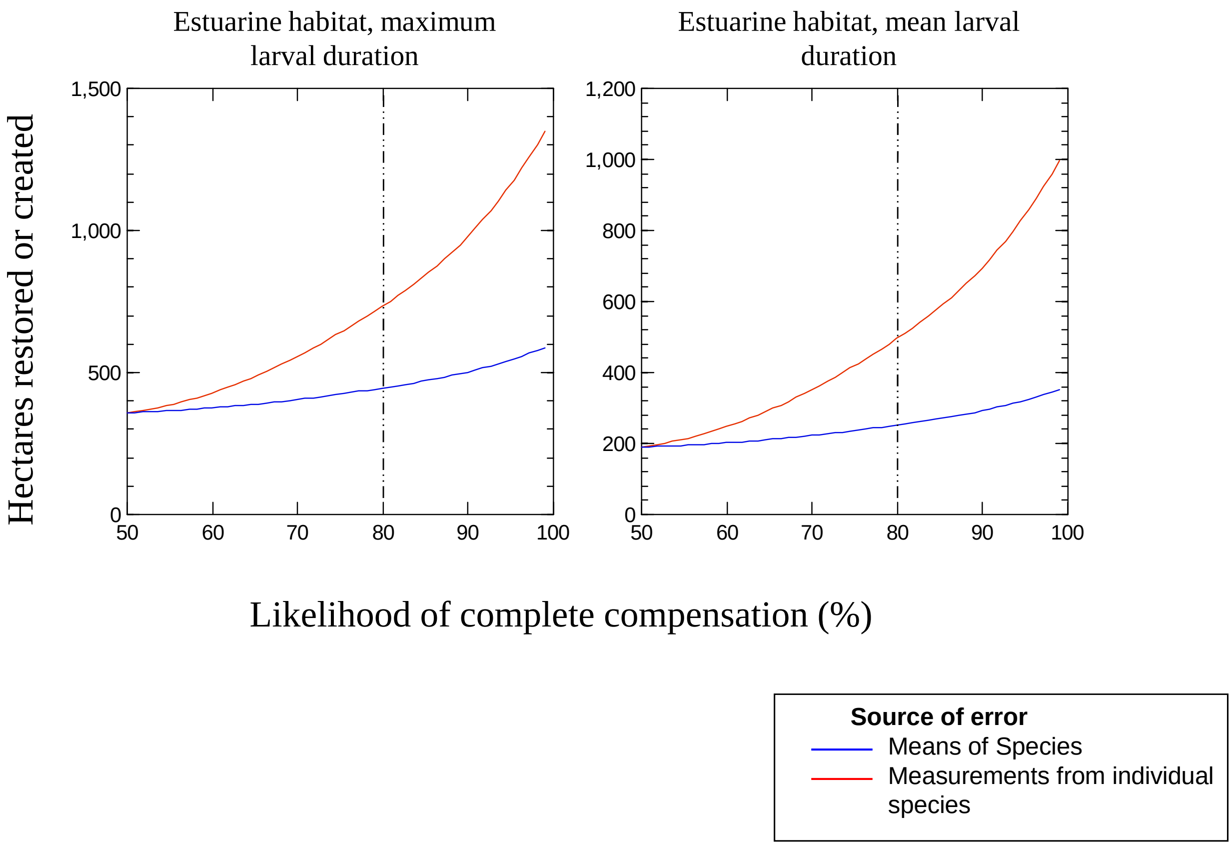

Figure 2e. Likelihood of complete compensation (%) Morro Bay Power Plant.

Moss Landing Power Plant

All results based on *mean* larval duration

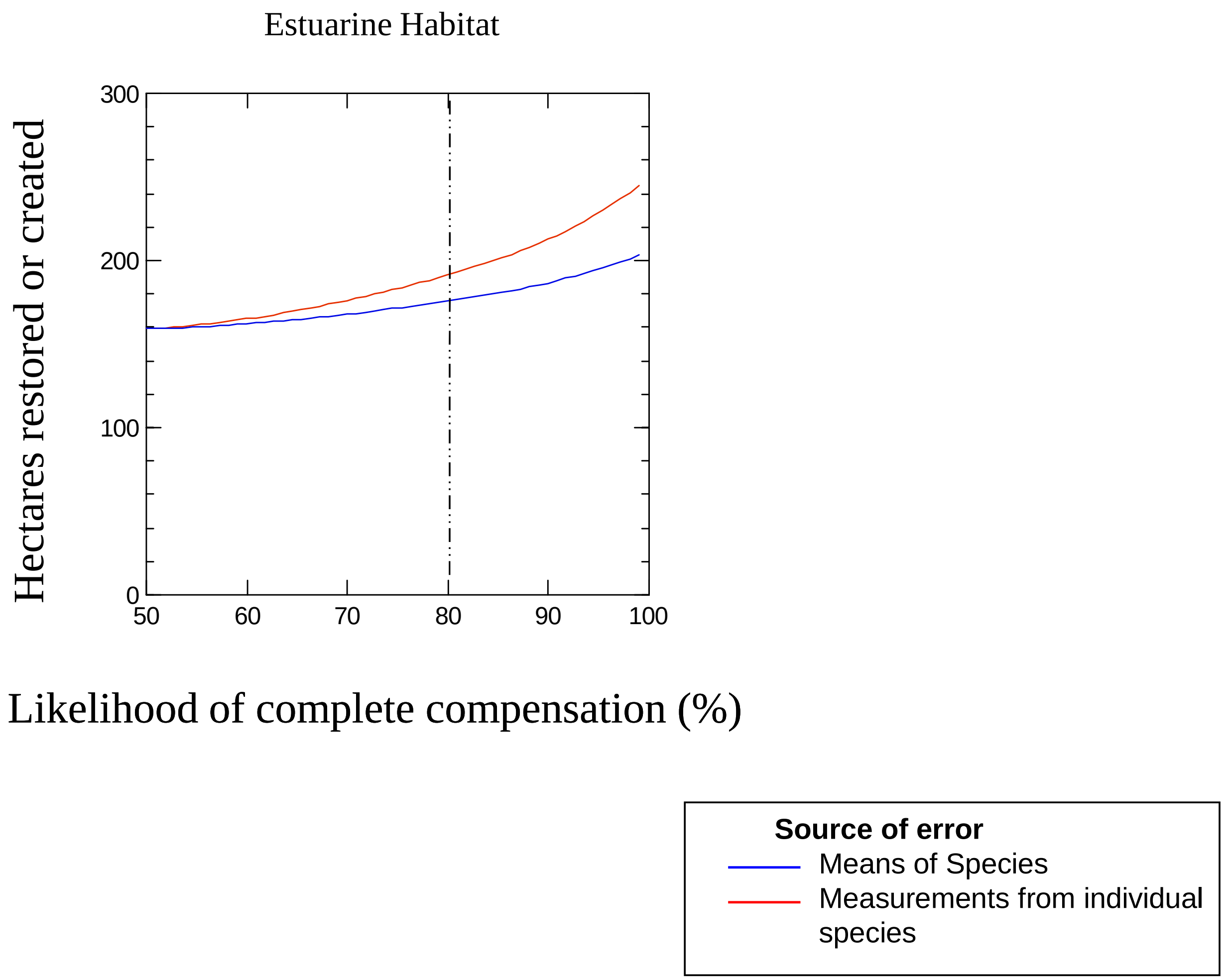

Figure 2f. Likelihood of complete compensation (%) Moss Landing Power Plant.

APA-1

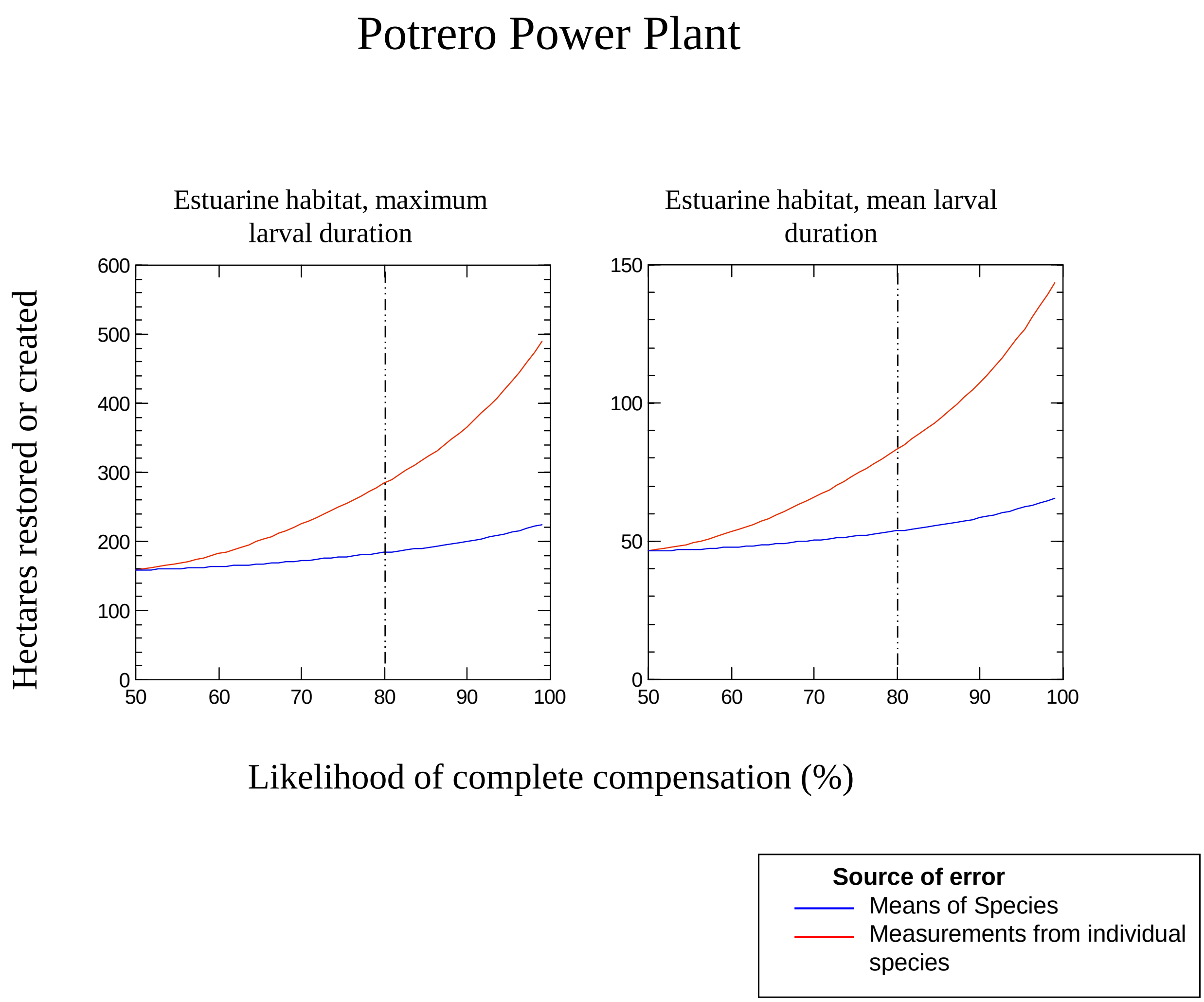

Figure 2g. Likelihood of complete compensation (%) Potrero Power Plant.

Appendix F- Summary Tables of Salinity and Brine Studies

Associated with the Draft Staff Report Including the Draft Substitute Environmental Documentation for the Proposed Desalination Amendment

Table F-1. No observed effect (NOEC), lowest observed effect LOEC, and median effect concentration (EC50) or 25 percent effect concentration (EC25, denoted by the *) for range-finder and definitive tests. Mean EC is the average of the two definitive test results. All results are based on measured salinities in ppt. Modified From Hyper-Salinity Toxicity Thresholds for Nine California Ocean Plan Toxicity Test-Final Report. (Phillips et al. 2012)

Organism	Endpoint	Test	NOEC	LOEC	EC 50	Mean EC
Red Abalone	Development	Range Finder	34	>34	37.8	36.8
		Definitive 1	34.9	35.6	36.4	
		Definitive 2	34.9	35.6	37.1	
Purple Urchin	Development	Range Finder	34	40	36.9	38.1
		Definitive 1	35.5	36.8	37.9	
		Definitive 2	37.4	38.6	38.4	
Sand Dollar	Development	Range Finder	<43	43	37.8	39.6
		Definitive 1	37.7	38.6	39.5	
		Definitive 2	38.1	38.7	39.7	
Sand Dollar	Fertilization	Range Finder	<43	43	39.0	40.3
		Definitive 1	37.6	39.5	41.2	
		Definitive 2	37.6	39.5	39.5	
Mussel	Development	Range Finder	41	42	42.3	43.3
		Definitive 1	<40.2	40.2	42.2	
		Definitive 2	42.2	43.9	44.3	
Purple Urchin	Fertilization	Range Finder	40	47	43.3	44.2
		Definitive 1	41.1	43	44.4	
		Definitive 2	41.6	41.9	44	
Mysid Shrimp	Survival	Range Finder	43	49	50.1	47.8
		Definitive 1	44.9	50.2	48	
		Definitive 2	45.8	49.2	47.7	
	Growth	Range Finder	49	>49	>49*	>49.7*
		Definitive 1	50.2	>50.2	>50.2*	
		Definitive 2	49.2	>49.2	>49.2*	
Giant Kelp	Germination	Range Finder	49	57	59.1	55.5
		Definitive 1	49	54	55.8	
		Definitive 2	44	49	55.2	
	Growth	Range Finder	49	57	52.7*	47.3*
		Definitive 1	<45	45	48.3*	
		Definitive 2	<44	44	46.3*	

Organism	Endpoint	Test	NOEC	LOEC	EC 50	Mean EC
Topsmelt	Survival	Range Finder	56	63	60.2	61.9
		Definitive 1	55	60	60.4	
		Definitive 2	60	65	63.4	
	Biomass	Range Finder	56	63	57.3*	59.3*
		Definitive 1	55	60	57.3*	
		Definitive 2	60	65	61.2*	

Table F-2. No observed effect (NOEC), lowest observed effect (LOEC), and median effect concentration (EC50) or 25 percent effect concentration (EC25) for Monterey Bay Aquarium seawater RO brine effluent tests.

Protocol	Endpoint	NOEC	LOEC	EC50
Mussel	Development	38.8	42.7	43.3
Giant Kelp	Germination	53.0	>53.0	>53.0
	Growth	53.0	>53.0	51.8
Topsmelt	Survival	50.8	>50.8	>50.8
	Biomass	50.8	>50.8	>50.8

Table F-3. Biological impacts of concentrated discharges. Modified from Roberts et al. 2010.

Species	Study Type	Conditions/ Location	Observed Biological Effects	Reference
Seagrass				
Posidonia oceanica	Lab exposure	15-d exposure to 38-43 ppt	Decreased growth after exposure to salinities > 40 ppt; 50% mortality at 45 ppt	Latorre 2005
Posidonia oceanica	Lab exposure	15-d exposure to 23-57 psu	Reduction of vitality and mortality at salinities > 39.1, at 45 psu 50% of plants died	Sánchez-Lisazo et al. 2008
Cympodocea nodosa	Field study	Barranco del Toro Beach, Canary Islands	Decreased presence near outfall discharges. Farther away from the outfall discharge the seagrass improved condition	Perez and Ruiz 2001
Caulerpa prolifera	Field study	Barranco del Toro Beach, Canary Islands	Decreased presence near outfall discharges. Farther away from the outfall discharge the seagrass condition improved	Perez and Ruiz 2001
Posidonia oceanica	Field study	Formentera, Spain	Increased leaf necrosis and decreased carbohydrate storage near discharge site, relative to control locations	Gacia et al. 2007
Posidonia oceanica	Field study	Key West, Florida	Seagrass photosynthesis inhibited after exposure to 12% brines for 24 hours	Chesher 1971
Posidonia oceanica	Field study	Shark Bay, WA	Increased mortality and senescence at salinities of 50-65 ppt	Walker and McComb 1990

Species	Study Type	Conditions/ Location	Observed Biological Effects	Reference
Posidonia oceanica	Field study	Alicante, Spain	Exposed to brines in the field for 3 months. Exposures raised salinity to 38.4-39.2 ppt in experimental plots and caused mortality, surviving plants had reduced shoot and leaf abundance	Sánchez-Lizaso et al. 2008
Posidonia oceanica	Field study	Balearic Islands, Spain	Reduced growth and presence of necrotic tissue in seagrass from transects impacted by brine, but there was no extensive meadow decline	Gacia et al. 2007
Plankton				
	Field study	Key West, Florida	Reduced abundance in water surrounding brine discharge area. Majority of effects attributed copper levels in brine	Chesher 1971
Ascidians				
	Lab exposure	Key West, Florida	Relatively more sensitive than other invertebrates exposed in the study, 50% mortality after exposure to 5.8% effluent	Chesher 1971
	Field study	Key West, Florida	Reduced abundances in areas surrounding brine discharges. Majority of effects attributed to copper levels in brine	Chesher 1971
Mysids				
Leptomysis posidoniae	Lab exposure	15 d exposure to 23-57 psu	Mortality observed at salinities > 40 psu and it was temperature dependent	Sánchez-Lisazo et al. 2008
Echinoderms				
Paracentrotus lividus	Lab exposure	15 d exposure to 23-57 psu	Mortality observed at salinities > 40 psu and it was temperature dependent	Sánchez-Lisazo et al. 2008
	Field study	Alicante, Spain	Disappeared from meadow in front of desalination plant, lower vitality observed in seagrass in the same area	Fernandez-Torquemeda et al. 2005
	Field study	Key West, Florida	Reduced abundances in areas surrounding the effluent discharge area. Majority of effects attributed to copper levels in brine	Chesher 1971
	Lab exposure	Key West, Florida	Reduced survival after exposure to 8.5% dilutions	Chesher 1971
	Field study	Key West, Florida	Died within 2-3 days of exposure, survival improved when copper emissions were reduced following plant maintenance	Chesher 1971
Paracentrotus lividus	Field study	Balearic Islands, Spain	Sea urchins and sea cucumbers absent from transects impacted by brine	Gacia et al. 2007
Mollusks				

Species	Study Type	Conditions/ Location	Observed Biological Effects	Reference
Sepia apama (squid embryos)	Lab exposure	99-d exposure to 39-55 ppt	Total mortality observed after exposure to 50 ppt. Egg hatching decreased at 45 ppt. Reduced growth after exposure to 45 ppt	Dupavillon and Gillanders 2009
Crassostrea virginica (juveniles and adults)	Lab exposure	60-d exposure to 45-55 psu	Brines contained high Cu concentrations. Effects in juveniles and adults observed at Cu levels between 19 -43 ug/L. Effects included, reduced reproduction and increased fungal infections.	Mandelli 1975
Tapes philippinarum (clams)	Lab exposure	0.5-72 h exposure to 31-100 ppt	Mortality found at 60 ppt after 48 hours, sluggish behavior bserved after 24 hours at 60 and 70 ppt.	Iso et al. 1994
Fish				
Pagrus major (juveniles)	Lab exposure	0.5-72 h exposure to 31-100 ppt	Mortality observed at 50 ppt after 24hours, body coloration changed at this salinity after 0.5 hour of exposure.	Iso et al. 1994
Pleuronectes yokohumae (eggs/ larvae)	Lab exposure	0.5-144 h exposure to 31-100 ppt	Larvae mortality at 55 ppt after 140 hours of exposure; egg hatchability was delayed at concentrations > 50 ppt after 73 hours.	Iso et al. 1994
Benthic	**Communities**			
	Field study	Alicante, Spain	Communities close to outfall discharges were dominated by nematodes (up to 98%); polychaetes, mollusks and crustaceans more abundant with increasing distance from discharge	Del Pilar Ruso et al. 2007
	Field study	Alicante, Spain	Reduced polychaete abundance and diversity adjacent to outfall. Ampharetidae and Paraonidae were the most and least sensitive families (respectively)	Del Pilar Ruso et al. 2008
	Field study	Antarctica	A study of diatom communities found reduced richness and abundance in areas receiving brine, even though salinity measurements were not different at outfall and reference locations D46	Crockett 1997
	Field study	Grand Canaria, Canary Islands	A study of meiofauna communities found lower abundance of copepods and nematodes near outfall discharge, abundances increased away from the discharge point. A shift in particle size also contributed to the changes in abundance	Riera et al. 2011

Species	Study Type	Conditions/ Location	Observed Biological Effects	Reference
	Field study	Tampa, Florida	No changes in the abundance of the benthic community including sea grasses, algae, hard and soft corals, and other invertebrates despite salinity increases of up 40 times higher than baseline data	Blake et al. 1996
	Field study	Hurghada, Egypt	Many fish species declined and even disappeared, as well as many planktonic organisms and corals, near the area around the plant	Mabrook 1994
	Field study	Blanes, Spain	No significant impact found by discharges after visual census. Lack of effects attributed to high natural variability and to rapid dilution	Raventos et al. 2006

Appendix G- Economic Analysis

Associated with the Draft Staff Report Including the Draft Substitute Environmental Documentation for the Proposed Desalination Amendment

Economic Analysis of the Proposed Desalination Amendment to the Water Quality Control Plan for Ocean Waters of California

June 2014

Prepared For:
U.S. Environmental Protection Agency
Office of Water
Standards and Health Protection Division
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Contract GS-10F-0146L
BPA-10-03

Table of Contents

List of Exhibits

Abbreviations

APF	Area production foregone
CCC	California Coastal Commission
CDP	Coastal Development Permit
CEQA	California Environmental Quality Act
CWA	Clean Water Act
EIR	Environmental Impact Report
ETM	Empirical transport model
ENR CCI	Engineering News Record Construction Cost Index
gpm	Gallons per minute
MG	Million gallons
mgd	Million gallons per day
MMA	Marine Managed Area
NAICS	North American Industrial Classification System
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and maintenance
Ocean Plan	Water Quality Control Plan for Ocean Waters of California
Porter-Cologne	Porter-Cologne Water Quality Control Act
ppt	Parts per thousand
psu	Practical salinity units
RO	Reverse Osmosis
SIC	Standard Industrial Classification
$scwd^2$	Santa Cruz Water Department and Soquel Creek Water District
State Water Board	State Water Resources Control Board
SWQPA-GP	State Water Quality Protection Areas – General Protection
TDS	Total dissolved solids
ZID	Zone of initial dilution

Executive Summary

The State Water Resources Control Board (State Water Board) is proposing an amendment to the Water Quality Control Plan for Ocean Waters of California (Ocean Plan) addressing sea water intakes and brine disposal from desalination plants. Specifically, the amendment would: (1) define the how the regional water boards will determine the best site, design, technology, and mitigation measures for intakes and discharge outfalls for new or expanded desalination facilities as specified under Porter-Cologne Section 13142.5(b); and (2) establish receiving water limitations for salinity as well as monitoring and reporting requirements for all desalination facilities.

This report presents economic considerations related to the proposed amendment to address provisions under the Porter-Cologne Water Quality Control Act (Porter-Cologne), and the California Environmental Quality Act (CEQA). These considerations include compliance with the requirements, methods to achieve compliance, and the costs of those methods. Compliance actions and costs attributable to the proposed amendment are those that would not likely be incurred under the existing regulatory framework. There are a number of existing regulations addressing the potential impacts associated with intakes and brine discharges from desalination plants, including the Ocean Plan, Porter-Cologne, the CEQA, and the California Coastal Act.

Existing Facilities

Under the proposed amendment, desalination brine discharges may only increase ambient salinity by 2 ppt. The proposed amendment also identifies primary options available for brine discharges from desalination plants to comply with the receiving water limits. These options include discharging raw brine through a multiport diffuser or commingling the brine with treated wastewater for dilution credits. Dischargers must implement the method that is most protective of marine resources based on a comparison of the magnitude of marine life mortality between dilution and discharging raw brine using multiport diffusers, or another proposed discharge technology.

Under existing regulations, dischargers must prevent degradation of marine communities. Most of the current National Pollutant Discharge Elimination System (NPDES) permit requirements for desalination brine are based on facilities providing a minimum dilution ratio or measuring salinity effects based on acute toxicity. There is no numeric-based limit applicable to all brine dischargers. Consequently, under the proposed amendment, dischargers that do not currently have dilution or mixing zone studies indicating less than a 2 ppt increase above ambient salinity or are not currently operating multiport diffusers may incur incremental costs.

Based on conceptual and preliminary estimates from proposed facilities, Abt Associates estimated that capital unit costs for multiport diffusers could range from $0.02 per gallon per day (gpd) to $0.15 per gpd. For operation and maintenance (O&M) costs, Abt Associates estimated average costs of $1.46 per million gallon (MG) treated for activities such as periodic cleaning and inspection of the system.

To estimate incremental statewide costs to existing brine discharges from desalination plants, Abt Associates used information in current NPDES permits on existing discharge controls and conditions and unit costs for multiport diffusers. Thus, estimated incremental annual costs for the 14 existing desalination plants could range from between approximately $1.1 million to $6.6 million.

New and Expanding Plants

The proposed amendment, once adopted, represents the baseline regulatory framework for the development of new desalination facilities. Thus, the timing for adoption will affect the incremental nature of the requirements. However, existing regulations and policies also provide for similar considerations in constructing new desalination capacity. Thus, there may be little change under the proposed amendment.

For example, the Porter-Cologne Section 13142.5(b) requires the regional water board to determine the best site, design, technology, and mitigation measures feasible to minimize the intake and mortality of all forms of marine life at new desalination facilities in California. However, Porter-Cologne does not define or describe best site, design, technology, or mitigation measures. In addition, the California Coastal Commission (CCC) has the authority to delay or reject permits if applicants do not conduct adequate environmental impact assessments for the effects on marine life due to entrainment and impingement. The CCC exercised this authority in November 2013 in voting to delay permitting for Poseidon Resource’s proposed Huntington Beach desalination facility until the company performed a feasibility study for subsurface seawater intake structures. The current plan for the facility uses open ocean intakes, which opponents argue are harmful to marine life (Joyce, 2013).

For mitigation, all entities constructing new or expanded facilities must fully mitigate impacts to marine life, through either in-lieu funding or mitigation under the proposed amendment. Whether this change imposes incremental discharge and intake control costs is uncertain. For example, the CEQA requires entities to mitigate identified significant impacts that cannot be avoided.

Nonetheless, this report provides information on costs associated with subsurface intakes, surface intake screens, multiport diffusers, and mitigation measures. For example, when compared to the cost of surface water intakes, subsurface intakes could decrease total project capital costs by 2% to 9% due primarily to reduced pretreatment costs. Subsurface intakes produce a higher quality feed water that is low in suspended solids and other pollutants, whereas the feed water from surface water intakes must be pretreated to remove foulants prior to the reverse osmosis process.

Surface intake screens could account for up to 1.2% of total project capital and 0.3% of annual total O&M costs. Multiport diffusers could account for up to 0.8% of total project capital and 0.1% of annual total O&M costs.

For mitigation, Foster et al. (2013; Appendix 4) indicates that compensation can be attained for between approximately $36,000 and $154,000 per acre, depending on the water body type.

• Introduction

The State Water Resources Control Board (State Water Board) is proposing an amendment to the Water Quality Control Plan for Ocean Waters of California (Ocean Plan) addressing seawater intakes and brine disposal from desalination facilities. This report presents analysis of economic factors related to the amendment.

o Need for the Proposed Rule

Desalination processes salt water for human use, but can have negative effects on the marine environment. Brine discharged from desalination plants is highly concentrated, and can be toxic to aquatic life within a certain distance of the discharge location. In addition, water intake systems for these facilities can trap and kill fish and other aquatic organisms.

High salt concentrations make desalination brine denser than ocean water, allowing the discharge to settle on the ocean floor and adversely affect the health of benthic ecosystems. Several studies investigating the effects of elevated salinity levels have shown reduced survival rates for sea grasses and other bottom dwelling species, such as sea urchins and sea cucumbers (Gacia et al., 2007; Latorre, 2005; Sánchez-Lizaso et al., 2008).

The reverse osmosis (RO) process used in the majority of desalination plants leaves a variety of chemicals in plant discharges. Chemical additives such as antiscalants and antifoulants are used on intake water to protect membranes utilized in the RO process. Additionally, plants commonly blend the desalination brine with wastewater from plant cooling processes, which has a higher temperature than seawater and can contain a number of other dissolved chemicals. Concentrated doses of these chemicals within plant discharge can have potentially toxic effects on the growth and survival of marine organisms.

Seawater intake structures for desalination plants can be hazardous to aquatic life. Small fish and crustaceans can die from entrainment when they pass through the mesh screens of intake structures and cannot escape. Larger organisms can become impinged to the screens by the suction of the intake.

To address these issues, the State Water Board is proposing limitations on salinity in discharges, and requirements to limit the adverse impacts associated with intake for desalination.

o Scope of the Analysis

The Porter-Cologne Water Quality Act (Porter-Cologne) requires the regional water boards to take “economic considerations,” among other factors, into account when they establish water quality objectives. The other factors include the past, present, and probable future beneficial uses of water; environmental characteristics of the hydrographic unit under consideration; water quality conditions that could reasonably be achieved through the coordinated control of all factors affecting water quality in the area; the need for housing; and the need to develop and use recycled water. The objectives must ensure the reasonable protection of beneficial uses, and the prevention of nuisance.

To meet the economic considerations requirement, the State Water Board (1999; 1994) concluded that, at a minimum, the regional water boards must analyze:

Whether the proposed objective is currently being attained;
If not, what methods are available to achieve compliance; and
The cost of those methods.

If the economic consequences of adoption are potentially significant, the regional water boards must explain why adoption is necessary to ensure reasonable protection of beneficial uses or prevent nuisance. The Boards can adopt objectives despite significant economic consequences; there is no requirement for a formal cost-benefit analysis.[1]

The amendment to the Ocean Plan that the State Water Board is proposing does not include water quality objectives, but rather limitations on water discharges (receiving water limitations) for a particular sector. Nonetheless, to inform policy development, the State Water Board is considering economic factors similar to developing water quality objectives. As such, under a contract with the United States Environmental Protection Agency, Abt Associates provided the State Water Board with an analysis of economic considerations. Specifically, Abt Associates identified potentially affected facilities, likely incremental compliance actions and costs for these facilities under the proposed amendment, and economic factors related to the requirements for the design and construction of future desalination facilities, including mitigation.

o Organization of this Report

This report is organized as follows:

- **Section 2 –** describes the current applicable objectives and requirements that provide the baseline for the analysis of the incremental impact of the amendment.
- **Section 3 –** describes the proposed amendment limitations and implementation.
- **Section 4 –** describes the data we used to identify existing conditions and compliance methods and costs.
- **Section 5 –** describes the method we used to evaluate compliance under the current regulatory framework and the amendment for existing dischargers, and the potential incremental costs of compliance.
- **Section 6 –** discusses the potential for incremental compliance controls under the proposed amendment and presents estimates of unit costs for such controls.
- **Section 7 –** provides the references for the analysis.

Appendices provide detailed information on unit cost estimates (☐) and baseline conditions for existing desalination plants (☐).

[1] Water quality objectives establish concentrations protective of beneficial uses and the fishable/swimmable goals of the Clean Water Act (CWA), and thus are based on science and not economics. Under the CWA, economics can play a role in establishing water quality standards through the analysis of use attainability [removal of a beneficial use which is not an existing use under 40 CFR 131.10(g)]. However, the applicable economic criterion in such an analysis is not efficiency (i.e., maximizing net benefits, based on cost-benefit analysis) but distributional impacts (a determination of whether there will be substantial and widespread economic and social impacts from implementing controls more stringent than those required by sections 301(b) and 306 of the Act). This criterion may also be employed at the local level in the evaluation of temporary variances.

• Baseline for the Analysis

This Section identifies the current framework for regulating the quality of ocean waters in California. The current regulatory framework is the baseline against which the cost changes associated with the Amendment should be assessed. Thus, only costs that are greater or less than the costs associated with the baseline (i.e., incremental costs) would be attributable to the proposed amendment.

Several existing regulations address the potential impacts associated with desalination plants, including the Ocean Plan, Porter-Cologne, the Coastal Act discussed below. The CEQA requires environmental review of projects subject to government approvals, including desalination plant operation, construction, and expansion.

o Ocean Plan

The Ocean Plan does not currently contain objectives or receiving water limitations specific to salinity. However, it does require dischargers of desalination brine to monitor salinity as part of their core monitoring programs.

The Ocean Plan has provisions applicable to new and existing seawater intakes within a state water quality protection area for general protection (SWQPA-GP). For example, for existing permitted seawater intakes with capacity greater than one million gallons per day (mgd), the Ocean Plan requires controls to minimize entrainment and impingement by using best technology available. For new seawater intakes, the Ocean Plan prohibits open ocean intakes within SWQPA-GP; the plan allows new sub-seafloor intakes in these areas where studies indicate that there is no predictable entrainment or impingement of marine life. The Ocean Plan does not currently prohibit or regulate new or existing seawater intakes outside of SWQPA-GPs.

o Porter-Cologne Water Quality Control Act

For new or expanded coastal power plant or other industrial installation using seawater for cooling, heating, or industrial processing, Porter-Cologne Section 13142.5(b) requires use of the best available site, design, technology, and mitigation measures feasible to minimize the intake and mortality of all forms of marine life. However, Porter-Cologne does not define feasible.

o California Coastal Act

The Coastal Act contains narrative requirements related to protection of marine organisms and the marine environment. For example, Section 30230 requires marine resources to be maintained, enhanced, and where feasible, restored with special protection given to areas and species of special biological or economic significance. Uses of the marine environment must be carried out in a manner that will sustain the biological productivity of coastal waters, and that maintains healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.

In addition, Section 30231 requires the biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health to be maintained and, where feasible, restored. This may be accomplished through the following, among other means:

- Minimizing adverse effects of waste water discharges and entrainment;
- Controlling runoff;
- Preventing depletion of ground water supplies and substantial interference with surface water flow;
- Encouraging waste water reclamation;
- Maintaining natural vegetation buffer areas that protect riparian habitats; and
- Minimizing alteration of natural streams.

The Coastal Act also permanently established the California Coastal Commission (CCC), which has the mission to protect, conserve, restore, and enhance environmental and human-based resources of the California coast and ocean for environmentally sustainable and prudent use by current and future generations. In cooperation with local governments, the CCC regulates development (including construction, land division, and other activities that change the intensity of land use) in the coastal zone. In most cases, any new development project requires a Coastal Development Permit, which is issued by either the CCC or an authorized local government. As part of the permit application, entities must submit an Environmental Impact Report (see Section 2.4) for review if one is prepared.

o California Environmental Quality Act

The state legislature enacted the CEQA in 1970 as a system of checks and balances for land-use development and management decisions. The CEQA applies to entities undertaking projects defined in the act as an activity that:

- is undertaken by a public agency, or a private activity which must receive some discretionary approval from a government agency (meaning that the agency has the authority to deny the requested permit or approval) and
- may cause either a direct physical change in the environment or a reasonably foreseeable indirect change in the environment.

For example, the CEQA requires at least some environmental review of every development project subject to governmental approval, unless an exemption applies.

The CEQA requires the responsible entity to identify, avoid, and mitigate adverse environmental effects of the proposed Desalination Amendment. For all projects, the entity must determine whether the potential impacts of a project may be significant (defined as a substantial adverse change in the physical conditions which exist in the area affected by the proposed Desalination Amendment). Depending on this determination, the entity prepares one of the following documents:

- A Negative Declaration if no significant impacts will occur,
- A Mitigated Negative Declaration if the original project would have significant effects, but the agency revises it to avoid or mitigate the effects, or
- An Environmental Impact Report (EIR), if it finds significant impacts.

When an EIR shows that a project will have significant effects, the entity must demonstrate how these effects have been avoided, minimized, or mitigated through project design changes, selection of alternatives, or disproval of project.

The CEQA Guidelines define “mitigation” as including, in order of preference (CEQA Section 15370): 1) avoiding the impact altogether by not taking a certain action or parts of an action, 2) minimizing the impact by limiting the degree or magnitude of the action and its implementation, 3) rectifying the impact by repairing, rehabilitating, or restoring the impacted environment, 4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action, or 5) compensating for the impact by replacing or providing substitute resources or environments. If the significant effects are unavoidable, the agency must demonstrate that it is acceptable through a Statement of Overriding Considerations in balancing the economic, legal, social, technological, and other factors.

- **Summary**

As described above, there are existing regulations applicable to the discharge of wastes and intake structures for both existing and new desalination plants. However, the provisions are generally narrative, and may result in inconsistencies in permitting or controls across the state. For example, none of the regulations establish numeric objectives for salinity in ocean waters. The regulations only require that marine life be sustained and protected where feasible, but do not specify design considerations or control measures that must be considered.

• Description of the Proposed Amendment

This Section describes the implementation requirements of the proposed amendment which defines the how the regional water boards will determine the best site, design, technology, and mitigation measures for each new or expanded desalination facility as specified under Porter-Cologne Section 13142.5(b). The amendment also establishes receiving water limitations for salinity as well as monitoring and reporting requirements for all desalination facilities.

o Applicability

The proposed amendment applies to seawater desalination plants in California, and defines these facilities in terms of existing, new, or expanded.

Existing facilities are those that have permits and have at least commenced construction of the facility beyond site grading.

Expanded facilities are existing facilities for which the owner or operator does either of the following in a manner that could increase intake or mortality of marine life: 1) increases the amount of seawater used either exclusively by the facility or used by the facility in conjunction with other facilities or uses, or 2) changes the design or operation of the facility after the effective date of the amendment.

New facilities are facilities that do not meet the definition of existing or expanding facilities.

o Site, Design, Technology, and Mitigation Measures Feasibility Considerations

For each new or expanded facility, the regional water board shall analyze a range of feasible alternatives for the best site, design, technology, and mitigation measures, and determine the best combination to minimize intake and mortality of marine life. The Board’s analysis for expanded facilities will be limited to those expansions or other changes that result in the increased intake or mortality of marine life, unless the regional water board determines that additional measures that minimize intake and mortality of marine life are feasible for the existing portions of the facility.

▪ Site

Site is the general onshore and offshore location of a new or expanded facility. The regional water board requires the owner or operator of a new or expanded facility to:

Analyze the feasibility of subsurface intakes, including whether proposed design capacity is consistent with regional water needs;

Analyze the feasibility of placing intake, discharge, and other facility infrastructure in a location that avoids impacts to sensitive habitats and sensitive species;

Analyze the direct and indirect effects on marine life resulting from facility construction;

Analyze operation, oceanographic, bathymetric, geologic, hydrogeologic, and seafloor topographic conditions;

Analyze the presence of existing infrastructure and the availability of wastewater to dilute the facility’s brine discharge;

Ensure that the facility is sited a sufficient distance from any Marine Protected Areas (MPA) or State Water Quality Protection Areas (SWQPA).

- **Design**

Design is the layout, form, and function of a facility, including the configuration and type of infrastructure, including intake and outfall structures. The regional water board requires the owner or operator of each facility to:

Analyze the potential design configurations of the intake, discharge, and other facility infrastructure to avoid impacts to sensitive habitats and sensitive species;
If a surface intake is proposed, the regional board requires an analysis of potential designs in order to minimize entrainment and the Area Production Forgone (APF);
Ensure that intake and discharges are located a sufficient distance from a MPA or SWQPA so that the salinity within the boundaries of a MPA or SWQPA does not exceed natural background salinity;
Design the outfall so that the brine mixing zone does not encompass or otherwise adversely affect existing sensitive habitat;
Perform plume modeling and/or field studies to show that discharges do not result in dense, negatively-buoyant plumes that result in adverse effects due to elevated salinity or anoxic conditions occurring outside the brine mixing zone;
Design outfall structures to minimize the suspension of benthic sediments.

- **Technology**

Technology is the type of equipment, materials, and methods that are used to construct and operate the design components of the desalination facility. The regional water board shall apply the following considerations in determining whether a proposed technology best minimizes intake and mortality of marine life:

- **Intake technology:**
  - The regional water board shall require subsurface intakes unless it determines that subsurface intakes are infeasible based on an analysis of approved criteria;
  - Installation and maintenance of subsurface intakes shall avoid, to the maximum extent feasible, the disturbance of sensitive habitats and sensitive species;
  - Surface water intakes must be screened with a 0.5 mm (0.02 in) or smaller slot size screen. An alternate method of preventing entrainment can be used if the facility demonstrates that it provides an equivalent level of protection using a study with Empirical Transport Model (ETM)/ Area of Production Forgone (APF) approach;
  - In order to minimize impingement, through-screen velocity at the surface water intake shall not exceed 0.15 meters per second (0.5 feet per second).
- **Discharge technology:**
  - The preferred technology for minimizing intake and mortality of marine life resulting from brine disposal is to commingle brine with wastewater that would otherwise be discharged to the ocean, unless the wastewater is of suitable quality and quantity to support domestic or irrigation uses. Multiport diffusers are the

next best method for disposing of brine when the brine cannot be diluted by wastewater and when there are no live organisms in the discharge;
  - The regional water board shall require the owner or operator to analyze the brine disposal technology or combination of brine disposal technologies that best reduce the effects of the discharge of brine on marine life;
  - Other brine disposal technologies may be used if an owner or operator can demonstrate to the regional water board that the technology provides a comparable level of protection;
  - An owner or operator proposing to use flow augmentation as an alternative brine discharge technology must use low turbulence intakes and conveyance pipes and convey and mix dilution water in a manner that limits thermal stress, osmotic stress, turbulent shear stress, and other factors that could cause marine life mortality. Within three years of beginning operation the facility must submit to the regional water board an empirical study showing that the intake and mortality of marine life associated with flow augmentation is equal to or more protective than a facility using wastewater dilution or multiport diffusers. If the report shows it is less protective, the facility must either cease flow augmentation or re-design the flow-augmentation system. Facilities proposing to using flow augmentation through surface intakes are prohibited from discharging through multiport diffusers.

Mitigation

Mitigation is the replacement of marine life or habitat that is lost due to the activity of a desalination facility after minimizing marine life mortality through site, design, and technology measures. The regional water board requires the following mitigation measures:

- A Marine Life Mortality Report that projects the marine life mortality resulting from operation and construction of the facility after implementation of the facility's required site, design, and technology measures;
- The owner or operator shall mitigate for the marine life mortality determined in the report above by choosing to either complete a mitigation project or provide in-lieu funding.
  - **Mitigation Project:** The project must accomplish mitigation through the expansion, restoration, or creation of kelp beds, estuaries, coastal wetlands, natural reefs, MPAs, or other projects approved by the regional water board. The owner or operator must demonstrate that the project fully mitigates for intake-, discharge-, and construction-related marine life mortality. Intake-related marine life mortality must be mitigated using acreage that is at least equivalent in size to the APF calculated in the Marine Life Mortality Report. For every acre of discharge and construction-related disturbance, the owner or operator must restore one acre of habitat unless the regional water board determines that a greater than 1:1 ratio is needed.
  - **In-lieu Funding:** Instead of a project, the owner or operator may choose to provide funding to a mitigation program run by an approved public agency. The

amount of the fee associated with this option will depend on the cost of the mitigation project, or on the particular desalination facility's share of the cost. The mitigation program must result in the creation and ongoing implementation of a mitigation project that meets the requirements described for the first mitigation option and best compensates for intake and mortality of marine life caused by the facility.

o Receiving Water Limitations

The proposed amendment states that existing discharges of brine from desalination plants shall not exceed 2 parts per thousand (ppt) above natural background salinity, to be measured as total dissolved solids (TDS) no more than 100 meters (328 ft) horizontally from the discharge.

An owner or operator may submit a proposal to the regional water board for approval of an alternative salinity receiving water limitation. The facility-specific alternative receiving water limitation shall be based on the no observed effect level (NOEL) for the most sensitive species and toxicity endpoint as determined by chronic toxicity studies. The regional water board may require additional toxicity tests, information, or studies if needed. The regional water board may eliminate or revise a facility-specific alternative receiving water limitation for salinity based on a facility's monitoring data, the results from their Before-After Control-Impact (BACI) study, or other relevant information.

Existing facilities that do not meet the receiving water limitation at the edge of the brine mixing zone and throughout the water column must come into compliance by establishing a facility-specific alternative receiving water limitation for salinity as described above, or updating their brine discharge method to meet the 2 ppt limit.

o Monitoring and Reporting Programs

Owners and operators of desalination plants must submit a Monitoring and Reporting Plan to the regional water board for approval. The Monitoring and Reporting Plan shall, at a minimum, include monitoring for benthic community health, aquatic life toxicity, and receiving water characteristics. Receiving water monitoring for salinity shall be conducted at times when the monitoring locations are most likely affected by the discharge. New and expanded facilities must perform facility-specific monitoring to demonstrate compliance with the receiving water limitation for salinity, and evaluate the potential effects of the discharge within the water column, bottom sediments, and the benthic communities until the regional water board determines that the program is adequate to ensure compliance with the receiving water limitation. These facilities must also establish baseline biological conditions prior to discharge by conducting Before-After Control-Impact (BACI) biological surveys prior to commencement of construction.

• Data for the Analysis

To estimate the potential costs of implementing the proposed amendment, Abt Associates identified existing discharge conditions for National Pollutant Discharge Elimination System (NPDES)-permitted brine dischargers, the types of controls facilities may implement under the proposed amendment for compliance with the discharge and intake provisions, and the cost of those controls. Abt Associates relied on publicly available data sources for these analyses, as described below.

o Existing Facility Discharge Conditions

The State Water Board provided Abt Associates a list of potentially affected existing facilities discharging brine wastes to surface waters. Abt Associates used information in NPDES permits/fact sheets, State Water Board meeting minutes, and municipal websites to determine the facility type (e.g., desalination facility discharging to ocean waters), discharge flow, current effluent or receiving water limitations, the basis for limitations (e.g., results of mixing zone studies), monitoring requirements related to salinity, and outfall configuration (e.g., discharging through a multiport diffuser or commingled with another waste stream for dilution).

o Compliance Methods and Costs

Abt Associates relied primarily on feasibility studies and conceptual design reports for proposed desalination facilities in California to identify the types of controls that would enable compliance with the proposed amendment and the cost of those controls. The cost estimates generally represent conceptual level estimates, with reported accuracies ranging from -30% to +50%. The cost estimates also include varying contingency, installation, and other add-ons costs. Thus, there may be a significant range in unit costs for certain controls.

For mitigation costs, Abt Associates relied on the final report from the expert review panel (Foster, et al., 2013) submitted to the State Water Board in October 2013. The report estimates mitigation costs based on the cost of replacing the marine life or habitat lost by producing new, equivalent habitat, restoration that replaces the lost production, or other projects deemed equivalent.

• Potential Compliance and Costs: Existing Facility Requirements

This Section describes the method for evaluating current compliance with the amendment, identifies available compliance methods, and provides estimates of potential incremental compliance costs to existing dischargers.

o Overview of Method

The estimated compliance costs represent the cost of the incremental level of control above and beyond those activities already required under the existing regulatory framework. The method for evaluating potential impacts involves determining whether existing controls are sufficient for compliance with the proposed amendment, identifying the incremental compliance activities or controls needed to meet the provisions in the proposed amendment, and estimating the associated costs of those activities and controls.

o Affected Dischargers

Based on information provided by the State Water Board, Abt Associates has identified 13 existing seawater desalination facilities to which the proposed amendment would apply (**Exhibit 12-1**). This list does not include plants with NPDES permits that are not currently under construction (e.g., Huntington Beach Desalination Plant) or pilot/demonstration plants for full scale operations yet to be constructed.

Exhibit 12-1: Existing Seawater Desalination Plants in California

NPDES ID	Desalination Facility Name[1]	SIC Code	Brine Discharge (mgd)	Total Discharge (mgd)
CA0003751	PG&E, Diablo Canyon	4911	1.44	2540
CA0050016	Ocean View Plaza	4941	0.116	0.116
CA0061191	Pebble Beach Desalination Plant	4941	NS	0.72
CA0061794	US Navy, San Nicholas	4941	NS	0.067
CA0064564	Naval Base Ventura County	4941	NS	0.95
CA0109223	Carlsbad Desalination Project[2]	4941	54	540.5
CAG993001	City of Morro Bay	4941	0.9	0.9
CAG993001	Chevron, Gaviota	4941	0.14	1.2
CA0048143	Santa Barbara	4952	12.5	23.5
CA0107417	South Orange County Wastewater Authority - San Juan Creek Ocean Outfall	4952	2.8	38.78
CA0107433	City of Oceanside	4952	2	21
CA0107611	South Orange County Wastewater Authority - Aliso Creek Ocean Outfall	4952	1	34
CAG993003	Monterey Bay Aquarium	8422	0.04	>0.04

mgd = million gallons per day
NPDES ID = National Pollutant Discharge Elimination System Identification
NS = not specified
SIC = Standard Industrial Classification
1. Does not include NPDES-permitted plants that have not yet been constructed (e.g., Huntington Beach Desalination Facility).
2. Currently under construction.

o Compliance Methods and Costs

Under the proposed amendment, desalination brine discharges may only increase ambient salinity by 2 ppt. The proposed amendment identifies the primary options available for brine discharges from desalination plants to comply with the receiving water limits, including discharging raw brine through a multiport diffuser or commingling the brine with treated wastewater for dilution credits. Dischargers must implement the method that is most protective of marine resources based on a comparison of the magnitude of marine life mortality between dilution and discharging raw brine using multiport diffusers, or other proposed discharge technology.

Under existing regulations, dischargers must prevent degradation of marine life. Most of the current NPDES permits requirements for desalination brine are based on facilities providing a minimum dilution ratio or measuring salinity effects based on acute toxicity. There is no numeric-based limit applicable to all brine dischargers. Thus, under the proposed amendment, facilities that do not currently have dilution or mixing zone studies indicating less than a 2 ppt increase above ambient salinity or are not currently operating multiport diffusers may incur incremental costs.

Abt Associates based estimates of potential incremental costs to existing desalination brine dischargers on costs associated with multiport diffusers because the availability and necessary quantities of dilution water is site-specific. **Exhibit 12-2** provides a summary of unit cost estimates from planned desalination plants in California.

Exhibit 12-2: Unit Cost Estimates for Multiport Diffusers

Location	Source	Project Costs (2013$)		Flow (mgd)[1]	Unit Costs (2013$)	
		Capital	Annual O&M		Capital ($/gpd)[2]	O&M ($/MG)[3]
Camp Pendleton	Malcolm Pirnie (2008)	$21,943,658	$73,230	150.0	$0.15	$1.34
Monterey Peninsula Water Supply Project	Leeper and Naranjo (2013)	$516,684		13.4	$0.04	-
West Basin, 20 mgd[4]	WBMWD (2013)	$952,676	$16,655	20.0	$0.05	$2.28
West Basin, 60 mgd[4]	WBMWD (2013)	$1,103,802	$16,655	60.0	$0.02	$0.76

gpd = gallon per day
MG = million gallons
mgd = million gallons per day
O&M = operation and maintenance
1. Represents the total flow of the waste discharge.
2. Calculated by dividing project capital costs by flow in gpd (mgd × 1,000,000).
3. Calculated by dividing annual project O&M costs by flow and 365 days per year.
4. Costs represent average for El Segundo and Redondo Beach sites.

A number of site-specific factors can affect the design of a diffuser. For example, the Camp Pendleton desalination plant design is broken up into three phases with the first for 50 mgd, and each subsequent phase adding an additional 50 mgd, up to 150 mgd. To accommodate this variability in flow, the facility proposal includes a specially designed Y-shaped diffuser. The facility will be able to close one branch of the "Y" during periods of low flow and open it when the facility is operating at full capacity (Malcolm Pirnie, 2008). Conversely, feasibility studies for the 2 potential 60 mgd desalination plants to service the West Basin Municipal Water District indicate that a conventional single multiport diffuser design would provide sufficient dilution and capacity.

Characteristics of receiving waters can also influence diffuser design. An analysis of the expected brine salinity and ocean currents at the West Basin facilities showed that 5-port diffusers would meet ambient salinity requirements, whereas Camp Pendleton's diffuser is designed to have 130 ports even though the flows differ by only a factor of 3 (WBMWD, 2013).

Lastly, the cost estimate in **Exhibit 12-2** are conceptual and preliminary, and include varying add-on factors such as installation/mobilization, contingencies, legal and administrative fees, professional or engineering fees, contractor overhead and profit, etc. Details for the individual unit cost calculations are in ☐. Given the numerous site-specific factors affecting costs and the significant range in capital unit costs (i.e., an order of magnitude between the high and low estimates), Abt Associates used the range of capital unit costs to estimate the potential incremental impacts to existing desalination brine dischargers, $0.02 per gallon per day (gpd) to $0.15 per gpd.

For operations and maintenance (O&M) costs, Abt Associates used an average of $1.46 per MG treated because the maintenance activities for multiport diffusers are typically similar regardless of diffuser design (e.g., periodic cleaning and inspection of the system).

o Statewide Costs

Abt Associates used information in current NPDES permits on existing discharge controls and conditions to determine which existing desalination plants in California may incur incremental costs to comply with the brine discharge provisions in the proposed amendment. Appendix B provides detailed baseline information for each facility for this evaluation.

Abt Associates estimated annual costs based on the unit cost estimates presented in Section ☐0, and the facility-specific flows shown in **Exhibit 12-3**. Annual costs include capital costs annualized at 5% over 20 years plus annual O&M costs. The annualization rate is based on interest rates for the Carlsbad desalination facility currently under construction. WBMWD (2013) indicates that the useful life of a diffuser is approximately 20 years. As shown in the exhibit, incremental annual costs could range between approximately $1.2 million and $6.8 million.

Exhibit 12-3: Potential Incremental Compliance Costs for Existing Desalination Plants

NPDES ID	Facility Name	Flow (mgd)		Incremental Controls Needed	Rationale	Multiport Diffuser Costs		
		Brine	Total			Capital[1]	Annual O&M[2]	Annualized Costs[3]
CA0003751	PG&E, Diablo Canyon	1.44	2540	No	Commingled (brine 0.06% of effluent)	$0	$0	$0
CA0050016	Ocean View Plaza	0.116	0.116	No	Diffuser; dilution study indicates ambient salinity increase < 2ppt	$0	$0	$0
CA0061191	Pebble Beach Desalination Plant	NS	0.72	Possibly	Rip rap slope	$14,400 to $108,000	$400	$1,600 to $9,100
CA0061794	US Navy, San Nicholas	NS	0.067	No	Low volume discharged via dispersion through sand	$0	$0	$0
CA0064564	Naval Base Ventura County	NS	0.95	No	Commingled with permeate (pass-through water)	$0	$0	$0
CA0109223	Carlsbad Desalination Plant	54	540.5	Possibly	No diffuser; dilution study indicate increase in ambient salinity > 2ppt	$10,810,000 to $81,075,000	$288,000	$1,155,400 to $6,793,700
CAG993001	City of Morro Bay	0.9	0.9	No	Diffuser system; general permit justification indicates discharge at or below seawater salinity	$0	$0	$0
CAG993001	Chevron, Gaviota	0.14	1.2	No	Commingled with diffuser	$0	$0	$0
CA0048143	Santa Barbara	12.5	23.5	No	Commingled with diffuser; intermittent	$0	$0	$0
CA0107417	South Orange County Wastewater Authority - San Juan Creek Ocean Outfall	2.8	38.78	No	Commingled with diffuser	$0	$0	$0

Exhibit 12-3: Potential Incremental Compliance Costs for Existing Desalination Plants

NPDES ID	Facility Name	Flow (mgd)		Incremental Controls Needed	Rationale	Multiport Diffuser Costs		
		Brine	Total			Capital[1]	Annual O&M[2]	Annualized Costs[3]
CA0107433	City of Oceanside	2	21	No	Commingled with diffuser	$0	$0	$0
CA0107611	South Orange County Wastewater Authority - Aliso Creek Ocean Outfall	1	34	No	Commingled with diffuser	$0	$0	$0
CAG993003	Monterey Bay Aquarium	0.04	>0.04	No	Commingled; permit indicates effect of brine on salinity negligible	$0	$0	$0
Total	NA	A	A	NA	NA	$10,824,400 to $81,183,000	$288,400	$1,157,000 to $6,802,800

mgd = million gallons per day
NA = not applicable
NPDES ID = National Pollutant Discharge Elimination System Identification
NS = not specified
O&M = operations & maintenance
1. Total flow in gpd multiplied by $0.02 per gpd to $0.15 per gpd.
2. Total flow multiplied by $1.46 per MG and 365 days per year.
3. Capital costs annualized at 5% over 20 years plus annual O&M costs.

o Limitations and Uncertainties

Limited facility-specific information is available from current NPDES permits (e.g., not enough detail on the outfall structure, limited data on available dilution/mixing zone). Thus, the estimates of the potential incremental costs may over- or underestimate actual compliance costs. For example, relatively low cost dilution options such as combining brine discharge with a nearby wastewater treatment plant effluent could reduce compliance costs. Site-specific factors could result in higher or lower unit costs for installation of multiport diffusers than those presented in **Exhibit 12-3**.

• Potential Compliance and Costs: New and Expanded Plant Requirements

The proposed amendment, once adopted, represents the baseline regulatory framework for the development of new desalination facilities. Thus, the timing of adopting the proposed amendment will determine whether the requirements are baseline or incremental for any particular entity. This Section discusses current plans for additional desalination capacity, methods of compliance with the proposed amendment, and costs of the required activities and controls.

o New and Expanding Plants

The State Water Board has identified plans for a number of desalination plants that may meet the definition of new or expanded, depending on the effective date of the amendment. For example, Poseidon Resources has obtained local land use permits for the Huntington Beach facility but has not yet received a Coastal Development Permit (CDP) from the CCC. Thus, construction of the plant has been delayed until Poseidon Resources can conduct additional studies on environmental impacts. The West Basin Water District is also working towards compliance requirements for a CDP and NPDES permit for a desalination plant for which it has yet to receive approval. Since there are numerous efforts underway to conceptualize, plan, and design new and expanded plants, it is not feasible to identify all such activity.

o Potential Compliance with the Proposed Amendment

Under the proposed amendment, entities constructing new and expanded desalination plants need to utilize subsurface intake structures where feasible. If an applicant demonstrates to the satisfaction of the Regional Board that a subsurface intake is not feasible, the applicant may utilize a surface water intake after demonstrating a level of biological protection equivalent to or better than a subsurface intake and after taking mitigation measures into account. At minimum, surface water intakes would need to include intake screens.

Currently Porter-Cologne Section 13142.5(b) requires the regional water board to determine the best site, design, technology, and mitigation measures feasible to minimize the intake and mortality of all forms of marine life at new desalination facilities in California. However, Porter-Cologne does not define or describe best site, design, technology, or mitigation measures.

In addition, the CCC has the authority to delay or reject permits if applicants do not conduct adequate environmental impact assessments for the effects on marine life due to entrainment and impingement. For example, in November 2013, the CCC voted to delay permitting for the Huntington Beach desalination facility until the company performed a feasibility study for subsurface seawater intake structures. The current plan for the plant uses open ocean intakes, which opponents argue are harmful to marine life (Joyce, 2013).

Thus, there is uncertainty regarding whether the proposed amendment would result in incremental intake controls and configurations compared to the current regulatory framework.

Nonetheless, the Sections below provide information on various types of subsurface intakes and surface intake screens.

Once constructed, facilities would need to meet the receiving water limits for salinity. As shown in Section □0, there are several ways existing facilities are complying with this provision. The fact that there are dischargers that may need to make changes to their existing discharge structure indicates that there could be changes to the construction of new outfalls associated with the proposed amendment.

For mitigation, all entities developing new or expanded plants must fully mitigate impacts to marine life and habitat, through either an in-lieu fee program, or mitigation under the proposed amendment. However, the CEQA already requires entities to mitigate identified significant impacts that cannot be avoided. Additionally, even if impacts are not significant pursuant to the CEQA, entities may be required to conduct mitigation under other regulations.

For example, the EIR for the Poseidon Resources desalination plant in Carlsbad does not identify the impingement and entrainment effects to be significant under the CEQA. Nonetheless, the CCC required Poseidon Resources to develop a Marine Life Mitigation Plan, which includes the restoration of at least 37 acres of estuarine wetlands, as a special requirement of its CDP (CCC, 2011). This mitigation acreage was imposed pursuant to the CCC’s and the State Water Board’s respective responsibilities under the Coastal Act and the California Water Code, both of which employ different standards of review than the CEQA’s “significant impact” threshold. This suggests that mitigation requirements under the proposed amendment are unlikely to represent incremental activity. Nonetheless, the Sections below also provide information on mitigation compliance and costs.

o Compliance Methods

As discussed above, new and existing facility designs may include subsurface well intake structures, surface water intake screens, multiport diffusers for brine discharges, and mitigation. The Section below discusses subsurface intakes, surface water intake screens, and mitigation; see Section □0for discussion of multiport diffusers.

▪ Subsurface Well Intakes

There are four main types of intake technologies that provide subsurface feedstock water:

Vertical wells – drilled into sediments directly below the well site and require favorable geology and hydrology. For example, vertical wells require sand formations with adequate permeability and porosity to produce a sufficient supply of feedstock water.

Slant wells – drilled at an angle between vertical and horizontal (which is more costly than drilling straight down). These slant wells can be advantageous in locations where vertical depth is limited.

Ranney (radial) wells – horizontal water collection wells with a central concrete caisson from which lateral well screens are arranged in a radial pattern. Design options for the lateral screens are highly adaptable, so the wells can be installed in settings that may otherwise limit subsurface intakes (e.g., shallow bedrock, limited horizontal extent of target aquifer). They also use less area than a conventional well field and minimize groundwater entrance velocity, reducing the frequency of required maintenance (Riegert, 2006).

Infiltration galleries – can be constructed either offshore or onshore. Infiltration galleries intake water through a series of buried horizontal wells that lie underneath a specially-engineered filter bed that blocks sediment and debris but allows seawater to seep through. Because these beds provide filtration, infiltration galleries require less pretreatment for RO units, but require a particular substrate and wave energy to be feasible for offshore locations (RBF Consulting, 2009).

Subsurface intake wells are generally associated with higher capital and construction costs than open or screened surface intakes. Subsurface intakes also typically require a larger installation area than surface intakes in order to provide adequate source water to a facility, resulting in higher land acquisition costs. However, subsurface intake systems typically have much lower operating costs due to reductions in feedwater pretreatment, biofouling, and mitigation costs (since they eliminate impingement and entrainment).

- **Surface Water Intakes Screens**

The proposed amendment requires desalination facilities using surface water intakes to use wedgewire screens with 0.5 mm or smaller slot size, or other screening technology that is at least as effective as the wedgewire screen in reducing entrainment of juvenile organisms, larvae, and eggs. The screens must also be adequately maintained for the duration of the facility's operation.

Wedgewire technology reduces impingement and entrainment of aquatic life by (Bechtel, 2012):

Acting as physical barriers to prevent aquatic organisms sufficiently larger than the screen slot size from being entrained;

Using a sweeping current in the source water to move aquatic organisms away from the screen faces; and

Utilizing a slow through-slot intake velocity at the screens to further exclude early life stages of aquatic organisms.

The feasibility and costs of wedgewire screens varies based on facility design and site characteristics. However, screen costs generally represent a small portion of overall project costs, and can reduce operation, maintenance, pretreatment, and mitigation costs compared to an uncontrolled open intake.

- **Mitigation**

Under the amendment, the State Water Board's preferred mitigation strategy for desalination intake impacts is habitat creation, restoration, or enhancement (SWRCB, 2013). For operational impacts related to intakes, the mitigation acreage requirements will depend on the APF as determined by an empirical transport model (ETM). Foster et al. (2013; Appendix 4) describe this approach. APF models provide an estimate of the scale of loss resulting from the intake impacts, and as such, a measure of the mitigation needed to compensate for the loss. The approach yields a "currency" in the form of habitat acreage that is needed to offset the impact (Appendix 4, page 1). APF is based on impacts to a set of sample species, and this approach assumes that the mean of the samples represents the true loss rate across all affected species. The APF covers all losses, direct and indirect, for which mitigation is needed.

For operational mortality related to discharges from the facility, the owner or operator must estimate (and include in the Marine Life Mortality Report) the area or volume in which salinity will exceed 2 ppt above natural background, and the mortality associated with discharges. Similarly, the owner or operator must estimate mortality associated with construction of the facility. For both discharge and construction related impacts, the owner or operator can estimate the area of disturbance associated with mortality using any acceptable approach.

Mitigation requirements will depend on the type of habitat needed to compensate for losses. For example, as noted by Foster et al. (2013; Appendix 4, page 3), wetland creation and restoration (which may be used to compensate for losses in estuaries or soft-bottom open coastal areas) is more expensive per acre than reef creation (which compensates for losses in rocky bottom open coastal areas). Additionally, rather than completing a mitigation project, owners and operators may choose to instead provide in-lieu funding to a mitigation program run by an approved public agency.

o Compliance Costs

This Section provides cost estimates for subsurface well intakes, surface intake screens, multiport diffusers, and mitigation that may be employed for compliance under the proposed amendment.

▪ Subsurface Well Intakes

The incremental cost of using subsurface well intakes represents the difference between the cost of the baseline intake option (e.g., surface water intake) and the cost of the subsurface intake. Typically, costs for subsurface well intakes are more costly than surface intake structures. However, source water from subsurface intakes will have lower suspended solids, which decreases the amount of pretreatment needed and thus, total project costs.[2] Subsurface intakes also reduce biofouling in the seawater transmission pipeline and system, decreasing chemical usage and the frequency of maintenance activities.

However, most feasibility studies for proposed desalination plants show the cost of subsurface wells versus the cost of surface intakes without considering the decrease in pretreatment requirements and maintenance activities. Hence, data are limited for the comparison of costs for the two options. **Exhibit 12-4** shows the total project costs for surface and subsurface intakes for two proposed desalination plants, including differences in pretreatment.

[2] Note that in some areas subsurface water may be high in iron and manganese, which would need to be removed prior to the RO system to prevent fouling. This could increase pretreatment costs, although they would still likely be less than those required for surface intakes (Kennedy/Jenks Consultants, 2011).

Exhibit 12-4: Comparison of Total Capital Costs for Subsurface and Surface Intake Structures (millions 2013$)

Location	Source for Estimates	Total Capital Project Costs	
		Subsurface Intake	Surface Intake
Monterey Peninsula[1]	Leeper and Naranjo (2013)	$195 - $287	$199 - $300
Camp Pendleton[2]	RBF Consulting (2009)	$2,604 - $2,873	$2,875 - $3,144

1. Open intake structures require an additional $33 million in capital costs related to pretreatment.
2. Additional pretreatment for surface intakes includes a submerged ultrafiltration system and an underground ultrafiltration filtrate storage tank (RBF Consulting, 2009, Table 10-7).

As shown in the exhibit, costs for subsurface intake structures may decrease total capital costs by approximately 2% to 9%. This is due primarily to the decrease in pretreatment controls needed for the cleaner intake water from subsurface wells. For example, for Camp Pendleton, the subsurface infiltration gallery is almost twice as much as the surface water intake structure. However, the surface water intake option requires more than $200 million more in pretreatment controls than the subsurface intake option.

- **Surface Water Intake Screens**

Exhibit 12-5 presents unit cost estimates for surface intake screens for proposed desalination plants in California. ☐provides the details for each of the estimates.

Exhibit 12-5: Estimated Unit Costs for Surface Water Intake Screens (2013$)

Location	Source	Total Costs		Size[2] (mgd)	Unit Costs	
		Capital	Annual O&M		Capital[3] ($/gpd)	O&M[4] ($/MG)
Camp Pendleton	Malcolm Pirnie (2008)	$33,174,664	$366,149	330	$0.10	$3.04
Monterey Peninsula	Leeper and Naranjo (2013)	$310,010	-	23	$0.01	-
scwd[2]	Kennedy/Jenks Consultants (2011)	$1,810,745	$154,106	11.3	$0.16	$37.36
West Basin (20 mgd)	WBMWD (2013)	$1,775,243	$37,993	20	$0.09	$5.20
West Basin (60 mgd)	WBMWD (2013)	$2,644,229	$42,678	60	$0.04	$1.95

MG = million gallons
mgd = million gallons per day
O&M = operation & maintenance
scwd[2] = Santa Cruz Water Department and Soquel Creek Water District
WBMWD = West Basin Water Management District
1. Escalated to 2013 dollars using the Engineering New Record Construction Cost Index.
2. Represents total intake volume per day.
3. Estimated by dividing total capital costs by intake flow in gpd (mgd × 1,000,000).
4. Estimated by dividing total O&M costs by intake flow in mgd and 365 days per year.

To put these costs into perspective, we compared the overall project capital and O&M costs to the cost of just the intake screens as shown in **Exhibit 12-6**.

Exhibit 12-6: Comparison of Surface Water Intake Screens to Total Project Costs (millions 2013$)

Location	Source for Estimates	Capital Costs			Annual O&M		
		Total Project	Intake Screen	% of Total	Total Project	Intake Screen	% of Total
Camp Pendleton	Malcolm Pirnie (2008)	$2,875 - $3,144	$33.2	1.1% - 1.2%	$135 - $178	$0.4	0.3%
Monterey Peninsula[1]	Leeper and Naranjo (2013)	$199 - $300	$0.3	0.1% - 0.2%	$14 - $15	-	-
West Basin (20 mgd)	WBMWD (2013)	$275 - $342	$1.8	0.5% - 0.6%	$18	$0.04	0.2%
West Basin (60 mgd)	WBMWD (2013)	$664 - $827	$2.6	0.3% - 0.4%	$52	$0.04	0.1%

mgd = million gallons per day
O&M = operation and maintenance
1. Total Project capital cost range for Monterey represents cost estimates for surface and subsurface intakes.

- **Multiport Diffusers**

As shown in **Exhibit 12-2**, unit costs for multiport diffusers could range from approximately $0.02 per gpd to $0.15 per gpd for capital and average approximately $1.46 per MG treated for O&M. **Exhibit 12-7** provides a comparison of diffuser costs to total project costs.

Exhibit 12-7: Comparison of Multiport Diffuser Costs to Total Project Costs (millions 2013$)

Location	Source for Estimates	Capital Costs			Annual O&M		
		Total Project	Diffuser	% of Total	Total Project	Diffuser	% of Total
Camp Pendleton	Malcolm Pirnie (2008)	$2,604 - $3,144	$21.9	0.7% - 0.8%	$117 - $178	$0.07	0.1%
Monterey Peninsula[1]	Leeper and Naranjo (2013)	$195 - $300	$0.5	0.2% - 0.3%	$13 - $15	-	-
West Basin (20 mgd)	WBMWD (2013)	$275 - $342	$1.0	0.3%	$18	$0.02	0.1%
West Basin (60 mgd)	WBMWD (2013)	$664 - $827	$1.1	0.1% - 0.2%	$52	$0.02	0.0%

1. Total project capital cost range for Monterey represents cost estimates for surface and subsurface intakes.

- **Mitigation**

Desalination plant owners and operators must mitigate for impacts resulting from intake, construction, and discharges, through either the implementation of a mitigation project, or payment to a mitigation program run by an approved public agency. For intake-related impacts, the mitigation acreage required will be determined by the APF method, as described in Section ☐o☐. In addition, owners and operators must also mitigate impacts resulting from construction and discharges, using at least a 1:1 mitigation ratio (i.e., one acre of mitigation for every acre impacted). As such, the size of required mitigation projects depends on the size of the impacts associated with both construction and operation (specific to intake and discharges).

Exhibit 12-8 shows the estimated unit mitigation costs for several power plants, based on the APF method, shown in costs per acre of mitigation (Foster, et al., 2013). On average, compensation can be attained for an average of $36,000 per acre for wetlands and $154,000 per acre for rocky reefs.[3]

Note that desalination plants are likely to use smaller volumes of water compared with power plants, and as such may be associated with lower intake-based mitigation project costs. On the other hand, however, the amendment requires that desalination plant owners and operators also mitigate for construction- and discharge-related impacts, which will increase the required mitigation acreage relative to intake-only mitigation projects.

Actual costs for individual mitigation projects will vary based on site-specific factors, and may be significantly higher or lower than averages.

Exhibit 12-8. Estimated Mitigation Costs for Power Plant Intakes[1]

Facility (year)	Intake Volume (mgd)	APF (acres)	Total Cost (millions; 2013$)[2]	Cost per Acre (2013$)[2]
Wetland/Estuary				
Moss Landing (2000)	360	840	$23.2	$27,601
Morrow Bay (2001)	371	760	$20.6	$27,145
Poseidon (2009)	304	37	$12.4	$334,368
Huntington Beach (2009)	127	66	$5.5	$82,748
Rocky Reef				
Diablo (2006)	2,670	543	$83.7	$154,098

APF = area production foregone
mgd = million gallons per day
Source: Foster et al. (2013), Appendix 4.
1. Costs likely do not include project monitoring and administration.
2. Updated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

o Summary

Depending on the outcome of an environmental impact analysis for a new or expanded plant, the proposed amendment could result in incremental costs or cost savings associated with the design and construction of subsurface intakes, surface intake screens, multiport diffusers, and mitigation measures. For example, when compared to the cost of surface water intakes, subsurface intakes could decrease total project capital costs by 2% to 9%, due primarily to reduce pretreatment costs. Surface intake screens could account for up to 1.2% of total project capital and 0.3% of

[3] Updated to 2013$ using ENR CCI.

annual total O&M costs. Multiport diffusers could account for up to 0.8% of total project capital and 0.1% of annual total O&M costs.

For mitigation, Foster et al. (2013; Appendix 4) indicates that compensation can be attained for between approximately $36,000 and $154,000 per acre, depending on the water body type.

o Limitations and Uncertainties

Once adopted, the proposed amendment will represent the regulatory baseline for any new facility or facility expansion. However, there is evidence that facility planners are already considering the feasibility of subsurface intakes and surface intake screens, and the potential environmental impacts to marine life associated with each option as part of the design process, under the current regulatory framework, as a way to avoid delays and denials of the necessary permits caused by insufficient consideration and analysis of environmental impacts. Further, entities may already have to mitigate for significant environmental impacts under CEQA and the Coastal Act, through avoidance, minimization, or compensatory actions. Thus, it is unclear whether the intake structure and mitigation costs in Section □o are attributable to the amendment or would be incurred under the existing framework.

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• Unit Costs

This appendix provides the details for the unit cost estimates for brine controls, intake structures, and intake screens. The cells in the tables shaded in green are from the cited source document, whereas Abt Associates calculated the remaining cells based on the information in the source document.

A.1 Brine Controls

Exhibits A-1 through A-9 show facility-specific details used to develop unit costs for brine controls.

Exhibit A-1: Camp Pendleton Multiport Diffuser Capital Costs

Material / Equipment	Cost (2008$)	Cost (2013$) [2]
7' Diameter Diffuser Pipe Concrete Cover	$3,600,000	$4,055,802
Structure at outfall "Y"	$2,000,000	$2,253,223
Diffuser Orifices	$750,000	$844,959
Equipment Subtotal	$6,350,000	$7,153,984
Installation/Construction [1]	$5,243,792	$5,907,717
Equipment and Installation Subtotal	$11,593,792	$13,061,701
Contingency	40%	
Equipment, Installation, & Contingency Subtotal	$16,231,309	$18,286,381
Engineering + Construction Management:	20%	
Total Capital Cost	$19,477,571	$21,943,658
Percent of O&M attributable to diffuser [3]	50%	
Annual O&M	$65,000	$73,230

Source: Malcolm Pirnie (2008) for shaded cells.
1. Estimated installation as a percent of equipment costs by dividing the total project equipment cost by the total installation costs and assuming that installation is proportional to equipment cost (see Exhibit A-2).
2. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI). Used CCI of 8600 for 2008 dollar year as specified in Malcolm Pirnie (2008).
3. Estimated the percent of annual operation & maintenance (O&M) costs based on the facility needing annual inspection of the discharge and intake structures, and assuming that it takes the same amount of time to inspect each structure (i.e., 50% of O&M costs are attributable to the outfall/diffuser system).

Exhibit A-2: Camp Pendleton Project Costs used to Estimate Installation as a Percent of Capital Equipment

Component	Cost (2008$)
Capital Costs	
Intake Headers	$8,400,000
Intake Screens	$1,200,000
Brine Discharge Line	$10,440,000
WWTP Effluent Discharge Line	$3,480,000
Diffuser	$6,350,000
Gravel trench bedding	$1,300,000
Total Capital Equipment Cost	$31,170,000
Installation Costs	

Exhibit A-2: Camp Pendleton Project Costs used to Estimate Installation as a Percent of Capital Equipment

Component	Cost (2008$)
Barges	$3,960,000
Cranes	$1,620,000
Tugboat	$900,000
Diver Crews	$6,300,000
Tradesmen	$12,960,000
Total Installation /Construction Cost	$25,740,000
Installation as a percent of capital equipment	83%
Annual Inspection Cost [1]	$130,000

Source: Malcolm Pirnie (2008) for shaded cells.
1. Cost for a dive crew and support vessel for two weeks.

Exhibit A-3: Monterey Peninsula Diffuser Capital Cost

Component	Cost (2012$)/Quantity	Cost (2013$) [1]
New Diffusers	$500,000	$516,684
Total intake flow (mgd) [2]	23	
Total product water flow (mgd)	9.6	
Calculated brine flow (mgd)	13.4	

mgd = million gallons per day
Source: Leeper and Naranjo (2013) for shaded cells.
1. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).
2. Source for intake flow: RBF Consulting (2013)

Exhibit A-4: West Basin Diffuser Capital Cost, El Segundo Site, 20 mgd

Component	Cost (2012$)	Cost (2013$) [3]
Diffusers Materials and Installation (Labor) Costs	$659,933	$686,936
Diffuser Construction Costs, including add-ons [1]	$890,910	$927,363
Total Capital Cost - Diffusers [2]	$1,051,273	$1,094,289

mgd = million gallons per day
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Add-ons include mobilization/demobilization, bonds and insurance, overhead and profit, and contingency calculated as 35% of material and labor costs.
2. Total capital cost includes 18% of construction and add-on costs for professional services.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-5: West Basin Diffuser Capital Cost, El Segundo Site, 60 mgd

Component	Cost (2012$)	Cost (2013$) [3]
Diffusers Materials and Installation (Labor) Costs	$765,960	$797,301
Diffuser Construction Costs, including add-ons [1]	$1,034,046	$1,076,357
Total Capital Cost - Diffusers [2]	$1,220,174	$1,270,101

mgd = million gallons per day
Source: West Basin Municipal Water District (2013) for shaded cells
1. Add-ons include mobilization/demobilization, bonds and insurance, overhead and profit, and contingency calculated as a percent of material and labor costs.
2. Total capital cost includes 18% of construction costs for professional services.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-6: West Basin Diffuser Capital Cost, Redondo Beach Site, 20 mgd

Component	Cost (2012$)	Cost (2013$) [3]
Diffusers Materials and Installation (Labor) Costs	$489,128	$509,142
Diffuser Construction Costs, including add-ons [1]	$660,323	$687,342
Total Capital Cost - Diffusers [2]	$779,181	$811,063

mgd = million gallons per day
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Add-ons include mobilization/demobilization, bonds and insurance, overhead and profit, and contingency calculated as a percent of material and labor costs.
2. Total capital cost includes 18% of construction costs for professional services.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-7: West Basin Diffuser Capital Cost, Redondo Beach Site, 60 mgd

Component	Cost (2012$)	Cost (2013$) [3]
Diffusers Materials and Installation (Labor) Costs	$565,380	$588,514
Diffuser Construction Costs, including add-ons [1]	$763,263	$794,494
Total Capital Cost - Diffusers [2]	$900,650	$937,503

mgd = million gallons per day
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Add-ons include mobilization/demobilization, bonds and insurance, overhead and profit, and contingency calculated as a percent of material and labor costs.
2. Total capital cost includes 18% of construction costs for professional services.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-8: West Basin Capital Cost Add-ons

Cost Component	Percent [1]
Mobilization/ Demobilization [2]	2%
Bonds & Insurance [2]	1%
Overhead & Profit [2]	12%
Contingency [2]	20%
Subtotal Construction Cost [2]	35%
Professional Services [3]	18%

Source: West Basin Municipal Water District (2013) for shaded cells
1. Represents Base scenario (study presents cost estimates for low, base, and high scenarios).
2. Cost components calculated as a percent of total material and labor costs.
3. Cost component calculated as a percent of total construction cost.

Exhibit A-9: West Basin Desalination Plant - O&M Costs

Component	Annual Cost (2012$)	Cost (2013$) [2]
El Segundo, 20 mgd	$16,000	$16,655
El Segundo, 60 mgd	$16,000	$16,655
Redondo Beach, 20 mgd	$16,000	$16,655
Redondo Beach, 60 mgd	$16,000	$16,655

mgd = million gallons per day
O&M = operation & maintenance
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

A.2 Intake Controls

Exhibits A-10 through A-28 show facility-specific details used to develop unit costs for intake controls.

Exhibit A-10: Camp Pendleton Intake Screens Capital Costs

Material / Equipment	Cost (2008$)	Cost (2013$) [2]
Intake Headers (2 pipes,10.5' diameter, 3500' each)	$8,400,000	$9,463,538
Intake Screens (6' diameter)	$1,200,000	$1,351,934
Equipment Subtotal	$9,600,000	$10,815,472
Installation/Construction [1]	$7,927,623	$8,931,352
Equipment and Installation Subtotal	$17,527,623	$19,746,824
Contingency	40%	
Equipment, Installation, & Contingency Subtotal	$24,538,672	$27,645,553
Engineering + CM:	20%	
Total Capital Cost	$29,446,406	$33,174,664

Source: Malcolm Pirnie (2008) for shaded cells.
1. Estimated installation as a percent of equipment costs by dividing the total project equipment cost by the total installation costs and assuming that installation is proportional to equipment cost (see Exhibit A-2).
2. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI). Used CCI of 8600 as specified in the report.

Exhibit A-11: Camp Pendleton Intake Screens O&M Costs

Material / Equipment	Annual Cost (2008$)	Cost (2013$) [1]
Inspection Cost as % of total Inspection cost [2]	50%	
Total inspection cost	$130,000	$146,460
Intake screen inspection	$65,000	$73,230
Intake Screen Semiannual Airbust Crew	$100,000	$112,661
Intake Screen Semiannual Airbust Vessel	$30,000	$33,798
Intake Screen Annual Cleaning Crew	$100,000	$112,661
Intake Screen Annual Cleaning Vessel	$30,000	$33,798
Annual O&M	$325,000	$366,149

O&M = operation & maintenance
Source: Malcolm Pirnie (2008) for shaded cells.
1. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI). Used CCI of 8600 as specified in the report.
2. Estimated the percent of annual inspection costs based on the facility needing annual inspection of the discharge and intake structures, and assuming that it takes the same amount of time to inspect each structure (i.e., 50% of costs are attributable to the intake system).

Exhibit A-12: Camp Pendleton - Subsurface Infiltration Gallery Capital

Component	Cost (2009$)	Cost (2013$) [3]
Deep Infiltration Gallery Intake - Phase 1 [1]	$54,817,150	$62,126,061
Deep Infiltration Gallery Intake - Phase 2 [2]	$24,070,950	$27,280,391
Deep Infiltration Gallery Intake - Phase 3 [2]	$14,830,950	$16,808,398
Deep Infiltration Gallery Intake - Total Equipment	$93,719,050	$106,214,850
Construction Contingency (percent of equipment)	40%	
Subtotal - Equipment + Construction Contingency	$131,206,670	$148,700,790
Implementation (percent of equip + constr contingency)	25%	
Total Capital	$164,008,338	$185,875,988

Source: RBF Consulting (2009) for shaded cells.
1. For 50 million gallons per day (mgd).
2. For addition of 50 mgd.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI) from January 2009$.

Exhibit A-13: Camp Pendleton - Subsurface Infiltration Gallery O&M

Component	Annual Cost (2009$)	Cost (2013$) [3]
Power Requirement Costs for Intake [1]	$4,730,354	$5,361,064
Feed Intake System Cleaning Costs [2]	$120,000	$136,000
Total O&M	$4,850,354	$5,497,064

O&M = operation & maintenance
Source: RBF Consulting (2009) for shaded cells.
1. Based on energy costs of $0.10/kWh in 2009 dollars.
2. Based on 2 weeks per year for cleaning and includes vessel and crew.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI) from January 2009$.

Exhibit A-14: Monterey Peninsula Slant Well Intake Capital Cost

Component	Cost (2012$)	Cost (2013$) [2]
Slant Cost [1]	$50,323,000	$52,002,187
Intake Pump Station Costs [1]	$6,363,000	$6,575,322
Intake Pipeline Costs [1]	$4,697,000	$4,853,730
Total Slant Wells Cost	$61,383,000	$63,431,239

Source: Leeper and Naranjo (2013) for shaded cells.
1. Includes implementation costs as 20% of equipment, and contingency and mitigation costs as 25% and 1%, respectively, of equipment and installation costs. Also includes land cost for well installation.
2. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-15: Monterey Peninsula Ranney Collector Intake Capital Cost

Component	Cost (2012$)	Cost (2013$) [4]
Ranney collectors	$23,000,000	$23,767,468
Temporary Sheet Piling and Wave Protection for Construction	$3,700,000	$3,823,462
Subtotal Base Construction	$26,700,000	$27,590,930
Implementation 20%	$5,340,000	$5,518,186
Land [1]	$1,100,000	$1,136,705
Subtotal for equip, installation, and land	$59,840,000	$61,836,752
Contingencies as percent of equip, installation, and land	25%	$0
Mitigation as percent of equip, installation, and land	1%	$0
Ranney Collector Total (equipment, installation, land, contingency, and mitigation)	$75,398,400	$77,914,307
Additional Beach Pipeline Cost [2]	$1,400,000	$1,446,715
Pump Station Costs [3]	$6,363,000	$6,575,322
Total Ranney Collector Cost	$83,161,400	$85,936,344

Source: Leeper and Naranjo (2013) for shaded cells.
1. Original estimate excludes land cost from the Ranney collector cost because they assume they would have already purchased the land for the preferred option. Thus, Abt Associates added the land cost to the estimate to obtain total stand-alone project costs.
2. Includes implementation costs as 20% of equipment, and contingency and mitigation costs as 25% and 1%, respectively, of equipment and installation costs.
3. Original estimate does not include pump station costs; however, for consistency with the slant well estimates, Abt Associates included the pump station costs (the report does not indicate that pump station costs would be avoided under the Ranney collector option).
4. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-16: Monterey Peninsula Intake Screen Capital Cost

Component	Cost (2012$)	Cost (2013$) [2]
Total Wire Screens Cost [1]	$300,000	$310,010

Source: Leeper and Naranjo (2013) for shaded cells.
1. Includes implementation costs as 20% of equipment, and contingency and mitigation costs as 40% and 1%, respectively, of equipment and installation costs.
2. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-17: scwd² Intake Screens Capital Cost

Component	Cost (2010$)	Cost (2013$) [2]
Intake Screens [1]	$1,645,000	$1,810,745

Source: Kennedy/Jenks Consultants (2011) for shaded cells.
1. Costs include 9.75% tax on total materials cost, 15% contractor overhead & profit (OH&P) on materials and installation cost, 30% of total cost for contingency, and 5% of total cost for mid-point of construction.
2. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-18: scwd² Intake Screens O&M

Component	Annual Cost (2010$)	Cost (2013$) [2]
Screen and pipeline cleaning (every 16 weeks)	$140,000	$154,106

O&M = operation & maintenance
Source: Kennedy/Jenks Consultants (2011) for shaded cells.
1. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-19: West Basin Capital Cost for Intake Screens - El Segundo Site, 20 mgd

Component	Cost (2012$)	Cost (2013$) [3]
Material and Labor for Screens	$1,086,776	$1,131,244
Construction costs (with add-ons) [1]	$1,467,148	$1,527,180
Total Capital Cost, including professional fees [2]	$1,731,234	$1,802,072

mgd = million gallons per day
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Add-ons include mobilization/demobilization, bonds and insurance, overhead and profit, and contingency calculated as a percent of material and labor costs.
2. Total capital cost includes 18% of construction costs for professional services.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-20: West Basin Capital Cost for Intake Screens - El Segundo Site, 60 mgd

Component	Cost (2012$)	Cost (2013$) [3]
Material and Labor for Screens	$1,623,056	$1,689,467
Construction costs (with add-ons) [1]	$2,191,126	$2,280,781
Total Capital Cost, including professional fees [2]	$2,585,528	$2,691,322

mgd = million gallons per day
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Add-ons include mobilization/demobilization, bonds and insurance, overhead and profit, and contingency calculated as a percent of material and labor costs.
2. Total capital cost includes 18% of construction costs for professional services.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-21: West Basin Capital Cost for Intake Screens - Redondo Beach Site, 20 mgd

Component	Cost (2012$)	Cost (2013$) [3]
Material and Labor for Screens	$1,054,416	$1,097,560
Construction costs (with add-ons) [1]	$1,423,462	$1,481,706
Total Capital Cost, including professional fees [2]	$1,679,685	$1,748,413

mgd = million gallons per day
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Add-ons include mobilization/demobilization, bonds and insurance, overhead and profit, and contingency calculated as a percent of material and labor costs.
2. Total capital cost includes 18% of construction costs for professional services.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-22: West Basin Capital Cost for Intake Screens - Redondo Beach Site, 60 mgd

Component	Cost (2012$)	Cost (2013$) [3]
Material and Labor for Screens	$1,566,256	$1,630,343
Construction costs (with add-ons) [1]	$2,114,446	$2,200,963
Total Capital Cost, including professional fees [2]	$2,495,046	$2,597,137

mgd = million gallons per day
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Add-ons include mobilization/demobilization, bonds and insurance, overhead and profit, and contingency calculated as a percent of material and labor costs.
2. Total capital cost includes 18% of construction costs for professional services.
3. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-23: West Basin Additional Project Capital Cost Components

Cost Component	Percent
Mobilization/ Demobilization [1]	2%
Bonds & Insurance [1]	1%
Overhead & Profit [1]	12%
Contingency [1]	20%
Subtotal Construction Cost [1]	35%
Professional Services [2]	18%

Source: West Basin Municipal Water District (2013) for shaded cells.
1. Given as a percent of total material and labor cost.
2. Given as a percent of total construction cost.
3. Study presents cost estimates for low, base, and high scenarios.

Exhibit A-24: West Basin Intake Screen O&M Cost

Component	Annual Cost (2012$)	Cost (2013$) [2]
El Segundo, 20 mgd	$35,000	$36,432
El Segundo, 60 mgd	$41,000	$42,678
Redondo Beach, 20 mgd	$38,000	$39,555
Redondo Beach, 60 mgd	$41,000	$42,678

mgd = million gallons per day
O&M = operation & maintenance
Source: West Basin Municipal Water District (2013) for shaded cells.
1. Assumed that costs were in 2012 dollars based on cost estimate date of 9/11/2012.
2. Escalated to 2013$ using the Engineering News Record Construction Cost Index (ENR CCI).

A.3 Total Project Costs

Exhibit A-25: Camp Pendleton Total Project Capital Cost Estimates (Grid Power)

Site	Phase 1	Phase 2	Phase 3	Total (2009$)	Total (2013$) [3]
SRTTP [1]	$1,245,000,000	$556,000,000	$502,000,000	$2,303,000,000	$2,603,669,146
MCTSSA [2]	$1,303,000,000	$642,000,000	$598,000,000	$2,543,000,000	$2,875,002,448

Source: RBF Consulting, 2009
1. Uses a subsurface intake.
2. Uses a surface intake.
3. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-26: Camp Pendleton Total Project Capital Cost Estimates (Cogeneration)

Site	Phase 1	Phase 2	Phase 3	Total (2009$)	Total (2013$) [3]
SRTTP [1]	$1,328,000,000	$635,000,000	$578,000,000	$2,541,000,000	$2,872,741,337
MCTSSA [2]	$1,387,000,000	$718,000,000	$676,000,000	$2,781,000,000	$3,144,074,639

Source: RBF Consulting, 2009
1. Uses a subsurface intake.
2. Uses a surface intake.
3. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-27: Camp Pendleton Total Plant O&M Cost Estimates (Grid Power)

Intake Type	Annual Cost	Total (2009$)	Total (2013$) [1]
Subsurface	$103,600,000	$103,600,000	$117,125,542
Screened Open Ocean	$119,300,000	$119,300,000	$134,875,262

O&M = operation & maintenance
Source: RBF Consulting, 2009
1. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-28: Camp Pendleton Total Plant O&M Cost Estimates (Cogeneration)

Intake Type	Annual Cost	Total (2009$)	Total (2013$) [1]
Subsurface	$130,800,000	$130,800,000	$147,876,650
Screened Open Ocean	$157,700,000	$157,700,000	$178,288,591

O&M = operation & maintenance
Source: RBF Consulting, 2009
1. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-29: West Basin 20mgd Total Plant Capital Cost Estimates

Site	Low (2012$)	Base (2012$)	High (2012$)	Low (2013$) [1]	Base (2013$) [1]	High (2013$) [1]
El Segundo	$261,767,000	$291,248,000	$325,803,000	$272,477,849	$303,165,137	$339,134,041
Redondo Beach	$265,833,000	$295,772,000	$330,864,000	$276,710,219	$307,874,248	$344,402,125

mgd = million gallons per day
Source: WBMWD (2013)
1. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-30: West Basin 60mgd Total Plant Capital Cost Estimates

Site	Low (2012$)	Base (2012$)	High (2012$)	Low (2013$) [1]	Base (2013$) [1]	High (2013$) [1]
El Segundo	$635,003,000	$706,520,000	$790,344,000	$660,985,729	$735,429,025	$822,682,893
Redondo Beach	$641,168,000	$713,379,000	$798,017,000	$667,402,985	$742,568,678	$830,669,853

mgd = million gallons per day
Source: WBMWD (2013)
1. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-31: West Basin 20mgd Total Plant O&M Cost Estimates

Site	Base (2012$)	Base (2013$) [1]
El Segundo	$17,669,000	$18,391,971
Redondo Beach	$17,656,000	$18,378,439

mgd = million gallons per day
O&M = operation & maintenance
Source: WBMWD (2013)
1. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-32: West Basin 60mgd Total Plant O&M Cost Estimates

Site	Base (2012$)	Base (2013$) [1]
El Segundo	$49,554,000	$51,581,625
Redondo Beach	$49,631,000	$51,661,776

mgd = million gallons per day
O&M = operation & maintenance
Source: WBMWD (2013)
1. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-33: Monterey Peninsula 9.6mgd - Total Plant Capital Cost with Subsurface Intakes

Cost Range	Capital Cost (2012$)	Cost (2013$) [1]
Low	$188,900,000	$195,203,248
Base	$222,200,000	$229,614,408
High	$277,800,000	$287,069,679

Cost Range	Capital Cost (2012$)	Cost (2013$) [1]
mgd = million gallons per day Source: Leeper and Naranjo (2013) 1. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).		

Exhibit A-34: Monterey Peninsula 9.6mgd - Total Plant O&M Cost with Subsurface Intakes

Cost Range	Annual O&M Cost (2012$)	Cost (2013$) [1]
Base	$12,970,000	$13,402,785
mgd = million gallons per day O&M = operation & maintenance Source: Leeper and Naranjo (2013) 1. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).		

Exhibit A-35: Monterey Peninsula 9.6mgd - Total Plant Capital Cost with Surface Intakes

Incremental Cost (2012$) [1]	Total Capital Cost – Low (2012$)	Total Capital Cost – Base (2012$)	Total Capital Cost – High (2012$)	Total Capital Cost - Low (2013$) [2]	Total Capital Cost - Base (2013$) [2]	Total Capital Cost - High (2013$) [2]
Contingency Plan I-2: Open ocean intake offshore from CEMEX property						
$3,600,000	$192,500,000	$225,800,000	$281,400,000	$198,923,374	$233,334,534	$290,789,804
Contingency Plan I-8: Construct a new open ocean intake near Moss Landing, with feedwater pumped to a desalination plant at the CBR site						
$12,200,000	$201,100,000	$234,400,000	$290,000,000	$207,810,340	$242,221,500	$299,676,770
mgd = million gallons per day Source: Leeper and Naranjo (2013) 1. Compared to a cost scenario using a slant well intake structure. 2. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).						

A.4 Surface Intake Structure Costs

Exhibit A-36: Camp Pendleton - Surface Intake Component Capital Cost

Component	Cost (2009$)	Cost (2013$) [3]
Surface Intake - Phase 1 [1]	$34,510,000	$39,111,306
Surface Intake - Phase 2 [2]	$11,400,000	$12,919,991
Surface Intake - Phase 3 [2]	$8,100,000	$9,179,994
Surface - Total Equipment	$54,010,000	$61,211,291
Construction Contingency (percent of equipment)	40%	
Subtotal - Equipment + Construction Contingency	$75,614,000	$85,695,808
Implementation (percent of equip+constr contingency)	25%	
Total Capital	$94,517,500	$107,119,760
Source: RBF Consulting, 2009 1. For 50 million gallons per day (mgd). 2. For addition of 50 mgd. 3. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).		

Exhibit A-37: Monterey Peninsula 9.6mgd Desalination Plant - Surface Intake Component Capital Cost

Contigency Intake	Additional Component Cost [1] (2012$)	Baseline Cost [2] (2012$)	Total Intake Component Capital Cost (2012$)	Total Intake Component Capital Cost - (2013$) [3]
Contigency Plan I-2: Open ocean intake offshore from CEMEX property	$46,200,000	$100,000	$46,300,000	$47,844,946
Contigency Plan I-8: Construct a new open ocean intake near Moss Landing, with feedwater pumped to a desalination plant at the CBR site	$71,863,000	$0	$71,863,000	$74,260,937

mgd = million gallons per day
Source: Leeper and Naranjo (2013)
1. Compared to a slant well intake structure.
2. Components used cost scenario for a slant well intake structure that are listed at no cost in contigency plans. For Contingency Plan I-2, this includes $100,000 in land.
3. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

Exhibit A-38: Monterey Peninsula 9.6mgd Desalination Plant - Surface Intake Component O&M Cost

Contigency Intake	Incremental Cost [1] (2012$)	O&M Cost – Base (2012$)	Total Capital Cost - Base (2013$) [2]
Contigency Plan I-2: Open ocean intake offshore from CEMEX property	$1,000,000	$13,970,000	$14,436,153
Contigency Plan I-4: Direct intake of water from Moss Landing Harbor, using existing Marine Refractory intake infrastructure, with feedwater pumped to a desalination plant at the CBR site	$1,400,000	$14,370,000	$14,849,501
Contigency Plan I-7: Convert existing Marine Refractory outfall into an open ocean intake, with feedwater pumped to a desalination plant at the CBR site	$1,400,000	$14,370,000	$14,849,501
Contigency Plan I-8: Construct a new open ocean intake near Moss Landing, with feedwater pumped to a desalination plant at the CBR site	$1,400,000	$14,370,000	$14,849,501

O&M = operation & maintenance
Source: Leeper and Naranjo (2013)
1. Compared to a cost scenario using a slant well intake structure.
2. Escalated to 2013$ using Engineering News Record Construction Cost Index (ENR CCI).

• Facility Information

Exhibit B-1 shows the information used to determine if incremental controls will be needed for existing NPDES-permitted desalination facilities.

Exhibit B-1: Existing Desalination Facility Information

NPDES ID	Desalination Facility Name	SIC Code	City	Brine Flow (mgd)	Total Flow (mgd)	Discharge Description /Controls	Existing Effluent Limits	Existing Monitoring Requirements	Other	Need for Incremental Controls?
CA0064581	West Basin Demonstration Plant	3559	West Basin	0.05	0.58	Desalinated water is combined with brine prior to discharge. 1300 ft offshore, 30ft deep	Minimum dilution of 10:1.	None specified	Permit indicates that facility is temporary/used to evaluate full-scale options for the future plant.	No
CA0003751	PG&E, Diablo Canyon	4911	San Luis Obispo	1.44	2540	Discharges up 2540 mgd of seawater, in-plant chemical wastes, low-level radioactive wastes, and stormwater runoff to Diablo Cove.	None related to salinity.	None related to salinity.		No
CA0050016	Ocean View Plaza	4941	Monterey	0.116	0.116	Facility discharges brine through a diffuser that extends approximately 1000 feet into Monterey Bay, at a depth of 50 ft. Mixing study indicates that under worst-case conditions discharge could increase ambient salinity of 33.5 psu by 2% (or by 0.67 psu).	Minimum initial dilution of 37:1.	Daily average flow (mgd) and daily peak rate (gpm).		No
CA0061191	Pebble Beach Desalination Plant	4941	Avalon	Not specified	0.72	Discharge of reverse osmosis brine, filter backwash, untreated seawater, and wastewater from flushing the seawater supply pipeline through a rip rap slope to the Pacific Ocean.	Minimum initial dilution factor of 5:1.	None related to salinity.	Permit notes that the 37% increase in effluent TDS is not expected to result in saline concentrations in the effluent that would result in the degradation of marine life or marine waters.	Possibly

Exhibit B-1: Existing Desalination Facility Information

NPDES ID	Desalination Facility Name	SIC Code	City	Brine Flow (mgd)	Total Flow (mgd)	Discharge Description /Controls	Existing Effluent Limits	Existing Monitoring Requirements	Other	Need for Incremental Controls?
CA006 1794	US Navy, San Nicholas	494 1	San Nicho las Island	Not specif ied	0.06 7	Discharge of RO reject brine and filter backwash into a brine well 250 feet from the shore-line, which disperses through sand and enters the San Nicolas lsland Harbor.	None related to salinity.	Monthly sampling for TDS.		No
CA006 4564	Naval Base Ventura County	494 1	Port Huene me	Not specif ied	0.95	Brine and permeate are discharged through a pipe positioned on a rock rip-rap 13 feet from to the Port Hueneme Harbor.	None related to salinity.	Annual monitorin g for salinity.	Because they aren't using the permeate and are discharging it back into the water from which it came with the brine, it is essentially pass-through water and should not affect ambient salinity.	No
CA010 9223	Carlsbad Desalination Project	494 1	Carls bad	54	540. 5	Brine diluted from salinity of 67 ppt to sublethal level of 40 ppt prior to discharge through in-plant dilution. Remainder of dilution achieved through natural mixing via low velocity (1 to 3 feet per second) discharge into high energy surf zone seaward of the point of discharge.	Avg daily TDS = 40 ppt, avg hourly TDS = 44 ppt. Minimu m initial dilution of 15.5:1.	Weekly monitorin g of salinity.	Facility construction began early 2013. Depending on construction, proposed amendment adoption, and final design for outfall structure, the facility may incur incremental costs.	Possibl y
CAG99 3001	City of Morro Bay	494 1	Morro Bay	0.9	0.9	Discharge flows through an outfall diffuser system into the ocean.	None related to salinity.	TDS monitorin g required upon plant start-up and annually thereafter .	Discharge salinity is less than or comparable to seawater per Regional Board Order to permit under a General Permit.	No

Exhibit B-1: Existing Desalination Facility Information

NPDES ID	Desalination Facility Name	SIC Code	City	Brine Flow (mgd)	Total Flow (mgd)	Discharge Description /Controls	Existing Effluent Limits	Existing Monitoring Requirements	Other	Need for Incremental Controls?
CAG993001	Chevron, Gaviota	4941	Gaviota	0.14	1.2	Wastewaters discharged through an outfall/diffuser system to the ocean include the following: 0.001 mgd of sewage from an aeration treatment/ultraviolet disinfection system, 0.14 mgd of reverse osmosis reject brine, 0.36 mgd of excess seawater, and 0.072 mgd of boiler blowdown.	Minimum dilution of 72:1	TDS monitoring required upon plant start-up and annually thereafter.		No
CA0048143	Santa Barbara	4952	Santa Barbara	12.5	23.5	Effluent (secondary wastewater and brine) is discharged through a 8,720 foot diffuser to the Pacific Ocean into water approximately 70 feet deep. Provides a minimum initial dilution of 44:1 when brine is being discharged.	Minimum initial dilution 120: 1 without brine, and 44: 1 with brine.	Weekly for salinity during discharges of brine; may reduce to annually when brine is not discharged.	Requires annual inspection of diffuser. Flow reported is maximum; may also discharge 3.9 mgd, 4.1 mgd, or 9.4 mgd.	No
CA0107417	South Orange County Wastewater Authority - San Juan Creek Ocean Outfall	4952		2.8	38.78	Discharge via the San Juan Creek Ocean Outfall through a multiport diffuser.	Minimum 100:1 initial dilution.	None specified		No
CA0107433	City of Oceanside	4952	Oceanside	2	21	Combined waste discharge through the Oceanside Ocean Outfall, which ends in a 230ft diffuser. The diffuser has 14 5-inch diameter ports and 10 4-inch diameter ports.	Minimum initial dilution of 87:1.	None related to salinity.		No

Exhibit B-1: Existing Desalination Facility Information

NPDES ID	Desalination Facility Name	SIC Code	City	Brine Flow (mgd)	Total Flow (mgd)	Discharge Description /Controls	Existing Effluent Limits	Existing Monitoring Requirements	Other	Need for Incremental Controls?
CA0107611	South Orange County Wastewater Authority - Aliso Creek Ocean Outfall	4952		1	34	Discharge via the Aliso Creek Ocean Outfall through a multiport diffuser.	Minimum 237:1 initial dilution.	monthly offshore salinity		No
CAG993003	Monterey Bay Aquarium	8422	Monterey	0.04	>0.04	The brine discharge is blended with the exhibit water outfall. The effluent is effectively diluted due to the large volume of discharge water, which is at ambient salinity, and the effects of the brine effluent are considered to be negligible.	None.	None.		No

gpm = gallons per minute
mgd = million gallons per day
NPDES ID = National Pollutant Discharge Elimination System Identification
psu = practical salinity units
RO = reverse osmosis
SIC = Standard Industrial Classification
TDS = total dissolved solids
ZID = zone of initial dilution
Source: Current NPDES permits; for City of Morro Bay: http://www.swrcb.ca.gov/rwqcb3/board_info/agendas/2009/dec/item_17/stfrpt_17.pdf; for Monterey Bay Aquarium: http://montereybay.noaa.gov/resourcepro/resmanissues/pdf/110806desal_final.pdf