Diablo Canyon Power Plant

Thermal Effects Monitoring Program
Analysis Report

Chapter 2 –
Assessment of Thermal Effects

November 5, 1998

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GLOSSARY OF TERMS AND ABBREVIATIONS

Acute Effect	Temporary or short-term impact caused by power plant discharge or other change in environment
Benthic	Pertains to or lives on the sea-bottom
BIC	Balanced Indigenous Community
Biofouling	Undesired growth of marine organisms on man-made structures
Biotic Category	Classification of living organisms based on habitat or position in food-web
Chronic Effect	Long-term impact caused by power plant discharge or other change in environment
Cross-condenser	Measured differences in variables such as temperature or pressure between inlet and outlet ends of heat exchange apparatus
Crustose	Growth form of marine plants forming crusts on substrates
Delta-T	Temperature difference from ambient
Filamentous	Growth form of marine plants in thread-like shape; having filaments
GIS	Geographic Information System; database software to store, retrieve, analyze, and display spatial or map-type data
Hydroid	Small colonial invertebrate related to sea anemones
Intertidal	Area of shore and associated organisms living between high- and low-water marks
Isotherm	Line of equal temperature for a given period
Pelagic	Open ocean-inhabitant; free swimming
Plankton	Plants or animals drifting with the surrounding water, including animals with weak locomotion powers
RIS	Representative Important Species
Senescence	Advancing age; refers to an annual process whereby some marine algae (kelp) degrade at the end of the growth and reproduction seasons
Taxon	Any definite unit in classification of plants and animals; taxonomic units
Upwelling	Physical oceanographical process in coastal regions whereby surface water is replaced by colder, nutrient-rich bottom water; caused by a combination of wind stress and Coriolis forces

1.0 INTRODUCTION

This chapter, *Assessment of Thermal Effects*, is the second chapter of a two volume report entitled, *The Diablo Canyon Thermal Effects Analysis Report*. This analysis and assessment of the DCPP thermal discharge effects monitoring data is submitted to the California Regional Water Quality Control Board - Central Coast Region (RWQCB or Regional Board) by Pacific Gas and Electric Co. (PG&E) in compliance with Waste Discharge Requirements, Order No. 90-09 (NPDES Permit) for Diablo Canyon, as amended by the Regional Board, February 10, 1995. Chapter 1- *Changes in the Marine Environment Resulting from the Diablo Canyon Power Plant Discharge* (Analysis Report) provides a comprehensive analysis of the data from the Thermal Effects Monitoring Program (TEMP) studies and was submitted in December 1997. This *Assessment of Thermal Effects* (Assessment Report) evaluates protection of beneficial uses by assessing the biological effects identified in the Analysis Report data using relevant regulatory guidance and decision criteria.

The Diablo Canyon NPDES permit limits the thermal discharge to 12.2°C (22°F) above the ambient seawater temperature except during heat treatments. During heat treatment, the daily average temperature cannot exceed ambient by more than 13.9°C (25°F) and maximum increases must be less than 27.8°C (50°F) above ambient. In addition, the duration of the maximum temperature elevation cannot exceed 1 hour during any 24-hour period.

The thermal component of DCPP's discharge is subject to a narrative water quality objective which requires that the limit imposed on the discharge be sufficient to "assure protection of the beneficial uses" of the receiving water. The state does not provide specific guidance on how to make a protection of beneficial uses determination, but for thermal discharges relies in part on the standard of protection set by the federal Clean Water Act (CWA): the protection of a balanced indigenous community (BIC).

In order to make a protection of beneficial uses determination, this report assesses the ecological significance of the discharge effects on the beneficial uses of the water body. Ecological significance is evaluated through the use of various scientific and regulatory assessment approaches such as U.S. EPA's Section 316(a) regulations, guidance, and administrative decisions on BIC and Ecological Risk Assessment (ERA) Guidelines. The findings of this assessment are validated by comparison to those of prior thermal effects assessments and regulatory decisions made for DCPP, as well as power plant siting policy and thermal requirements at other ocean-sited power plants.

As part of the multi-agency committee process used to review the thermal effects data, a draft of this chapter was circulated to the members of the committee, including the Regional Board staff and their independent experts, EPA, California Department of Fish and Game, and County of San Luis Obispo. However, written comments were received only from the County.

The Assessment Chapter is organized as follows:

Section 2 describes the regulatory framework for evaluating thermal discharges from both the state and federal perspectives.

Section 3 presents a brief summary of Diablo Canyon and its setting, and then describes the prior permitting and regulatory history of the DCPP thermal discharge.

Section 4 describes the evaluation approach, based on available guidance, that PG&E will use to determine if the DCPP thermal discharge protects beneficial uses.

- Section 5 presents a summary of the observed effects reported in Chapter 1 (1997 Analysis Report) and then evaluates the ecological significance of the observed effects.
- Section 6 assesses the protection of beneficial uses and evaluates the reasonableness of the findings in light of the prior assessments, regulatory findings, and siting policy.

2.0 REGULATORY FRAMEWORK

This section describes the regulatory background for evaluating thermal discharges from both the state and federal perspective. This information is presented with the intent of providing a historical context for the regulation of thermal discharges and the methods used at both the state and federal levels to assess whether an established limit meets the applicable standard.

2.1 Overview

Elevated temperature discharges are regulated in California through water quality objectives established by the State Water Resources Control Board (SWRCB or State Board) in the Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California (Thermal Plan).[1] The thermal discharge at Diablo Canyon is defined as an existing coastal discharge in the Thermal Plan and is subject to a narrative standard which requires that the limits imposed on the discharge be sufficient to "assure protection of the beneficial uses" of the receiving water. The Thermal Plan does not provide guidance on how to make a protection of beneficial uses determination regarding a thermal discharge temperature limit. At the federal level, Section 303(g) of the Clean Water Act (CWA) requires that any state water quality standard for heat be consistent with the standard set forth in Section 316. Section 316(a) authorizes the establishing of an alternative limit for heat where a discharger can show that the alternative limit will assure protection of a "balanced indigenous population of fish, shellfish, and wildlife in and on the water body to which the discharge is made." There are federal regulations and draft guidance on how to assess a thermal discharge's compliance with Section 316.

Background is provided in this section on how the standards were set and how they have been interpreted. The intent of this information is to provide a historical context for the standards established for thermal discharges and the tools used at both the state and federal level to assess whether an established limit meets the water quality objective. This section also provides information on one of the newest tools from the Environmental Protection Agency (EPA) for assessing environmental change, the Ecological Risk Assessment (ERA) process. These same approaches will be used to evaluate Diablo Canyon's thermal discharge.

2.2 California Regulation of Thermal Discharges

The Porter-Cologne Water Quality Control Act (Porter-Cologne) states that the activities and factors that affect the state's water quality must be regulated to "attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible."[2] The State Board and Regional Board are the state agencies with primary responsibilities for the coordination and control of water quality and, in exercising their responsibilities, must conform to and implement Porter-Cologne policies.[3]

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[1] SWRCB, Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California, September 1975.

[2] Water Code, Section 13000.

[3] Water Code, Section 13001.

The State Board meets its responsibility to coordinate California water quality through the development and issuance of a series of plans and policies. These plans and policies are then used by the nine Regional Boards to develop basin-specific water quality control plans (Basin Plans). The plans and policies that directly relate to the regulation of thermal discharges are discussed in more detail below.

Central Coast Basin Plan

The Central Coast Basin Plan establishes the historical, present and potential beneficial uses for the Basin.[4] For each beneficial use, the Basin Plan specifies the water quality objectives necessary to ensure protection of that use. The Basin Plan includes by reference various State Board and Regional Board plans and policies to protect water quality including those previously discussed. The Regional Board establishes water quality objectives that in its judgment will ensure the reasonable protection of the designated beneficial uses, considering all the demands made or to be made upon the water.[5] The nine beneficial uses established by the Basin Plan that have been incorporated into the Diablo Canyon NPDES Permit (Order No. 90-09) as existing or anticipated in the vicinity of the Diablo Canyon discharge are discussed in Section 4.

Thermal Plan

The Thermal Plan establishes specific water quality objectives for elevated temperature, including thermal discharges. As noted earlier, DCPP is defined in the Thermal Plan as an existing coastal discharge. Thermal limits set for existing coastal discharges are required "to assure protection of the beneficial uses and areas of special biological significance." New coastal thermal discharges are subject to more stringent criteria, including a maximum temperature limit of 11.1°C (20°F) above the receiving water, an offshore discharge, and a maximum 2.2°C (4°F) difference in temperature from the receiving water at various points from the discharge.

The "general water quality provisions" section of the Thermal Plan sets out specific criteria for the use of dispersion (i.e., mixing) zones in areas of special biological significance or where necessary to protect a specific beneficial use.[6] In addition, the Thermal Plan contains specific numeric objectives for the dispersion zone for new discharges. Review of both of these Thermal Plan provisions and definitions confirm the appropriateness of allowing a mixing zone in establishing thermal discharge limits. Given both the difference between the requirements for existing and new discharges and the explicit availability of a dispersion zone even in areas where additional limitations are needed to protect a specific beneficial use, it is clear that the protection of beneficial uses assessment is not an 'end of the pipe' assessment.

The Thermal Plan requires existing dischargers such as DCPP to conduct a study to define the effect of the discharge on beneficial uses and to identify design and operating changes if the discharge is not in compliance with the Plan.[7] Additionally, all thermal discharges must be monitored to determine

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[4] RWQCB, Basin Plan, September 1994.

[5] United States v. State Water Resources Control Board, 182 Cal. App. 3d 82, 227 Cal Rpt. 161 (1986); State Water Resources Control Board v Office of Administrative Law, 12 Cal. App. 4th 697, 16 Cal. Rptr. 2d 25 (1993).

[6] Thermal Plan at 6 (General Water Quality Provisions, Number 1).

[7] Thermal Plan, Implementation, ¶3, p. 7.

compliance with permit requirements.[8] Thermal discharges that are deemed significant by the State or Regional Boards shall be required to implement expanded monitoring programs (either continuous or periodic) to determine whether the limits provide "adequate protection to beneficial uses (including the protection and propagation of a balanced indigenous community of fish, shellfish, and wildlife, in and on the body of water into which the discharge is made)."[9] Thus, the monitoring requirement directly references protection of beneficial uses as incorporating a 'community' or receiving water body-wide assessment concept. The Thermal Plan does not provide any specific requirements for how a protection of beneficial uses determination is made. However, a reference to the BIC standard, along with guidance found in State Board Order 83-1, clearly suggests that the Board has always understood that a thermal discharge may cause reasonable effects, yet still adequately protect beneficial uses on a community basis.

Ocean Plan

The Ocean Plan establishes water quality objectives to protect the beneficial uses of California's ocean waters and is applicable to all ocean/coastal discharges. However, the Ocean Plan does not establish water quality objectives for the thermal component of ocean discharges; rather it incorporates by reference the objectives defined in the Thermal Plan discussed above. In establishing receiving water quality objectives, the Ocean Plan provides guidelines for defining the physical dispersion zone ('zone of initial dilution') for point source discharges. As is typical for water quality objectives, compliance with Ocean Plan objectives is determined by sampling beyond the zone of initial dilution.

Power Plant Policy

This State Board power plant policy provides guidance in planning and permitting new power plants that use inland waters for cooling and to keep the consumptive use of freshwater for such cooling to a minimum.[10] The policy establishes a preference for the use of ocean, rather than inland waters for power plant cooling. The first five principles contained in the policy describe the preference:

- *"It is the Board's position that from a water quantity and quality standpoint the source of power plant cooling water should come from the following sources in this order of priority depending on site specifics such as environmental, technical and economic feasibility consideration: (1) wastewater being discharged to the ocean, (2) ocean, (3) brackish water from natural sources or irrigation return flow, (4) inland wastewaters of low TDS [sic] total dissolved solids, and (5) other inland waters."*

The basis for this preference is explained in the policy as follows:

> *"Although many of the impacts of coastal power plants on the marine environment are still not well understood, it appears the coastal marine environment is less susceptible than inland waters to the water quality impacts associated with power plant cooling. Operation of existing coastal power plants indicate that these facilities either meet the standards of the State's Thermal Plan*

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[8] Thermal Plan, Implementation, ¶8, p. 8.

[9] Ibid.

[10] SWRCB, Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling, June 1975.

and Ocean Plan or could do so readily with appropriate technological modifications. Furthermore, coastal locations provide for application of wide range of cooling technologies which do not require the consumptive use of inland waters and therefore would not place an additional burden on the State's limited supply of inland waters. These technologies include once through cooling which is appropriate for most coastal sites, potential use of saltwater cooling towers, or use of brackish waters where more stringent controls are required for environmental considerations at specific sites."[11]

2.3 Federal Regulation of Thermal Discharges

The federal regulation of thermal discharges has a complicated regulatory and legal history. Congress recognized that heat is unique in that it does not persist in the environment and does not continually degrade water quality as other substances may. To avoid the substantial costs of thermal control whenever possible, Congress adopted special provisions in the CWA. First, Section 104(t) required EPA's Administrator to "conduct continuing comprehensive studies of the effects and methods of control of thermal discharges," that were to "...consider (1) economic feasibility including cost effectiveness analysis, and (2) the total impact on the environment." Second, Section 316(a) allows for a variance to "any effluent limitations proposed for the thermal component of any discharge" that are "...more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is made."[12] Third, Section 303(g) and (h) require that "water quality standards relating to heat be consistent with the requirements of Section 316 of this Act."

In 1974, the EPA promulgated technology-based limitations for thermal discharges.[13] These regulations essentially required that all steam electric generation units over 500 MW cease the use of once-through cooling systems and install or 'backfit' a closed-cycle technology by 1981. The regulations were challenged on several grounds and in 1976, EPA's regulations were invalidated by the Federal Court of Appeals for the Fourth Circuit.[14] The Court found that while EPA had considered the costs of the thermal backfit requirement, it had not adequately evaluated the environmental benefits. EPA never issued new technology-based regulations for limiting thermal discharges from steam electric plants. Therefore, thermal requirements must be set by using 'best professional judgment' for technology-based limitations or state water quality standards for water quality-based limitations. Water quality limits generally do not apply to the point of discharge, but apply at the edge of the mixing zone.[15]

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[11] Ibid., at p. 3 (Basis of Policy, ¶3).

[12] 33 USC 1326(a). As Representative Clark stated during the House debate on the legislation, "Section 316(a) . . . recognizes that heat is less harmful than most 'pollutants' and that consideration should be given to the dissipative capacities of the receiving waters." Senate Comm. On Public Works, 93rd Cong., A Legislative History of the Water Pollution Control Act Amendments of 1972 at 273-274.

[13] 39 Fed. Reg. 3686 (October 8, 1974); 39 Fed. Reg. 28926 (August 12, 1974); 39 Fed. Reg. 30073 (August 20, 1974).

[14] Appalachian Power Company v. Train, 545 F.2d 1351 (4th Cir. 1976).

[15] See e.g., EPA, Compendium of State Water Quality Limits for Thermal Discharges and Mixing Zones, August 15, 1990, p. 1 (prepared by Wade Miller Associates); 40 CFR 131.

2.3.1 *Section 316(a) Variance*

Section 316(a) authorizes the establishment of an alternative limit (in lieu of a more stringent state limit) where a discharger can show that the alternative limit will assure the protection of a "balanced indigenous population of fish, shellfish and wildlife in and on the waterbody to which the discharge is made." This alternative limit is known as a Section 316(a) variance. The EPA, Congress, and the judiciary have provided guidance as to the meaning of the statutory terms of Section 316(a). For example, the EPA issued Section 316(a) regulations in 40 CFR Sec. 125, subpart H. The Agency also drafted interagency technical guidance in 1974, 1975, and 1977 to assist dischargers in developing the necessary studies to assess the protection of BIC and to coordinate the environmental assessments required by the Nuclear Regulatory Commission (NRC) under the National Environmental Policy Act (NEPA) and by the EPA under the Clean Water Act. The EPA worked extensively with the National Resource Council and the U.S. Fish and Wildlife Service to develop this guidance. Many existing power plants operate with Section 316(a) variances to state thermal limits resulting from assessments based on this guidance. EPA's technical guidance, together with the legislative and judicial records on Section 316(a), helps to answer the questions of what constitutes BIC, how the boundaries of the water body are determined, what degree of protection is required, and what level of 'assurance' is needed. The EPA's guidance on these question is discussed below.

Definition of Balanced, Indigenous Community

The terms 'balanced' and 'population' have been amplified by the EPA, the Congress, and the courts. The individual terms are discussed below in reverse order.

<u>Population</u> EPA has consistently recognized that the statutory term 'population', which biologists use to define the organisms of a particular species, is more properly interpreted as 'community,' which refers to assemblages of the populations of organisms occupying a body of water. Accordingly, EPA's regulations provide for issuance of alternative thermal effluent limitations if a balanced, indigenous *community* of shellfish, fish and wildlife, not necessarily particular populations within the community, will be maintained.[16]

<u>Balanced</u> To be 'balanced', EPA states that an aquatic community must not be "dominated by pollution-tolerant species whose dominance is attributable to polluted water conditions."[17] However, species diversity at each trophic level is not required[18] and some change to species composition and abundance is consistent with a 'balanced community' of fish, shellfish and wildlife. EPA's thermal assessment guidance lists the following as evidence of community imbalance:

- blocking or reversing short- or long- term successional trends of community development;
- a flourishing of heat-tolerant species and an ensuing replacement of other species characteristic of the indigenous community; or
- a simplification of the community with a resulting loss of stability.[19]

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[16] 40 CFR 125.73(a).

[17] 39 Fed Reg 11,435 (March 28, 1974), See also 40 CFR 125.71(c), 44 Fed Reg 32,951-52 (June 7, 1979).

[18] See 39 Fed Reg 36,178 (October 8, 1974), explaining EPA's final 316(a) regulations were modified from the proposed regulations "to delete the suggestion that diversity must be present at all trophic levels."

[19] Environmental Protection Agency (EPA). 1974. 316(a) Technical Guidance - Thermal Discharges. Water Planning Division, Office of Water and Hazardous Materials, U.S. EPA, Washington, D.C. (Draft of September 30, 1974) at 18-19.

Protection

EPA has recognized that "[e]very thermal discharge will have some impact on the biological community of the receiving water," and therefore "[t]he issue is the magnitude of the impact and its significance in terms of the short-term and long-term stability and productivity of the biological community affected."[20] EPA's 316(a) regulations for existing discharges indicate that communities will be protected adequately if 'appreciable harm' is avoided.[21] It is not intended that every change in flora and fauna should be considered 'appreciable harm'; rather the potential for harm requires an evaluation of whether changes in survival, growth and reproduction put the abundance and persistence of the water body populations at risk.

EPA's 316(a) guidance provides the following rationale upon which the regulator would base a decision that an existing thermal discharge protects the BIC:[22]

- There is no convincing evidence that there will be damage to the BIC resulting in such phenomena as those identified in the definition of 'appreciable harm':
  - substantial increase in abundance or distribution of any nuisance species or heat-tolerant community not representative of the highest community development achievable in receiving water of comparable quality;
  - substantial decrease of formerly indigenous species, other than nuisance species;
  - changes in community structure to resemble a simpler successional stage than is natural for the locality and season in question;
  - unaesthetic appearance, odor, or taste of the waters;
  - elimination of an established or potential economic or recreational use of the waters;
  - reduction of the successful completion of life cycles of indigenous species, including those of migratory species;
  - substantial reduction of community heterogeneity or trophic structure.[23]
- Receiving water temperatures outside any (State established) mixing zone are not in excess of the upper temperature limits for survival, growth, and reproduction, as applicable, of any representative, important species (RIS) occurring in the receiving water;
- The receiving waters are not of such quality that excessive growths of nuisance organisms will take place;

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[20] Boston Edison Company (Pilgrim 1 and 2), NPDES Permit Determination No. MA0024135 (Decision of the Regional Administrator, March 11, 1977) at 17.

[21] 40 CFR 125.73(c).

[22] EPA, 316(a) Technical Guidance - Thermal Discharges (Draft of September 30, 1974) at 23; EPA, NRC and FWS, 316(a) Technical Guidance Manual - Draft Guidance Manual (Draft of December 11, 1975) at 105.

[23] Ibid.

- A zone of passage will not be impaired to the extent that it will not provide for the normal movement of populations of RIS, dominant species of fishes, and economically important species of fishes, shellfish, and wildlife;

- There will be no adverse impact on threatened and endangered species; and

- There will be no destruction of unique or rare habitat without a detailed and convincing justification of why the destruction should not constitute a basis for denial.

Thus, a thermal effluent limitation will provide adequate protection unless the thermal discharge including the applicable mixing zone would cause biological changes so substantial that community imbalance, elimination, or replacement of the community of fishes, shellfish and wildlife would result. Ecological significance must be assessed in both quantitative and qualitative terms and other stresses on the community must be taken into account. For example, a slight decrease in the population of an endangered species may be more significant than a larger decrease to a species of comparable size in the community that is not endangered. Similarly, a slight decrease in the population of a species may be as significant if the species is subject to severe stress from other man-made or natural causes.[24] Additionally, the length of time the discharge has occurred and the nature of the discharge must be considered.[25]

The U.S. Court of Appeals for the First Circuit has determined that the proper inquiry is whether relevant species (e.g., RIS) will maintain their ability to "propagate and survive."[26] The court's finding makes clear that the assessment is not an 'end of the pipe' type evaluation. Rather it is made on a community-wide basis and the water body area assessed is not limited to the immediate area of the discharge. Factors that must be considered in determining whether the balanced, indigenous community will be adequately protected include the size and hydrodynamics of the water body, the risks posed by alternate cooling technologies, and the age and remaining useful life of the generating facility.[27]

Boundaries for Assessment

Water body Generally accepted scientific practice and EPA 316(a) decisions indicate that aquatic biological communities, and the water body segments they occupy, are defined in terms of one or more of the following criteria:

- natural geographic boundaries;

- common hydrologic, chemical, and biological characteristics;

- regions defined by human use patterns;

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[24] Boston Edison Co. (Pilgrim Units 1 and 2), Determination Regarding Issuance of Proposed NPDES Permit No. MA 0025135 at 16-17 (March 11, 1977).

[25] 40 CFR 125.73(c)(2).

[26] Seacoast Anti-Pollution League v. Costle, 597 F2d. 306, 310 (1st Circuit 1979).

[27] Ibid.

- regions in which life cycle functions of component populations are completed;
- regions in which critical ecological functions are performed; and
- State Continuing Planning Process under Section 303(e) of the CWA.

For power plants sited on enclosed water bodies, such as lakes, impact is typically determined on populations within the entire natural geographic boundaries of the water body.

Determination of water body boundaries for power plants sited on the open coasts of large ocean ecosystems requires balancing among the aforementioned criteria. Typically, the effects of thermal discharge are evaluated over an area encompassing the life cycles of the affected indigenous species' populations.

Mixing Zone Both EPA and most states, including California, have long recognized that it is neither necessary nor practical to require achievement of water quality objectives for pollutants, especially heat, at the discharge point. Thus, EPA and many states employ the concept of a mixing zone to establish permit limits for thermal discharges, as well as discharges of toxic materials. A mixing zone is a defined area, localized to the discharge, in which effects are permitted.

Underlying the regulatory concept of the mixing zone is the idea that localized effects will not be ecologically significant if their spatial dimension is limited in relation to the overall ecosystem to be protected. In describing the mixing zone concept, EPA explicitly emphasizes the spatial extent of effects as an important determinant of allowable ecological change:

> *"Conditions within the mixing zone would, thus, not be adequate to assure growth and reproduction of all organisms that might otherwise attempt to remain continuously within the mixing zone.... In all cases, the size of the mixing zone and the area within certain concentration isopleths should be evaluated for their effect on the overall biological integrity of the water body."*[28]

This assessment can therefore be viewed as a determination of the size of the allowable affected area (i.e., area within which thermal discharge effects are permitted). The area that encompasses the spatial extent of the effects from the thermal discharge is an allowable area provided that it does not threaten the maintenance of the water body's BIC.

Reasonable Assurance

It is generally accepted that scientific certitude is not possible when quantifying environmental impacts. Thus, EPA looks to 'reasonable assurance' as the basic standard of proof necessary to demonstrate compliance with the federal variance standard of protecting a balanced, indigenous community.[29]

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[28] Environmental Protection Agency (EPA). 1991. Technical Support Document for Water Quality Based Toxics Control. Washington, D.C.

[29] See e.g., Seacoast Anti-Pollution League v. Costle, 597 F.2d 306, 310 (1st Cir. 1979); Public Service Company of New Hampshire (Seabrook Station Units 1 and 2), NPDES Appeal No. 76-7 (Decision of Administrator), June 1977 ("Seabrook I); Public Service Company of New Hampshire (Seabrook Station Units 1 and 2), NPDES Appeal No. 76-7 (Decision of Administrator), August 1978 ("Seabrook II).

Further, EPA decisions support the premise that decisions on thermal discharges are to be made based on the "...best information reasonably obtainable..." and that the available information is sufficient if "...substantial uncertainty is avoided."[30] This approach can be summarized as requiring the discharger to present all relevant and reasonably obtainable data, account for any significant deficiencies, use available methodologies effectively, and provide a reasonable and well articulated basis for biological conclusions drawn by qualified scientists.

[30] Proposed NPDES Permit No. MA 0025135, Opinion of the Region I Administrator, March 1977 (Boston Edison, Pilgrim Units 1 and 2). The EPA Administrator refused to grant review in August of 1978.

3.0 DCPP Description and Regulatory History

This section presents brief descriptions of DCPP and its environmental setting, and then describes the prior regulatory actions governing the plant's thermal discharge.

3.1 Power Plant Description

DCPP is a two unit nuclear-fueled steam electric power plant located on a rocky headland between Point Buchon and Point San Luis in central California, about 138 km (86 mi) north of Point Conception (Figure 3-1). Each unit uses a four-loop pressurized-water nuclear reactor with operational design capacities of approximately 1,086 MWe for Unit 1 and 1,119 MWe for Unit 2. Commercial operation of Unit 1 began in May 1985, and commercial operation of Unit 2 in March 1986. DCPP is a base-loaded power plant and is designed to operate at fuel cycle capacity factors in excess of 90 percent.

During normal operation, seawater is drawn from Intake Cove into the intake structure and pumped approximately 26 m (85 ft) above sea level through the four condensers (two for each unit) where it is used to remove heat from steam used in the generating process. After passing through the condensers, the heated seawater flows through conduits back down to sea level and is discharged to Diablo Cove at the shoreline. The maximum combined flow from both units is approximately 1,778,000 gpm. The removal of heat from steam passing through the condensers of both units during normal operation results in a discharge temperature of approximately 11°C (20°F) warmer than the seasonally-varying incoming seawater temperatures. The discharge system consists of two parallel conduits (one for each unit). Immediately before discharging into Diablo Cove, cutouts in the center wall that separate the two conduits allow mixing to occur between the conduits when flows in the units are unequal. The velocity of the discharge into Diablo Cove is relatively high due to the momentum created by the water cascading down the discharge conduits.

Periodic biofouling control procedures are necessary to minimize the growth of marine fouling organisms in the plant's cooling water systems. DCPP was designed to use thermal backwash, or heat treatment, for macrofouling control. During heat treatment, partial recirculation of the cooling water flow results in a rise in temperature that is lethal to fouling organisms. The temperature of the heat treatment discharge water exceeds that of normal operation. The current NPDES permit limits the heat treatment delta T° to 25°F (13.9°C). A total of 13 heat treatments were conducted between 1985 and January 1989. Extensive biofouling control studies conducted at the site, beginning in 1981,[31] have led to the use of new biofouling control strategies. Initial studies demonstrated that manual cleaning of the dewatered intake conduits during planned outages and curtailments was a more effective method of fouling control. In 1989, manual cleaning became the preferred method of fouling control, although heat treatment remains as one of several options. No heat treatments have occurred since 1989. Chlorination of the cooling water flow has been used to control the formation of marine bacteria on the heat transfer surface of the condenser tubes. Chlorination was typically performed daily. Another development of the biofouling control program at DCPP is the use of the proprietary chemical Acti-Brom for fouling prevention. The treatment regimen involves injecting Acti-Brom into each operating intake conduit at a target concentration of 200 ppb. Studies conducted at the onsite biology laboratory have shown that this concentration is not toxic to macroinvertebrates, but inhibits settlement of fouling larvae by preventing

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[31] PG&E, Assessment of Alternative Demusseling Methods (July 5, 1985).

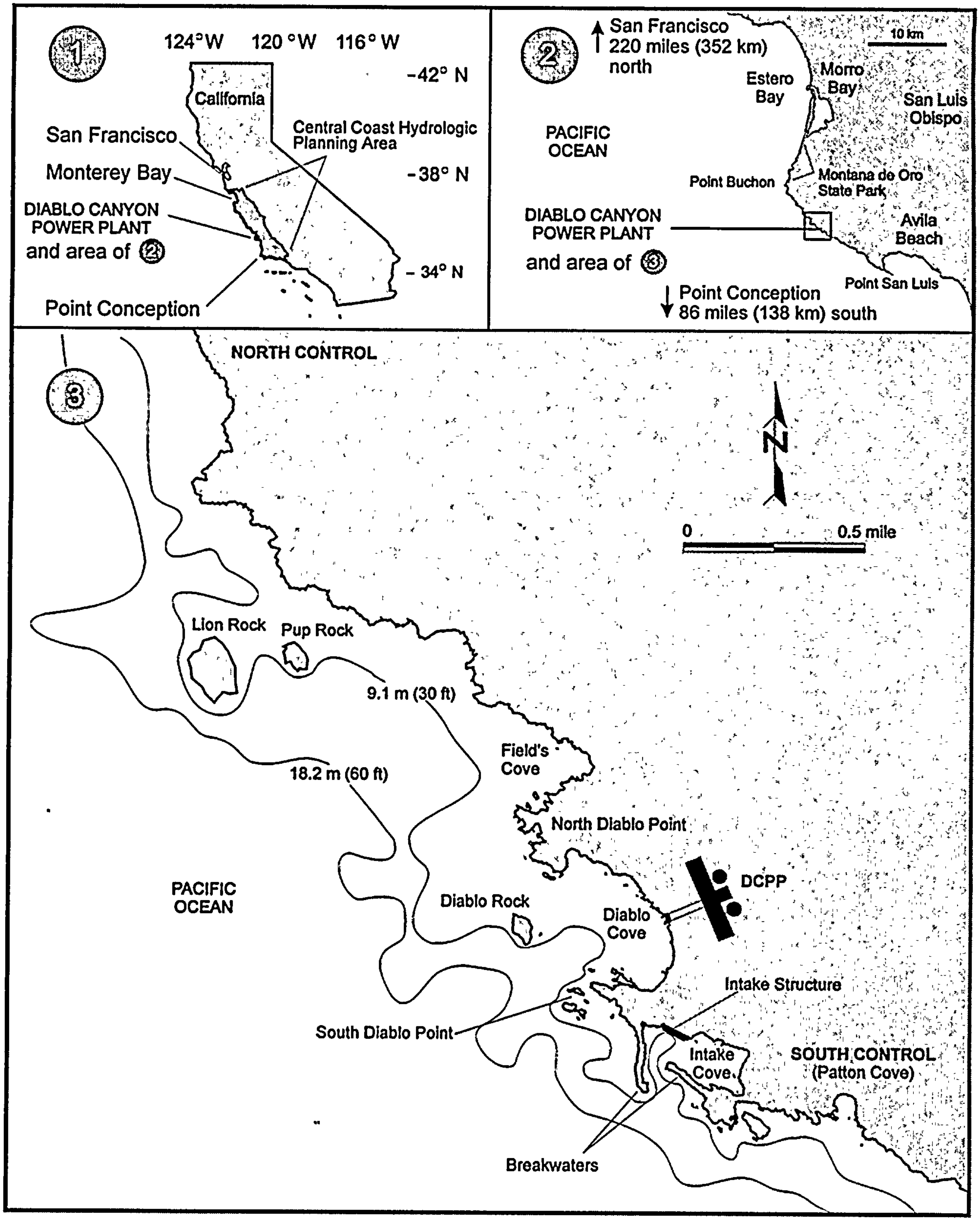

Figure 3-1. Location of the Diablo Canyon Power Plant (DCPP) and study area. Offshore bathymetric contours from U.S.G.S. Port San Luis Quadrangle-San Luis Obispo, 7.5 minute series (topographic) scale 1:24,000.

the formation of the primary slime (bacterial) layer. The total residual oxidant concentration of the discharge and the duration of chlorination are limited by the NPDES permit.

3.2 Assessment and Permit History

Studies on the marine environment at DCPP began in the mid-1960's when the area was first considered as a power plant site. The early studies were conducted to assess the baseline inventories of marine resources and the effects of power plant startup. Predictive studies were also conducted before plant start-up to identify the potential environmental effects of full-scale commercial plant operations. Studies have continued through plant operation to evaluate the predictive work and to document the effects of the discharge.

After completion of the Nuclear Regulatory Commission's (NRC) environmental review of the project, marine studies focused on collecting data to assess whether the plant's thermal discharge met the requirements of the Federal Clean Water Act, as well as California's Ocean and Thermal Plans and the Central Coast Basin Plan. The history of DCPP thermal discharge assessments and related water quality permitting activities is chronologically summarized in Table 3-1 and described below.

3.2.1 NRC Thermal Discharge Assessment

As required by NEPA, the NRC examines the potential environmental impacts of a nuclear power plant prior to issuing construction or operating permits. This environmental assessment includes a review of the effects of the proposed plant's thermal discharge and is referred to as an Environmental Statement. DCPP's Final Environmental Statement (FES) was completed by the Atomic Energy Commission (AEC), the NRC's predecessor, in May 1973 and an Addendum was completed in 1976.[32] The Statement was prepared by AEC staff using environmental reports submitted by PG&E,[33] as well as additional materials from government agencies and other organizations. The purpose of the FES was to evaluate the potential for environmental impacts to air, land, water, and the human community from the construction and operation of DCPP.

The. FES and Addendum reviewed and analyzed the available information on the predicted environmental effects that might be caused by a DCPP thermal discharge at a projected normal temperature elevation of approximately 10.6°C (19°F) and made the following findings:

- There would be no adverse effect on phytoplankton due to their ability to rapidly regenerate.
- Some zooplankton mortality was expected due to exposure to highest temperatures during passage through the cooling water system or contact with the plume near the point of discharge; however this was found to be insignificant due to rapid regeneration and recruitment.[34]

[32] AEC Directorate of Licensing, Final Environmental Statement related to the Nuclear Generating Station Diablo Canyon Units 1 & 2, May 1973 (Docket Nos. 50-275 and 50-323); NRC Office of Nuclear Reactor Regulation, Addendum to the Final Environmental Statement for the Operation of the Diablo Canyon Nuclear Plant Units 1 and 2 (May 1976) (Docket Nos. 50-275 and 50-323).

[33] PG&E, Environmental Report, Units 1 and 2 Diablo Canyon (1971), PG&E, Environmental Report Supplement No. 2 (1972).

[34] FES at iii.

Table 3-1. Permitting history related to the Diablo Canyon Power Plant thermal discharge.

Date	Event	Conclusion
1966	First marine environmental studies begin	
October 1969	First Waste Discharge Requirements issued	
1973	AEC issues Final Environmental Statement (FES)	Construction permits continued
1974	EPA establishes technology-based thermal limits	
October 1974	RWQCB issues Order 74-41 - first NPDES permit	
September 1975	State Thermal Plan adopted	
December 1975	Second Draft of Interagency Technical Guidance on Thermal Variances	
December 1975	316(a) Demonstration Work Plan submitted to RWQCB	
April 1976	Thermal Effects Monitoring Program (TEMP) study begins	
May 1976	NRC issues Addendum to FES	Operating license should be granted
July 1976	RWQCB issues Order 76-11	Establishes thermal discharge prohibition as of July 1981
August 1976	EPA thermal regulations invalidated	
May 1977	Final Draft - EPA Interagency Technical Guidance on thermal variances	
January 1982	RWQCB issues Order 82-24	Established thermal prohibition, unless TDAR and Alternatives Cooling Water System Report submitted by 4/1/82
March 1982	TDAR and Alternatives Cooling Water System Report submitted to Board	
June 1982	RWQCB issues Order 82-54	Order eliminated heat prohibition and established 20°F delta T limit for normal operation
March 1983	SWRCB issues Decision 83-1	Upholds Order 82-24 and amendments in Order 82-54
April 1983	RWQCB issues amended Order 82-54 to conform with SWRCB	
May 1985	Commercial operation of Unit 1 begins	
July 1985	Assessment of Alternative Demusseling Methods	
August 1985	RWQCB issues Order 85-101	Required final TEMP Assessment; set 22°F delta T limit for normal operation
March 1986	Commercial Operation of Unit 2 begins	
April 1988	First Final Thermal Effects Monitoring Report	
April 1989	Board Executive Officer states that final TEMP report has insufficient operational data	
May 1990	RWQCB issues Order 90-09	No change to thermal-related limits
February 1995	Board amends Order 90-09 Monitoring and Reporting Program	TEMP ended and Ecological Monitoring Program created
April 1995	First meeting of the Multi-agency Work Group	
July 1995	Ecological Monitoring Program implemented	
January 1996	Independent consultant begins work on Thermal Effects project	
December 1997	Final TEMP Analysis Report – Chapter 1, submitted to RWQCB	

- There would be a reduction of as much as 4-8 ha (10-20 acres) of bull kelp in Diablo Cove and a reduction in the kelp canopy within the 2.2°C (4°F) isotherm.[35]

- There would be a replacement of the existing benthic community in the area near the discharge where the plume contacts the bottom prior to lifting to the surface as it moves offshore (estimated to be approximately 4 ha [10 acres]).[36]

- Losses of over 70,000 black abalone and 40,000 red abalone may occur as a result of reduction in algal food species in more than half of the intertidal and subtidal zones in Diablo Cove. However, due to a subsequent increase in the sea otter population that had significant impacts on the existing abalone population, the Addendum predicted additional declines in abalone due to the thermal plume would be small.[37]

- No fish losses were expected as a result of the discharge but there would be attraction to, and avoidance of, the plume by juvenile and adult fishes.[38]

Overall, the FES found that there would be a shift in benthic organisms and fishes as a result of the replacement of cold-water species with narrow temperature tolerance ranges and an increase in species able to tolerate a wide range of temperatures. This resulted in a prediction that an increased number of warm-water-tolerant forms, indigenous to the general area, would occupy the habitat exposed to the plume.[39] The Addendum indicated that the effects of the thermal plume outside the cove would be minimal.[40]

After weighing the environmental, economic, technical, and other benefits against the environmental costs, and considering available alternatives, the AEC staff's conclusion in the FES was that construction permits should be continued. The staff reached the same conclusion in the Addendum and recommended that the operating license be granted.

3.2.2 Waste Discharge Requirements

DCPP was first issued a Waste Discharge Requirement (WDR) permit in October 1969.[41] This first permit predates the current Clean Water Act (CWA), as well as the State Thermal Plan. The overall objective of this initial WDR was "to protect public health, to protect beneficial uses made of the receiving waters and adjacent shorelines from unreasonable impairment and to prevent nuisance conditions from occurring." The WDR did not include any numeric thermal limits, but required that the temperature of the discharge "not cause undesirable ecological change or deleterious effect upon aquatic

[35] Addendum at ii and 5-3.

[36] FES at 5-37.

[37] FES at iii, 5-38; Addendum at ii.

[38] FES at iii.

[39] Ibid.

[40] Addendum at ii and Section 5.6.

[41] Central Coast Regional Water Quality Control Board, Waste Discharge Requirements, PG&E DCPP, adopted October 17, 1969.

plant and animal life." The permit included a definition of the term 'undesirable ecological change' from the California Department of Fish and Game (CDF&G). The definition included the following criteria: 1) for any point in the receiving water, including the areas within Diablo Cove, there shall be no acute toxicity to the marine biota due to the waste discharge; and 2) for the ocean waters beyond Diablo Cove, this discharge should not either directly or indirectly cause the following undesirable ecological changes or deleterious effects upon the marine environment: a) reduction in abundance or distribution of: bull kelp, pea kelp, abalones, or bony fishes; b) a reduction in abundance, distribution or variety of attached indigenous animal and plant life of rocky substrates; c) an increase in the distribution or abundance of round stingrays, bat rays, sunray sea stars, rock crabs, or sea urchins; d) an introduction of undesirable species such as the moray eel; e) any unforeseen change that adversely alters the ecological balance or productivity of the marine environment. The details in CDF&G's list of changes reflected the agency's best available information and judgment at the time. It is clear that these first narrative limits for the Diablo Canyon discharge incorporated the basic idea that substantial change within Diablo Cove was allowable and that the objective of the discharge limitation was to assure protection of the ecological balance of the receiving water beyond the localized area of effects.

3.2.3 Pre-Operational Permits and Assessments

Order 74-41

On October 11, 1974, the Regional Board issued Order No. 74-41, DCPP's first NPDES permit.[42] Although this Order made no explicit changes to DCPP's thermal limits, stating that the discharge requirements established in 1969 remained in effect, the Order does state that the California Thermal Plan and federal requirements established under Section 316 of the CWA apply to the discharge. Provision B.4 of the Order required DCPP to prepare a request for a thermal variance under Section 316(a) of the CWA, if necessary, by October of 1975.[43] Given the promulgation of EPA's thermal backfit requirements earlier in 1974, at this point in time, the DCPP discharge required a variance (see Section 2.3).

Original Section 316(a) Study Plan

To meet the requirements in Provision B.4. of Order No. 74-41, PG&E submitted a study plan to the Regional Board in December 1975. This plan, entitled *Diablo Canyon 316(a) Demonstration Study Plan*, described the studies that would be conducted to verify that a thermal discharge prohibition was more stringent than necessary to meet the federal variance standard of assuring "protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the Pacific Ocean" and that an alternative thermal limit would be sufficient. The 316(a) demonstration was designed to use field data to determine the potential effect of the plant's thermal discharge on the twenty-one representative, important species (RIS) selected for the study by the Regional Board and the CDF&G. Laboratory tests, physical model tests, and mathematical models were to be used to supplement the field data as necessary to provide a comprehensive, integrated analysis of the effect of the plant's thermal

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[42] Central Coast Regional Water Quality Control Board, DCPP NPDES Permit, CA 0003751; Order No. 74-41, October 11, 1974.

[43] Order No. 74-41, Provision B.4.

discharge. The data were also to be used to determine compliance with applicable physical and biological guidelines relative to mixing zone characterization.

Representative, Important Species (RIS)

PG&E and the CDF&G proposed RIS for DCPP not only on the basis of their recreational, commercial and ecological importance but also to represent the biotic categories referenced in EPA's 316(a) guidance.[44] The Regional Board and CDF&G approved a list of 21 RIS (Table 3-2).

Table 3-2. Representative Important Species (RIS) list.

Habitat-Formers	Shellfish and Invertebrates		Fishes
<u>Intertidal Habitat</u> **Un-named red seaweed** (*Gigartina canaliculata*) **Hollow-branched seaweed** (*Gastroclonium coulteri*) **Iridescent seaweed** (*Iridaea flaccida*) **Feather-boa kelp** (*Egregia menziesii*) <u>Subtidal Habitat</u> **Oar-blade kelp** (*Laminaria dentigera*) **Bull kelp** (*Nereocystis luetkeana*) **Tree kelp** (*Pterygophora californica*)	<u>Intertidal Habitat</u> **Aggregating sea anemone** (*Anthopleura elegantissima*) **Black abalone** (*Haliotis cracherodii*) **Ochre starfish** (*Pisaster ochraceus*) <u>Subtidal Habitat</u> **Red Abalone** (*Haliotis rufescens*) **Brown turban snail** (*Tegula brunnea*) **Red sea urchin** (*Strongylocentrotus franciscanus*)	**Purple sea urchin** (*Strongylocentrotus purpuratus*) **Sun stars** (*Pycnopodia helianthoides*) **Rock crab** (*Cancer antennarius*) **Kelp crab** (*Pugettia producta*)	<u>Intertidal Habitat</u> **Rock Prickleback** (*Xiphister mucosus*) <u>Subtidal Habitat</u> **Blue rockfish** (*Sebastes mystinus*) **Gopher rockfish** (*Sebastes carnatus*) **Cabezon** (*Scorpaenichthys marmoratus*)

These RIS, chosen to represent the BIC and its biotic categories were selected to detect appreciable harm from the DCPP discharge using species that were ecologically, commercially and recreationally important to the water body's beneficial uses. DCPP field studies and analysis were designed to focus on these RIS, but were adapted to also include a very broad range of other species making up the marine habitat. While discharge effects on BIC were expected to be reflected in the RIS, the other species provide key information on the marine habitat's species richness, diversity and ecological functions.

[44] EPA 316(a) Guidance 1977.

Order 76-11

The Regional Board issued DCPP a new NPDES permit in April 1976. At this time, the EPA technology-based regulations were still in place. Therefore, Order No. 76-11 included a prohibition on the discharge of heat after July 1, 1981, unless PG&E made a demonstration that the prohibition, or other heat-related limitations were more stringent than necessary to meet the federal variance standard.[45] The Order also noted that PG&E had submitted a study plan for a demonstration program under the requirements of Section 316(a) in December 1975. Thus, the studies at Diablo Canyon initially assumed that a federal variance from the 1974 technology-based limit would be necessary and the Regional Board permit reflected this fact. Additionally, the Order contained heat-related limits that were in effect until July 1981. These limits established a maximum discharge temperature increase of 13.9°C (25°F) and required the maximum increase to be no more than 12.2°C (22°F) for 12 hours in a calendar day and 24 hours in a calendar week. During heat treatments, the maximum increase allowed was 27.8°C (50°F) and the permit required the operation of the pumps of the unit not being treated.

Orders 82-24 and 82-54

In January 1982, after extensive public hearings, the Regional Board issued Order No. 82-24. This Order included a prohibition of thermal discharges, with very limited exceptions until July 1, 1982, or until the Regional Board had the opportunity to reconsider the prohibition in light of a technical report required to be submitted by PG&E prior to April 1, 1982. The technical report was to describe alternative plans to reduce the heat and volume of the proposed cooling water discharge and contain further information on the anticipated and possible thermal and volume effects of the discharge on the beneficial uses of the ocean. This requirement was met with the submission of two reports to the Regional Board on March 30, 1982: 1) Assessment of Alternatives to the Existing Cooling Water System (Alternatives Report)[46]; and 2) Thermal Discharge Assessment Report (TDAR).[47]

<u>Alternatives Report</u> The Alternatives Report presented an evaluation of alternatives to reduce the heat and volume of the cooling water discharge. The report identified several alternatives for retrofitting the plant's cooling water system to reduce the quantity of heat discharged to Diablo Cove. The costs of the retrofits were estimated to range from 1.6 to 3.1 billion dollars (in 1982 dollars) over the 30-year life expectancy of the plant. These costs were shown to be far in excess of the environmental benefits expected from the retrofits.

<u>TDAR</u> The TDAR found that an increase in the abundance and distribution of warmer water species would be expected in areas where the temperature was constantly 17.8°C (64°F) or greater. During normal plant operation, the 17.8°C (64°F) isotherm was expected to encompass the entire surface area of the cove and approximately 50 percent of the bottom area. The primary changes predicted included:

- areas dominated by bull kelp and tree kelp may, after exposure to the thermal plume, become dominated by warm water kelp species, such as giant kelp;

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[45] Order No. 76-11, Finding 15, Discharge Prohibition A.1.

[46] PG&E. 1982a. Assessment Alternatives to the Existing Cooling Water System. Prepared by TERA Corporation for Pacific Gas and Electric Company, San Francisco, CA.

[47] PG&E. 1982b. Diablo Canyon Power Plant Thermal Discharge Assessment Report. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corporation for Pacific Gas and Electric Company, San Francisco, CA.

- in the immediate vicinity of the discharge, a new community may form, dominated by thermally tolerant filter feeders such as sea anemones, barnacles, hydroids, and mussels;
- few changes were expected in the intertidal community, with greater change expected in the less thermally tolerant subtidal community; and
- the majority of the changes would occur in south Diablo Cove.

Order 82-54

Upon review of these reports, and additional public hearings, the Regional Board amended Order No. 82-24 in June 1982. The amendment (Order No. 82-54) deleted the prohibition on heat and established a maximum discharge temperature increase of 11.1°C (20°F), and also added limitations on the daily volume of the discharge, and the cross condenser delta T°. Both the original Order No. 82-24 and the amendment were appealed to the State Board on a variety of grounds by a number of petitioners, including PG&E. The appeals included a contention by some petitioners that the thermal limits were 'excessive'.

State Board Order 83-1

In March 1983, the State Board issued its decision upholding the thermal 11.1°C (20°F) limit.[48] The decision found that "normal two unit operation and heat treatment, will significantly alter the quality of waters in Diablo Cove" and concluded that "this alteration of water quality is not unreasonable."[49] The State Board based this conclusion on several factors. First, Porter-Cologne allows for the balancing of interests and it recognizes that water quality can be changed to some degree without unreasonably affecting the beneficial uses. Second, the State Board has an explicit policy preference for the siting of power plants on the coast.[50] Third, they stated that the CDF&G had been involved in the marine studies at Diablo Canyon for over ten years and believed the predicted changes were acceptable. Fourth, Diablo Cove is not an Area of Special Biological Significance and therefore, some change in water quality was acceptable. Fifth, under the Thermal Plan, a new power plant can be allowed a 11.1°C (20°F) limit and the State Board noted that an existing discharge such as Diablo Canyon would presumably be subject to a less stringent requirement. Finally, the limit was found not to be excessive when compared to other coastal power plants, both in California and at other locations outside the state.[51] For all of these reasons, the State Board found that the proposed limit was reasonable based on the predicted impacts. They also required PG&E to conduct Thermal Effects Monitoring Program (TEMP) studies as an extension of the work summarized in the TDAR, which would provide data on thermal impacts.

The Regional Board modified Order No. 82-54 to conform with the State Board's decision and issued a new amended Order No. 82-54 in April 1983. This Order maintained the thermal limit of a maximum discharge temperature increase of 11.1°C (20°F) (except during heat treatments) and also required PG&E

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[48] State Water Resources Control Board, Order No. 83-1, March 17, 1983.

[49] State Board Order No. 83-1, at p. 27.

[50] State Water Resources Control Board, Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling, June 19, 1975, Principle 1.

[51] See Table 6-1.

to submit within 36 months of commercial operation the results of its TEMP study. The Order also included a requirement that during heat treatment of Unit 1, Unit 2 circulating pumps must be run at full capacity with no commercial load and established a maximum discharge water temperature of 37.8°C (100°F) during heat treatments. PG&E was also required, prior to commercial operation of Unit 2, to evaluate ways to reduce the maximum temperature increase during heat treatments to 27.8°C (50°F).[52,53]

3.2.4 Operational Permits and Assessments

Order 85-101

Commercial operation of Unit 1 began in May 1985. In August 1985, the Regional Board issued Order No. 85-101. This Order raised the discharge temperature increase limit to a daily average of 12.2°C (22°F). The increase from 11.1°C (20°F) was based on additional operational information which indicated that the temperature during transient conditions such as load rejection, steam dump, generator trip, and the operation of engineered safety features could exceed 11.1°C (20°F) and might reach 12.2°C (22°F). During heat treatments, the daily average temperature increase was set at 13.9°C (25°F), with a maximum of 27.8°C (50°F) for one hour during a 24-hour period of treatment. Additionally, PG&E was required to provide results of the TEMP studies to the Regional Board by May 1988.[54] This requirement would supplement the predictions of the FES and its Addendum and the 1982 TDAR with operational information to provide the Regional Board further assurance that the existing limits were sufficient to protect beneficial uses.

1988 TEMP Final Report

As required by Provision 4.(a) of Order No. 85-101, PG&E submitted a report on the TEMP studies to the Regional Board in April 1988. This report included nine years of pre-operational data and approximately 30 months of operating data (18 months of two-unit operation). The overall conclusion of the report was that communities in the cove were still changing and that the protection of the beneficial uses of the cove was demonstrated by the continued presence of marine algal, invertebrate, and fish species whose composition, abundance, and distribution, though different than those previously found at the site, were representative of natural marine habitat. The key findings in the report were:

- Changes in the 65 species analyzed in the report were fairly evenly divided between increases and decreases: 43 percent increased; 31 percent decreased; and, 26 percent were unchanged.[55]

- The primary effect on algae was the early senescence of bull kelp. This was the only effect known to occur outside Diablo Cove. Within the cove, there was a decline in abundance and distribution in three species of underwater kelp and several species of intertidal red and

[52] Regional Board, Amended Order No. 82-24, Provision D.6 (April 13, 1983).

[53] PG&E, Assessment of Alternative Demusseling Methods (July 5, 1985).

[54] RWQCB, Order No. 85-101, Provision 4.(a), July 12, 1985.

[55] The percentages were reported incorrectly in the original Final TEMP Report (April 1988). These figures are the corrected ones, first published in PG&E, Ocean Summary Report, 1990.

brown algae. There was an increase in subtidal red algal species in the nearshore discharge area.

- Invertebrate abundances remained generally unchanged or increased significantly (acorn barnacle and aggregating anemone). No change in the distribution of red or black abalone was found. Rock crabs appeared to avoid the warmest areas of the cove.

- Some examples of plume avoidance were observed in fishes, but the primary effect was an increased attraction to the plume area, with fishes taking advantage of feeding opportunities provided by the plume.

The Regional Board staff reviewed the report and notified PG&E in April 1989 that the TEMP program was "appropriately designed and conducted in a satisfactory manner," but that it was "not conducted long enough to determine the steady state environment in and around Diablo Cove for the life of Diablo Canyon Power Plant."[56] It is important to note that the scientific consensus now believes that a 'steady state' will never be reached in Diablo Cove due to fluctuating discharge conditions (i.e., unit loads and outages, plume trajectories) and continual natural change from events such as warm El Niño currents and severe winter storms. Subsequently, the Executive Officer established a multi-agency workgroup, comprised of Regional Board and CDF&G staff, and PG&E and its consultants. In addition to providing guidance, the workgroup was to develop recommended monitoring requirements which would allow the Regional Board to determine whether beneficial uses were protected. The workgroup met throughout 1989 and early 1990, discussing a variety of data collection and analysis methodologies that would be incorporated into the TEMP study.

Order 90-09

The renewal of the permit in 1990 (Order No. 90-09) required PG&E to continue its TEMP studies, maintained the maximum discharge temperature increase of 12.2°C (22°F) (daily average), and maintained the limits for heat treatments.

Annual Reports

PG&E has submitted annual reports on the TEMP studies to the Regional Board since 1983. The reports present the previous years results using a variety of tabular and graphical analyses. These reports documented natural changes to the marine environment before plant operation and then provided an on-going assessment of changes following plant start-up.[57]

3.2.5 Present Assessment

Beginning in 1994, after nine years of commercial operation, Regional Board staff and PG&E began discussing the possibility of bringing the thermal effects studies to closure and preparing a comprehensive final assessment of the existing limits. PG&E submitted a draft proposal for a reduced

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[56] Letter from Bill Leonard, Executive Officer, Central Coast Regional Board, to Victor Furtado, Manager Environmental Services, PG&E, April 21, 1989.

[57] See Appendix A.

monitoring program that was reviewed by Regional Board and CDF&G staff. Based on the review, changes were made to address their concerns. In February 1995, the Regional Board voted to modify the existing monitoring program by requiring PG&E to prepare a comprehensive assessment of the thermal effects data collected and to implement the new monitoring program developed by PG&E, CDF&G, and Regional Board staff, referred to as the Ecological Monitoring Program.[58]

In addition to recommending the modification of the Monitoring and Reporting Program of Order No. 90-09, Regional Board staff also recommended the establishment of a multi-agency workgroup to advise on the development of the comprehensive thermal effects assessment and the hiring of an independent consultant to coordinate the technical aspects of the workgroup process. The workgroup decided that the comprehensive assessment should be formatted into two separate volumes or chapters: 1) an analysis of the data collected over the last twenty years and 2) an assessment of whether the existing thermal limits are adequate to protect beneficial uses. The first chapter of the report, the 1997 Analysis Report was submitted to the Regional Board in December 1997. These two chapters fulfill PG&E's obligation in Monitoring and Reporting Program 90-09, as modified by the Regional Board in February 1995.

3.2.6 Additional Background

Appendix A was compiled to demonstrate the breadth and scope of marine environmental studies conducted in the Diablo Canyon area. Since 1967, over 100 reports have been submitted to the Regional Board and other regulatory agencies such as U.S. EPA, the NRC and CDF&G. Additionally, studies have also been conducted directly by agencies. All of this work is referenced in Appendix A. The studies include not only TEMP-related monitoring, but predictive studies, baseline pre-operation studies, plume modeling and environmental assessments required by the NRC.

[58] RWQCB, Amendment of Order No. 90-09, February 10, 1995 (modification to Monitoring and Reporting Program).

4.0 Evaluation Approach

This section describes our approach for characterizing the importance of ecological changes resulting from the discharge and how this information and information from past assessments and decisions should be used in a determination of whether the changes affect the continued beneficial use of the receiving water. The approach uses the regulatory objectives and requirements identified in Section 2 and prior regulatory assessments discussed in Section 3. Since virtually any human activity will result in a change to some ecological component or process, a critical part of this regulatory determination is to distinguish the importance of the ecological changes associated with the operation of DCPP. To some degree, judgments about the importance of ecological changes will always involve choices among the values society places on natural resources and social needs. In this assessment, such a judgment will be required in considering whether the nature and extent of DCPP discharge effects are reasonable.

4.1 Beneficial Uses

The beneficial uses that the DCPP thermal discharge must protect are defined by the DCPP NPDES Permit Order No. 90-09 as:

- Marine Habitat
- Ocean Commercial and Sport Fishing
- Shellfish Harvesting
- Preservation of Rare and Endangered Species
- Wildlife Habitat
- Industrial Water Supply
- Navigation
- Water Contact Recreation
- Non-contact Water Recreation

This assessment focuses on discharge effects on the beneficial use of 'Marine Habitat'. The beneficial use of marine habitat is defined by the Basin Plan as uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fishes, shellfish, or wildlife (e.g., marine mammals, shorebirds). Our assessment of discharge effects in Section 5 uses the biotic categories defined in EPA 316(a) guidance on protection of a BIC. These categories include phytoplankton, zooplankton, habitat-formers (plants and algae), shellfish/invertebrates, fishes and vertebrate wildlife. All six categories are discussed in Section 5 and detailed assessments are presented for the categories of habitat-formers, shellfish/invertebrates and fishes. Therefore, our assessment of protection of marine habitat incorporates related biological uses (Commercial and Sport Fishing, Shellfish Harvesting, Rare and Endangered Species and Wildlife Habitat) by applying the concepts surrounding protection of a 'balanced indigenous community' (BIC). The EPA concept of protection of a BIC is similar to the protection required to support marine ecosystems as defined in the Basin Plan. Based on the concerns of the Regional Board the focus of this report is on the protection of marine habitat and associated uses and not on non-biological uses. It has been generally agreed upon that the discharge does not affect the four non-biological uses. Activities surrounding these uses are limited in the area around Diablo Canyon.

4.2 Determination of Ecological Significance

A summary of discharge effects on marine habitat, as identified in the 1997 Analysis Report, are presented in Section 5. These effects are evaluated in relation to protection of beneficial uses by using EPA's 316(a) guidance and proposed federal ecological risk assessment (ERA) criteria. Protection is determined by evaluating the ecological risk that these effects pose to the water body considering the nature, intensity, extent and reversibility of discharge effects.

4.2.1 Water Body Boundaries

As discussed in Section 2, the EPA 316(a) guidance prescribes criteria for determining the water body boundaries for overall assessment of a BIC. For determining the water body boundaries, typically the effects of the thermal discharge are evaluated over an area encompassing the life cycles of the affected indigenous communities. They can also be based on the State Continuing Planning Process under Section 303(e) of the CWA. Water body boundaries can also be assigned based on California's Porter-Cologne Water Quality Control Act that establishes individual regions for the purpose of water quality management.

Diablo Canyon is located within the Central Coast Region which extends from southern San Mateo County to northern Ventura County, a distance of approximately 300 linear miles. The region is also further subdivided into coastal segments for the purposes of water quality management. Diablo Canyon is located within a coastal segment that ranges from Point Buchon to Point San Luis, a total shoreline distance of approximately 26.8 km (16.7 mi) (using a 1:24,000 scale map). The coastal waters of the Central Coast region define the water body used in this assessment. This water body is an appropriate choice based on the biological community similarities found between them and Diablo Cove. Many of the marine plants, invertebrates and fishes found within the vicinity of Diablo Canyon have ranges that extend along thousands of miles of coastline from central California to Alaska. Iridescent seaweed, the dominant intertidal habitat-forming alga has a geographic distribution from Alaska to northern Baja California. Bull kelp, another important habitat-former in the subtidal has a distribution with more northern affinities; its distribution extends from Santa Barbara County to Alaska. Other species have distributions with more southern affinities, such as black abalone which is distributed from northern California to southern Baja California. The areas within the Central Coast region also share common oceanographic features.

To provide a more conservative assessment of water body effects the coastal segment between Point San Luis and Point Buchon is used for describing the spatial extent of discharge-related effects. This coastal segment is defined by the common biological communities and habitat types found there. The type of analysis used to detect effects of the discharge in the 1997 Analysis Report takes into account the fact that natural differences in abundances of organisms will be found among different areas being sampled. To determine what changes in abundance at the sampling locations may be a result of discharge effects, the analysis must assume that the natural forces of variation affecting the various sampling areas are approximately equal. This assumption was tested prior to analysis for discharge effects. The assumption would not be met if communities within the coastal segment where our sampling stations are located responded differently to natural forces of variation such as seasonal changes, storms, El Niño, etc. The assumption was met for most species supporting the use of this coastal segment as a water body for assessment. Areas to the north and south of this coastal segment contain large expanses of sandy beaches with habitat that is not similar to the predominately rocky shoreline found around Diablo Canyon. The communities in these areas are different from those within the rocky habitat of the coastal segment and would be subjected to different types of natural disturbances.

4.2.2 Ecological Significance

The potential of the thermal discharge to affect marine habitat is evaluated in Section 5 using factors derived from EPA guidance for both 316(a) thermal effects studies and ecological risk assessment (ERA).[59,60]

Ecological Risk Assessment

The ERA framework proposed for use here has been under development since 1989 and has been reviewed and commented on by a variety of scientific groups. ERA "evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors."[61] It is a process for organizing and analyzing information, assumptions, and uncertainties supporting regulatory decisions and resource management actions to control the impacts of chemical, physical, or biological stressors. The ERA guidance is used to assure that the assessment approach emphasized in this report is consistent with evolving directions in environmental impact assessment.

ERA guidance categorizes important factors for assessing the likelihood of adverse effects. The major ecological risk factors developed from ERA for this assessment are:

- the nature and intensity of effects;
- the spatial scale of effects; and
- the temporal scale of effects and potential for reversibility.

These three risk factors are used to evaluate discharge effects for individual species and biotic categories. The information to evaluate these factors was drawn largely from the thermal effects studies conducted at the DCPP and reported in the TDAR, 1988 TEMP Final Report, and 1997 Analysis Report, supplemented by additional DCPP monitoring data and information from the general literature.

Section 316(a) Draft Guidance

The EPA has developed a set of criteria to assist dischargers in developing the necessary studies to assess the protection of BIC that was presented in Section 2.3.1. In developing the criteria the EPA recognized that thermal discharges will have some effect on the BIC, but that the significance of the effects are related to the magnitude of the their impact on the short-term and long-term stability and productivity of the BIC. The guidance includes both decision criteria applied to each biotic category and "master rationales" that are applied to the community in general. Most of the criteria are specific conditions, such as blockage of migration, that can be used for determining whether a BIC is being protected. The broadest level of protection is provided by the criterion that a thermal discharge does not cause 'appreciable harm' to the BIC. The ERA framework is useful in identifying effects that may have caused 'appreciable harm' to the BIC. This assessment is presented in the conclusions to Section 5.

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[59] EPA, Proposed Guidelines for Ecological Risk Assessment, 61 Fed. Reg. 47552, September 9, 1996 (notice of availability and opportunity to comment).

[60] Environmental Protection Agency (EPA). 1992. Framework for Ecological Risk Assessment. Risk Assessment Forum. U.S. EPA, Washington D.C. EPA 630/R-92/001.

[61] Ibid.

4.3 Protection of Beneficial Uses Assessment

4.3.1 Protection of Beneficial Uses Based on an Assessment of Ecological Significance and the Order 83-1 Factors

An assessment framework to determine if the thermal discharge is protective of beneficial was developed by the State Board in Order 83-1 in March 1983 for their consideration of the DCPP thermal limit of 11.1°C (20°F). The factors identified by the State Board recognized that Porter-Cologne calls for a balancing process when assessing protection of beneficial uses that requires "...the activities and factors that may affect the quality of the waters of the state be regulated to attain the highest water quality that is reasonable, considering all demands being made, and to be made, on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." In Section 6, protection of beneficial uses will be assessed by evaluating the ecological significance of the observed effects in conjunction with the factors outlined by the State Board. These factors focus not only on the balancing of multiple uses and the need for reasonable protection, but also on the permitting history of the discharge, the applicable state policies, and the role of other agencies in the long-term evaluation of the site, both before and during operation.

4.3.2 Evaluation of Additional Evidence that a Protection of Beneficial Uses Finding is Reasonable and Consistent with Other Decisions and Policies

The State Board required PG&E to collect data on actual changes to provide reasonable assurance that their decision was supported. Beginning with commercial operation in 1985, PG&E collected data to document actual changes. Over the course of the last twelve years, these data were presented to the Regional Board in a series of annual reports and a summary report in 1988. The ability to detect small changes continued to grow as the amount of data increased. A review of this data and the findings of the 1997 Analysis Report provide the Regional Board with reasonable assurance that the 1983 decision was correct. This is supported by several lines of evidence presented in Section 6.3 including the following:

- comparisons of the observed effects with changes predicted in the TDAR;
- comparisons with discharge limits for other plants;
- comparisons with EPA guidance for duration and nature of studies; and
- involvement of multiple agencies in assessment process.

5.0 SUMMARY AND EVALUATION OF EFFECTS ON MARINE HABITAT

The thermal exposure of the marine habitat resulting from the DCPP discharge is a function of the ambient coastal water temperatures, the abundance and distribution of species in the receiving water body and the spatial and temporal distribution of temperature elevations in the discharge plume. The nature of the thermal exposure, the effects on different biotic groups and the ecological significance of those effects are presented in this section. Section 5.1 provides a description of the DCPP marine habitat and nature of the thermal exposure caused by the discharge. Section 5.2 presents some of the potential effects that can result from thermal exposure. Descriptions of the observed effects and ecological significance of those effects are summarized in Section 5.3. Conclusions concerning the effects on marine habitat are summarized in Section 5.4 using the BIC criteria.

5.1 DCPP Marine Habitat and Thermal Exposure

5.1.1 Marine Habitat / Biogeographical Communities

The marine habitat potentially exposed to the DCPP discharge plume is part of a biogeographical transition zone between the warm-temperate organisms found to the south and cool-temperate organisms to the north.[62, 63] California rocky nearshore intertidal and subtidal areas are characterized by diverse assemblages of algae, invertebrates, and fishes. The algae are of particular ecological importance as food and shelter for associated animals.[64] The high diversity of plants and animals, and their abundance and distributions within the nearshore zone result from variations in physical factors (temperature, substrate type, wave exposure, elevation, open space) and biological factors (grazing, predation, space competition, recruitment) that occur on a localized level.[65]

Considered on a broad geographic scale, the relatively cooler coastal water of central and northern California accounts for many of the differences in species comprising the marine communities north and south of Point Conception. Consequently, Point Conception is viewed to be a biogeographic boundary between the warm-temperate organisms found to the south and cool-temperate organisms to the north.[66] The mix of near-shore habitat types is similar throughout the California coast north of this boundary as water temperatures under the influence of ocean currents vary within a relatively defined range with latitude. As a consequence of these environmental conditions, assemblages of marine life similar to that in the exposed area at DCPP extend for hundreds of miles along the California coast. The marine

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[62] Murray, S.N. and M.M. Littler. 1981. Biogeographical analysis of intertidal macrophyte floras of southern California. J. Biogeogr. 8:339-351.

[63] Haury, L.R., J.J. Simpson, J. Pelaez, C.J. Koblinsky, and D. Wiesenhahn. 1986. Biological consequences of a recurrent eddy off Point Conception, California. J. Geo. Res. 91:12937-12956.

[64] Lubchenco, J. 1978. Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilities. Amer. Nat. 112:23-29.

[65] Foster, M.S. and D. R. Schiel. 1985. The ecology of giant kelp forests in California: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.2).

[66] Murray and Littler 1981; Haury et al. 1986.

communities of the central California coast are dominated by cool-temperate species, but species with warm-temperate distributions found primarily south of Point Conception are also indigenous to the area.[67]

Far from being stable entities, biological communities in open coastal areas such as near DCPP are subject to significant changes as a result of natural events. In Diablo Cove for example, storms associated with the 1982-1983 El Niño resulted in disturbance to large areas of the intertidal and shallow subtidal. During this period a cliff collapsed covering a large area of the intertidal in south Diablo Cove, and large boulders rolled about in other intertidal and subtidal areas. Prior to 1983, changes in subtidal habitat occurred with the arrival of sea otters into the Diablo Canyon area in 1974. Studies conducted in Diablo Cove prior to the TEMP documented substantial ecological changes in subtidal habitat in Diablo Cove, beginning in 1974 when sea otters reached the study area.[68, 69] Before the arrival of the sea otters, Diablo Cove had been overgrazed of algal cover by dense aggregations of red sea urchins *Strongylocentrotus franciscanus*.[70] Once sea otters became established in Diablo Cove, their foraging on red sea urchins reduced grazing pressures on subtidal algae. In response, the bull kelp *Nereocystis luetkeana*, tree kelp *Pterygophora californica*, and oar-blade kelp *Laminaria setchellii* increased in density. The TEMP studies began in 1976 after the subtidal algal assemblage in Diablo Cove had shifted in response to the reduction of algal grazers by sea otters. In addition to these species changes, long-term cycles caused by inter-annual El Niño warming resulted in occurrences of warm-temperate species more common south of Point Conception.

The Diablo Canyon study area provides a variety of habitats that may be categorized as intertidal, subtidal, or pelagic. Intertidal habitat fringes the shoreline within the range of elevation that is alternately exposed and submerged with the ebb and flood of the tides. Consequently, organisms inhabiting the intertidal zone must be adapted to withstand wide variations in temperature as they are intermittently exposed to both the atmosphere and direct sunlight. The abundance and vertical distribution of intertidal species are also controlled by their resistance to desiccation. Subtidal habitat lies below the low tide water elevation and consists of bottom-dwelling plants and animals, as well as associated free-swimming species. The pelagic habitat consists of all open water areas not immediately adjacent to the bottom or within the kelp forests. The aquatic species within this habitat consist of free swimming and drifting life in the ocean that are not part of the benthic assemblage. Transport by drift or migration/movement of organisms occurs offshore of the cove.

5.1.2 Marine Habitat Exposure to Plume

Under normal operating conditions, the DCPP thermal discharge enters the receiving water at the shoreline of Diablo Cove at a high velocity and at a temperature approximately 11°C (20°F) above ambient. The high velocity results from the 26 m (85 ft) drop in elevation prior to entering the receiving

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[67] Abbott, I.A. and W.J. North. 1971. Temperature influences on floral composition in California coastal waters. pages 72-79 *in* K. Nisizawa (ed.), Proc. 7th Int. Seaweed Symp., Wiley Interscience, New York.

[68] Gotshall, D.W., L.L. Laurent, S.L. Owen, J. Grant, and P. Law. 1984. A quantitative ecological study of selected nearshore marine plants and animals at the Diablo Canyon Power Plant site: a pre-operational baseline: 1973-1978. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 48.

[69] North, W.J. 1969. An evaluation of the marine flora and fauna in the vicinity of Diablo Cove, California. Marine Advisors, La Jolla, CA. p. 1097-1128.

[70] Burge, R.T. and S.A. Schultz. 1973. The marine environment in the vicinity of Diablo Cove with special reference to abalone and bony fishes. Calif. Dept. Fish Game, Mar. Res. Tech. Rpt. No. 19.

water. Once in Diablo Cove, the plume expands both laterally and vertically, and velocities and temperatures decrease with distance from the discharge point due to mixing with ambient water and dissipation to the atmosphere. As the plume's momentum decreases, thermal buoyancy causes the plume to detach (or 'lift-off') from the bottom and become a surface layer. In Diablo Cove, the lower boundary of the plume varies between -5 m (16 ft) and -11 m (36 ft) MLLW. As a result, bottom habitat in the deeper areas within and offshore of the cove are not exposed to the elevated temperatures of the plume. Verified physical model studies of the DCPP thermal discharge have indicated that the bottom habitat exposed to plume temperature elevations of 2°C (3.6°F) or greater is generally limited to only 9 to 13 ha (22 to 33 acres) in Diablo Cove.

Intertidal habitat within Diablo Cove is exposed to plume-related temperature elevations averaging between 3 and 4°C (5 to 7°F) above ambient, with maximum temperatures reaching 5 to 6°C (9 to 11°F) (Figure 5-1) above ambient. Intertidal habitat at the edge of the plume in Field's Cove and at South Diablo Point is exposed to mean temperature elevations of 1 to 1.5°C (2 to 3°F) above those simultaneously recorded at the north and south control stations (Figure 5-2).

Temperature elevations from the discharge in the subtidal decrease with increasing depth. Because the thermal plume becomes a surface layer, the subtidal habitat below 7.6 to 9.1 m (25 to 30 ft) is generally not exposed to elevated temperatures from the discharge. Outside the discharge turbulence zone, the subtidal habitat within Diablo Cove shallower than -5 m (15 ft) MLLW is exposed to temperature elevations averaging between 3 and 5°C (5 and 9°F) above ambient with a maximum of 5 to 7°C (9 to 13°F) in the northern part of the cove. In the southern part of the cove shallow subtidal temperature elevations are less, averaging between 2 and 3°C (4 and 5°F) above ambient with a maximum of about 3 to 4°C (5 to 7°F).

In the area beyond the cove, the surface plume is subject to buoyant spreading that is an essential process to dissipate the waste heat to the atmosphere. Environmental factors such as winds, tides, waves, and currents interact with each other, resulting in various thermal plume configurations. As a result, marine habitat beyond Diablo Cove is intermittently exposed to plume temperatures that are both lower and more variable than temperatures within the cove.

Nearshore water temperature monitoring data at various permanent locations described in the 1997 Analysis Report confirm the general pattern of shallow-water habitat exposure expected from verified plume models and field surveys. Data from these long-term temperature studies show that:

- Exposure to elevated temperatures from the DCPP discharge is primarily limited to shallow subtidal and intertidal marine habitat. The total surface area of the surrounding coastal waters contacted by the 1.1°C (2°F) surface isotherm can vary from 200-800 ha (500-2,000 acres) depending on plant operations and meteorological and oceanographic conditions. The area contacted is highly variable because under most conditions the plume is only inches thick a short distance from the cove.
- The high velocity and turbulent area within the central 'jet core' of the plume is limited to less than 2 ha (5 ac) and extends about 122 m (400 ft) offshore from the outfall where temperature increases range from 7 to 11°C (13 to 20°F). Discharge velocities and turbulence in this area exceed the ability of many species to remain attached to bottom substrate.

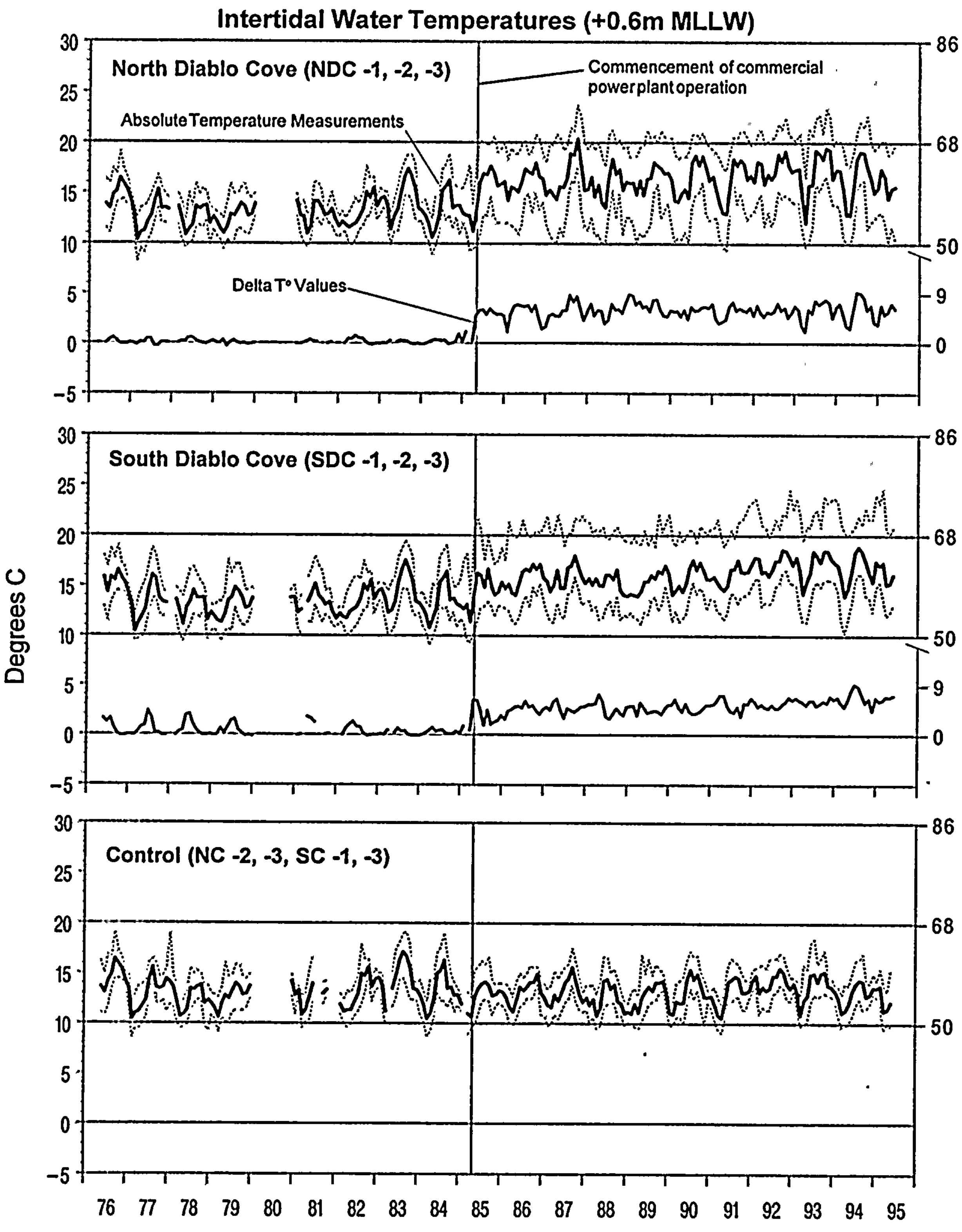

Figure 5-1. Intertidal monthly mean temperatures and delta T° values for the north and south Diablo Cove and control sampling areas. Dotted lines denote the highest and lowest 99 percentile values of 20-minute recordings that occurred in the month. Graph from the TEMP Analysis Report.

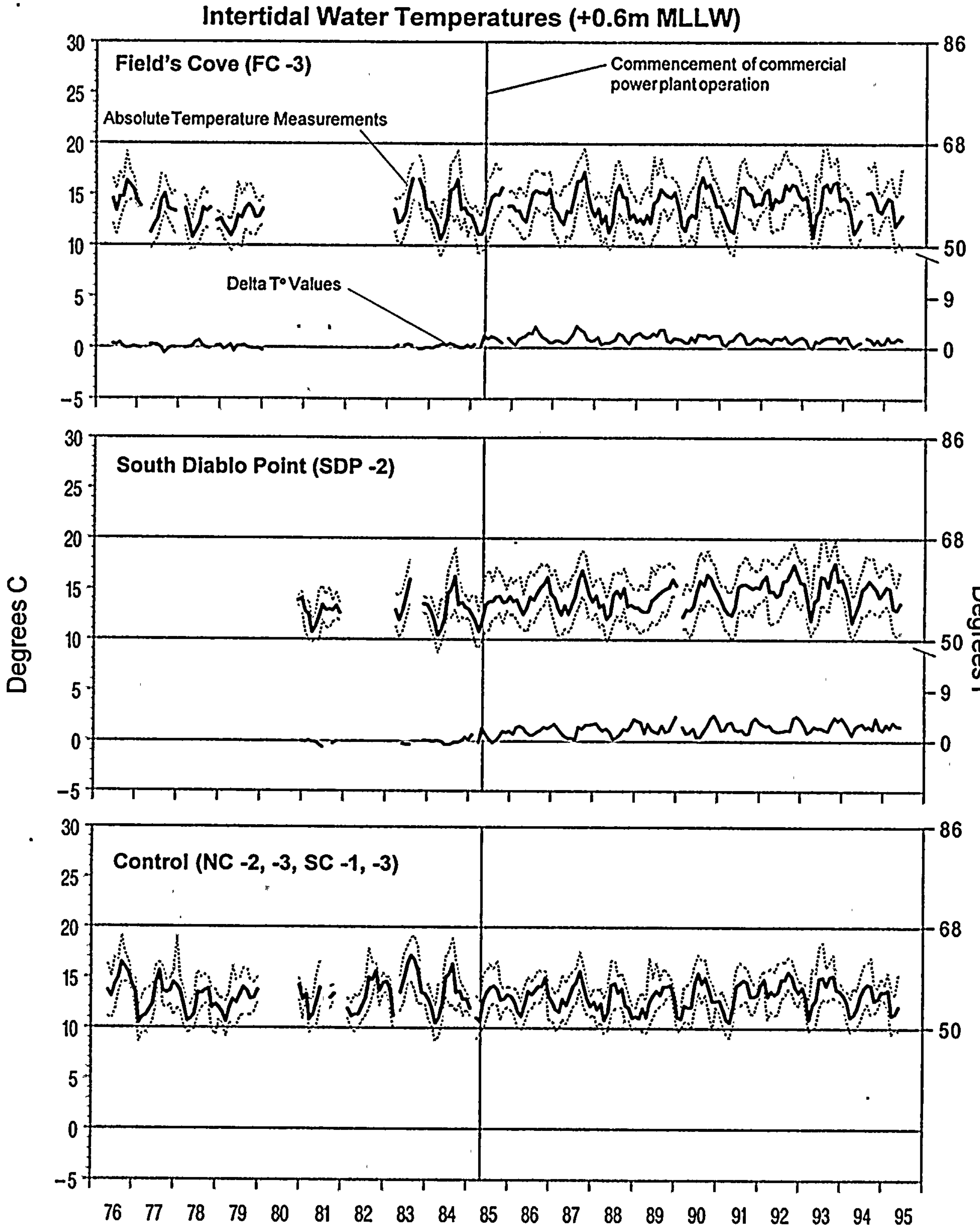

Figure 5-2. Intertidal monthly mean temperatures and delta T ° values for the Field's Cove, South Diablo Point, and control sampling areas. Dotted lines denote the highest and lowest 99 percentile values of 20-minute recordings that occurred in the month. Graph from the TEMP Analysis Report.

- The turbulent mixing in the 'jet core' rapidly reduces the 11°C (20°F) above ambient discharge temperature so that exposure of habitat outside this zone of high velocity is limited to temperatures of about 3 to 7°C (5 to 13°F) above ambient, including the shallow habitat close to the discharge point and most of the remainder of Diablo Cove (approximately 16 ha [40 ac]) to depths of about -8 m (25 ft).
- North and south Diablo Cove are continually exposed to temperatures above ambient during plant operation. Figure 5-1 compares intertidal water temperatures in Diablo Cove to control temperatures outside the cove. On average the temperatures are approximately 3-4°C above ambient.
- Field's Cove and South Diablo Point are intermittently exposed to temperatures above ambient during plant operation. Figure 5-2 compares intertidal water temperatures in Field's Cove and South Diablo Point to control temperatures outside the cove. On average the temperatures are approximately 1-1.5°C above ambient.

5.2 Potential Effects of the DCPP Thermal Plume on Marine Habitat

Thermal discharges into nearshore ocean waters can affect the mortality, growth, and reproduction of marine organisms, and their distribution and movements through temperature avoidance or attraction. Temperature affects metabolic processes of organisms by influencing the rates of chemical reactions and the effectiveness of enzymes. Among organisms lacking the physiological mechanisms to control tissue temperature, such as marine plants, invertebrates, and fishes, the rate of metabolism at rest rises nearly exponentially with temperature increase. These marine organisms can survive within a range of temperatures specific to each species, called the zone of thermal tolerance. The organism can adjust to the thermal environment physiologically, thereby shifting its tolerance range, but this acclimation has limits and ultimately a temperature may be reached that is lethal. Upper temperature limits for survival are dependent on the duration of exposure. Temperature elevations produced by thermal discharges have the potential to directly exceed the metabolic limits of exposed organisms, resulting in acute or chronic mortality.

The potential for thermal mortality from DCPP discharge temperatures decreases rapidly with increasing distance and mixing from the point of discharge. The highest temperatures are limited to a small portion of the subtidal cove habitat in the region of the discharge turbulence zone where mixing and dispersion is limited. This is the region where water velocities and turbulence also limit the habitation of most species. In habitats outside this zone, plume temperatures are generally below the upper tolerance limits of the RIS species tested in thermal studies at DCPP. However several exceptions have been found in the long-term monitoring studies and analyses. Thermal plume temperatures within the shallow areas of Diablo Cove exceed the predicted thermal tolerances of iridescent seaweed *Mazaella flaccida* in the intertidal, and bull kelp, tree kelp and oar-blade kelp in the subtidal.[71]

Although mortality effects can result from drops in temperature ('cold shock') below lower tolerance threshold temperatures, this effect has not been observed at DCPP. The relatively narrow range of ambient temperatures characteristic of the central California coast protects marine life from potential discharge cold shock.

[71] PG&E 1982b.

Potentially lethal temperatures are usually avoided by mobile species, such as fishes and many invertebrates. Mobile species will seek preferred temperatures and may in some cases also be attracted to warmer discharge temperatures. From a regulatory point of view, attraction to a thermal plume is not harmful except in cases where the attraction:

- causes a nuisance for recreational or commercial utilization of the resource;
- results in overwhelming dominance and simplification of the community; or
- leads to other discharge effects such as cold shock.

The pre-operational assessments predicted that species would be attracted to the DCPP discharge, although the species or the magnitude of attraction was not known with any certainty. Avoidance caused by discharge temperatures only becomes a problem when the affected area is large and results in a loss of access to critical habitat, blockage of major migration, or blockage of recruitment pathways. Within the range of thermal tolerance, most species exhibit optimal temperatures for physiological functions such as growth and reproduction. Outside of this range a species' long-term population potential is reduced. As a result, the effect of temperature on metabolism and behavior may indirectly affect marine life by changing the nature of the interactions among species present in the community.

5.3 Observed Effects of the DCPP Thermal Plume on the Marine Habitat

5.3.1 Introduction

This section summarizes the results of the TEMP studies and addresses ecological effects for six biotic categories: phytoplankton, zooplankton, habitat-forming species, shellfish/invertebrates, fishes and other vertebrate wildlife, as recommended by the EPA for assessing appreciable harm to a BIC.[72] Results presented in this section are primarily summarized from the 1997 Analysis Report, but have also been presented in various TEMP Annual Reports, the 1988 TEMP Final Report and various PG&E reports on the thermal plume. A list of DCPP environmental reports is presented as Appendix A.

As part of this summary, effects attributable to the DCPP discharge are evaluated for ecological significance with respect to EPA guidance for assessing protection of a BIC and three additional criteria based on ERA: nature and intensity of effects; spatial scale of effects; and temporal scale of effects. The spatial scale of effects is assessed by comparing the area of observed effects against the reach of unaffected similar habitats that occur in the greater study area from Point Buchon to Point San Luis, a shoreline distance of 26.8 km (16.7 mi) (using a 1:24,000 scale map) that includes coastline indentations.

Annual reports and other submittals prior to the 1997 Analysis Report used linear distances in describing distances between two points. At the request of the TEMP technical workgroup, the 1997 Analysis Report described the spatial extent of effects using shoreline distances. Shoreline distances include the various irregularities of the coastline not accounted for using a straight line distance. The technical workgroup thought that a shoreline measurement would be a more accurate way to describe the spatial extent of effects. The scale and source used to calculate shoreline distance can have a major impact on the measurement result. Maps drawn at a relatively gross scale and measurement derived from them may account for only major coastline features, such as coves, bays, islands, etc. Finer scale maps not only

[72] EPA 1974, 1977.

include major coastal features, but may also include smaller features such as large boulders, rocks and surge channels.

The differences that can occur when using linear and coastline distances and distances calculated using different scales are shown below. The coastline distances were calculated from a standard United States Geological Survey (USGS) 1:24,000 scale map[73] and also from a much finer scale map (1:9,000) prepared by PG&E for its land use program.

Measurement Type or Scale Base	Distance from North Diablo Point to South Diablo Point
Linear	1,200 ft- straight line distance across cove
1:24,000	3,122 ft- includes shoreline indentations
1:9,000	3,837 ft- includes shoreline indentations

The 1:9,000 scale map used to calculate the shoreline extent of effects in the 1997 Analysis Report was prepared by PG&E for the DCPP property and therefore is only available for the stretch of coastline owned by PG&E. The map is much more detailed than the commercially available USGS map. Shoreline distances derived from the 1:9,000 scale PG&E map cannot be directly compared to shoreline distances derived from the USGS 1:24,000 scale map, or to linear distances. The distances of shoreline affected for the different biotic groups are therefore presented as percentages of the shoreline between from Point Buchon to Point San Luis using the USGS 1:24,000 scale map.

The TEMP studies conducted from 1976 through June 1995 were designed to assess the effects of the discharge using changes in the abundances of habitat-formers, invertebrates and fishes. The studies were designed to monitor and detect changes in many species. The TEMP did not include experimental studies that could have potentially explained some of the processes causing the detected changes. In the absence of other information, statistically significant changes were determined as being caused by the discharge. In many cases, the detected changes were not the direct result of thermal effects. The TEMP data on habitat-formers, invertebrates and fishes cannot be assessed as a non-interacting assemblage of organisms. The marine habitat affected by the DCPP discharge is a biological community that is defined as an assemblage of organisms that interact on many levels in response to biological and physical factors. Strong interactions within the community would be predicted based on the duration and magnitude of the physical factors contributed by the discharge.[74]

Evidence of community interactions is provided in the results of multivariate analyses presented in the 1997 Analysis Report. Results for the intertidal community in Diablo Cove shows distinct trajectories of change from year-to-year during plant operation that are indicative of an interacting community. Changes in individual species also provided evidence of the importance of other factors besides discharge temperatures. For example, some species with expected tolerance to discharge temperatures decreased while unexpected increases occurred in other species with biogeographic distributions restricted to cooler water temperatures. The TEMP studies were able to document these patterns of

[73] A map scale of 1:24,000 depicts 1 inch on a map as 24,000 inches (2,000 linear feet) of the earth's surface.

[74] Schmitz, O.J. 1997. Press perturbations and the prediction of ecological interactions in a food web. Ecology 78:55-69.

community and individual species change, but for the most part were not able to provide explanations for the changes.

Biotic Categories

The EPA guidance for assessing the effects of discharge thermal effects on a BIC recommends that six biotic categories be considered: habitat-forming plant species, shellfish/invertebrates, fishes, phytoplankton, zooplankton, and marine vertebrate wildlife. Data on intertidal and subtidal plants (habitat-formers), shellfish/invertebrates and fishes were studied extensively as part of the TEMP.

Phytoplankton/Zooplankton

Two of the biotic categories, phytoplankton and zooplankton, were not studied or included in the DCPP assessment due to their low potential for thermal discharge effects. Despite the exposure of large numbers of individual phyto- and zooplankters to the thermal plumes from power plants, the EPA has long recognized that extensive study and analyses of thermal effects on phytoplankton are usually not warranted owing to their ubiquitous distribution, relative thermal tolerance, and high reproductive potential.[75] Based on available information and a prediction of low potential impact, zooplankton studies were not included in the monitoring plans submitted to the Regional Board for 316(a) studies at DCPP and have not been conducted as part of the TEMP. Some zooplankton mortality was expected due to exposure to highest temperatures during passage through the cooling water system or contact with the plume near the point of discharge; however this was found to be insignificant due to rapid regeneration and recruitment.[76]

Marine Vertebrate Wildlife

The marine vertebrate wildlife category (whale, sea lions, seals, sea otters and turtles) also has a low potential for impact by the thermal plume and was not studied as part of the TEMP. At least 21 species of cetaceans (whales, dolphins and porpoises), seven species of pinnipeds (seals and sea lions), and one fissiped species (sea otter) have been reported in central California, although few of these are common to the Diablo Canyon vicinity. Most marine mammals are wide-ranging, responding primarily to the availability of food resources, water temperatures, and the availability of suitable calving/pupping sites. Central California is a region where northern and southern species of marine mammals overlap in distribution. Only the southern sea otter is endemic to central California. Endangered vertebrate species are monitored as part of the plant's NRC operating license. Results from these efforts, including information on protected marine mammals, are reported annually to the NRC in the plant's Annual Environmental Operating Report. Annual surveys of the California gray whale migration past DCPP were done from 1981 to 1995. The gray whale survey was discontinued after this species was removed from the federal list of endangered species. Sea otter surveys began in 1973 and are still continuing.

[75] FES at iii.

[76] Ibid.

5.3.2 *Habitat-Forming Plant Species*

Marine plants increase biological diversity by increasing the variety and availability of habitat, shelter, and food resources for faunal assemblages of invertebrates and fishes. Similar to phytoplankton, marine plants function as primary producers in the fixation of energy and production of oxygen. Nearly all marine plants are algae (spore bearing plants). Surfgrass (*Phyllospadix* spp.) is the only flowering plant found intertidally and subtidally in the DCPP study area. It is included with algae in the present discussion, due to similarities in habitat and ecological function. Habitat-forming algae and plants were sampled in both intertidal and subtidal studies as part of TEMP.

Summary of Observed Changes

Intertidal Habitat-Formers

A total of 119 different algal taxa were sampled from the TEMP intertidal studies presented in the 1997 Analysis Report. Of these, 38 taxa formed 99 percent of the total algal cover in the pre-operation and operation study periods, and were analyzed individually for statistically significant changes relative to control stations. The remaining 81 taxa formed one percent of the total algal cover. These taxa were not analyzed individually, but were included in analyses of total algal cover, species richness (numbers of taxa), and diversity. Of the 38 taxa analyzed individually, statistically significant increases occurred in seven taxa and statistically significant decreases occurred in 26 taxa. No changes were detected or the test results were inconclusive for the five remaining taxa.

Differences between pre-operation and operation algal abundances in Diablo Cove, Field's Cove, and control stations at the lower sampling elevation (+0.3 m [1 ft] MLLW) show a gradient of decreasing discharge effects with increasing distance from the discharge (Figure 5-3). The control stations changed only slightly in individual species abundances between the study periods (Figure 5-3a). While some changes between periods occurred at the Field's Cove station (Figure 5-3b), changes between periods in Diablo Cove involved a greater number of taxa and were of greater magnitude (Figure 5-3c). For example, iridescent seaweed (*Mazzaella flaccida*), a common species in the upper and lower intertidal sampling areas, was the most abundant foliose-type species in all areas prior to power plant start-up. Iridescent seaweed is a thermally sensitive species[77] that is a good indicator of thermal gradients. In the control areas (unaffected by thermal discharges), this species increased slightly between periods, from a cover of 36.9% to 38.4% (Figure 5-3a). The abundance of iridescent seaweed declined at the Field's Cove station from 34.9% to 27.8% where intertidal water temperatures averaged less than 1°C above ambient (Figure 5-3b). In Diablo Cove, however, where intertidal temperatures averaged over 3°C above ambient, iridescent seaweed declined from 12.4% to 0.2% (Figure 5-3c).

In addition to iridescent seaweed, statistically significant decreases in abundances were detected in Diablo Cove for several other species that were abundant before plant operation. These included the rockweeds *Fucus gardneri* and *Pelvetia compressa*, and the nailbrush seaweed *Endocladia muricata*. These species were more abundant at the upper intertidal sampling elevation. Statistically significant decreases in rockweeds were not detected at the Field's Cove station, although a statistically significant decrease in nailbrush seaweed was detected at the upper elevation in Field's Cove. Statistically significant decreases were also detected in nailbrush seaweed at stations in the low-intertidal zone in

[77] PG&E. 1982c. Compendium of thermal effects laboratory studies, Vols. 1, 2, 3. Pacific Gas and Electric Company Rep. B-81-403, San Francisco, CA.

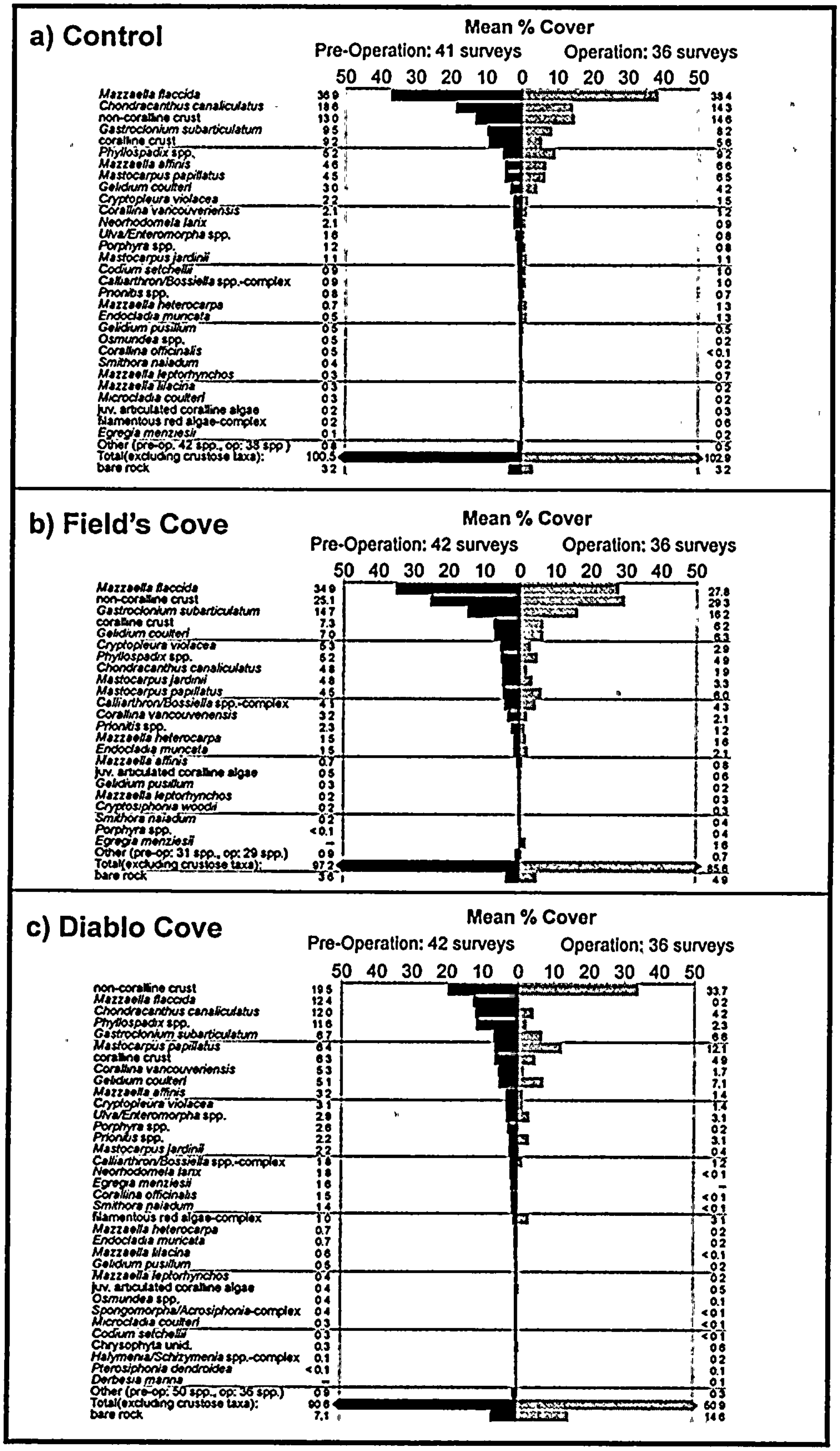

Figure 5-3. Changes in intertidal algal abundances between the pre-operation and operation study periods for three study areas at the low sampling elevation. Graph from the TEMP Analysis Report.

Diablo Cove and at South Diablo Point, but test results were inconclusive for this species at the low-intertidal zone station in Field's Cove. Statistically significant decreases in Diablo Cove were also detected for the red algae *Mastocarpus papillatus* and *Gastroclonium subarticulatum*, and surfgrass *Phyllospadix* spp. Declines in cover for these latter three taxa occurred at the upper sampling elevation, while their coverage increased or remained unchanged at the lower intertidal sampling elevation in Diablo Cove. Fewer changes in these species, relative to controls, were detected outside Diablo Cove. Increases in filamentous species occurred later in the study at some of the Diablo Cove stations, but no increases in this group were detected in Field's Cove or at South Diablo Point. Filamentous algae are known to be opportunistic colonizers[78] and increases in this group were probably facilitated by the bare rock space made available by decreases in foliose algae.

Three community-level indices for intertidal algae were analyzed for effects of the discharge in the 1997 Analysis Report. These indices were total algal cover, diversity, and species richness. Statistically significant declines in all three indices were detected from stations in Diablo Cove at both sampling elevations, while statistically significant declines in two of the three indices occurred outside the cove. Statistically significantly decreases were detected for total algal cover and diversity at only the upper sampling elevation in Field's Cove and decreases in total algal cover and species richness were detected at the South Diablo Point sampling elevation. Fewer significant changes in these community indices outside Diablo Cove provides evidence that changes in the intertidal algae decreased with distance from the power plant. Results summarizing the gradient of reduced effects outside Diablo Cove are shown for total algal cover (Table 5-1).

Table 5-1. Summary of changes in intertidal algal cover (excluding crustose forms) between pre-operation and operation periods.

Area	% change at +0.3 m (+1 ft) MLLW	% change at +0.9 m (+3 ft) MLLW
North and South Control	+2.4	+3.5
Field's Cove	-11.6	-9.5
South Diablo Point	(no transect at +0.3 m)	-23.4
Diablo Cove	-39.7	-43.7

The spatial extent of shoreline effects on intertidal algae is shown in Figure 5-4. Statistically significant declines in species abundances and overall algal cover were greatest in magnitude in Diablo Cove. South Diablo Point and the southern shoreline of Field's Cove were the southernmost and northernmost areas, respectively, where statistically significant declines were detected. However, declines in these two areas were substantially less than the decreases recorded in Diablo Cove, indicating that effects from the discharge decreased with distance from the discharge, and would be expected to decrease in magnitude further north and south. Based on qualitative observations, no effects on intertidal algae were observed south of South Diablo Point and along the northern shoreline of Field's Cove to Lion Rock where the frequency of plume contact is greatly reduced.

[78] Sousa, W.P. 1979. Experimental investigations of disturbance and ecological succession in a rocky intertidal algal community. Ecol. Monogr. 49:227-254.

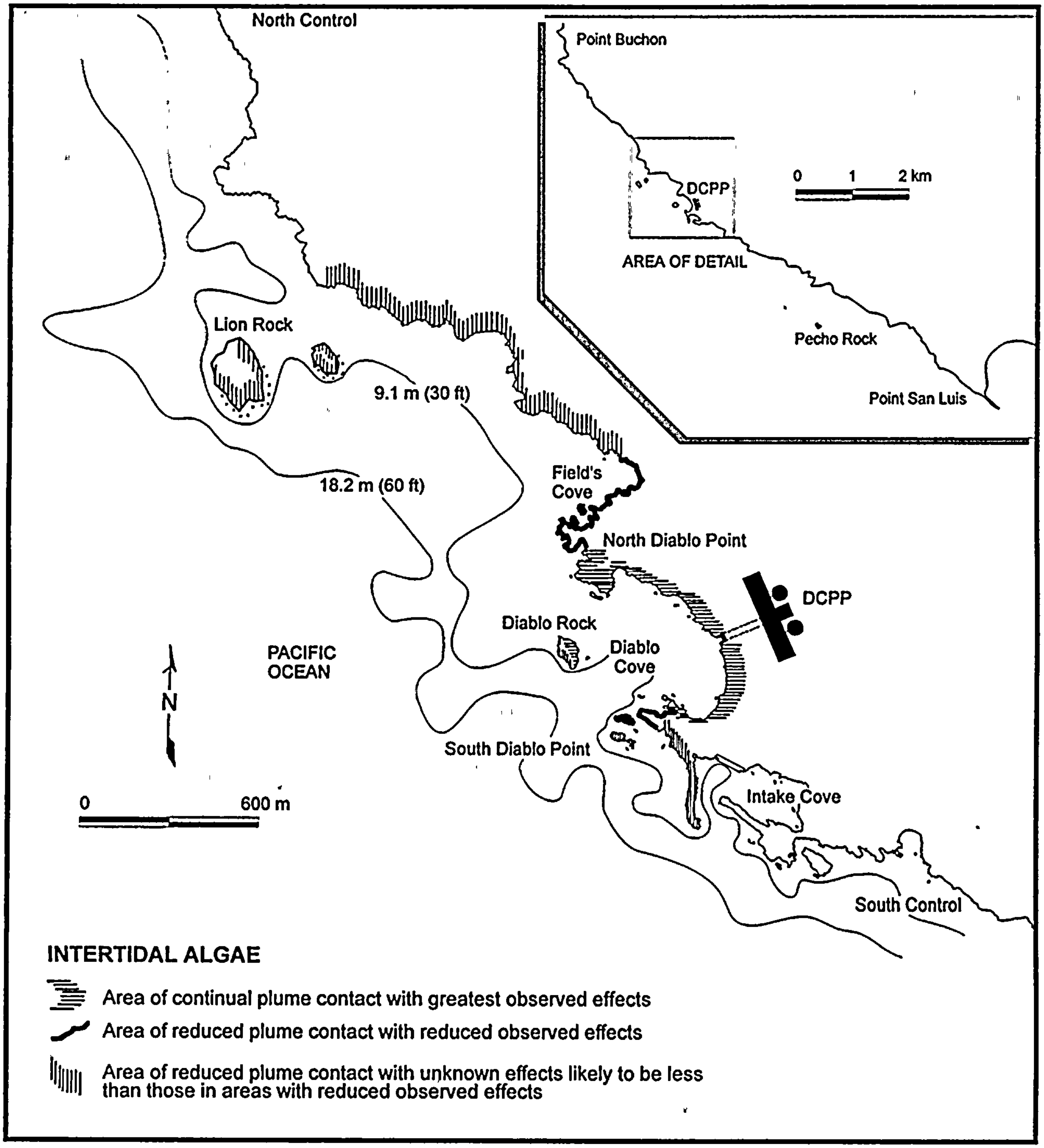

Figure 5-4. Map of the spatial extent of effects in intertidal algae. Illustration from the TEMP Analysis Report.

Subtidal Habitat-Formers

Subtidal algae have broader vertical distributions (to depths of about 28 m [90 ft] MLLW) than intertidal algae which are typically restricted to narrow elevation bands along the shoreline. Portions of species populations growing in shallow water are exposed to the thermal plume, while portions of the same populations growing in deeper water are unaffected by the plume. Subtidal species that form surface-canopies, such as bull kelp, are exposed to the thermal plume over a larger area than strictly benthic species. No subtidal pre-operational data from Field's Cove were collected, therefore, the following section only discusses discharge-related changes in Diablo Cove. All discussion of changes outside Diablo Cove is based on qualitative observations before plant operation and data from Field's Cove collected during plant operation.

The results of the TEMP subtidal studies presented in the 1997 Analysis Report showed that 109 different algal taxa were recorded from the subtidal studies. Of these, 39 of the taxa formed 99 percent of the total algal cover in either the pre-operation or operation study periods. The analysis results showed that 14 individual taxa increased and 11 decreased. No changes were detected or results were inconclusive for the remaining 14 taxa. Most were red algal understory species. These and all kelp species sampled in the TEMP were statistically analyzed on an individual basis for changes relative to controls. The total cover for the remaining 70 taxa contributed one percent of the total algal cover in either the pre-operation or operation study periods. These were not analyzed individually, but were included in the analyses of total algal cover, species richness, and diversity.

Increases in red algal understory species in the shallow subtidal of Diablo Cove after power plant start-up resulted in an overall increase in understory cover. The pre-operationally abundant red alga *Cryptopleura ruprechtiana* significantly decreased in cover, while previously sparse *C. violacea*, that occupies the same habitat as *C. ruprechtiana*, and is similar in size, color, and shape, significantly increased. Other red algal species that significantly increased in cover included *Gelidium robustum* and *Pikea/Farlowia* spp. In deeper areas of the cove red algal species composition and abundances of subcanopy kelps were indistinguishable from pre-operational conditions.

The spatial extent of changes in subtidal algae was evaluated separately for subtidal benthic and surface habitats. Effects to subtidal benthic algae were delineated by declines in subcanopy oar-blade and tree kelps and by shifts in red algal understory composition and abundance (Figure 5-5). The spatial area of these changes extended from the low intertidal to approximately the -4 m (15 ft) depth contour in north Diablo Cove, and at slightly shallower depths in south Diablo Cove. Deeper areas (to -7 m [25 ft]) were affected on the inshore side of Diablo Rock where the plume downwells slightly. Portions of the north and south headlands of the cove were also affected. No effects on bottom-dwelling algae were observed in other areas of Diablo Cove or outside of Diablo Cove. The region affected in Diablo Cove (including its headlands) represents about 40 percent of the subtidal benthic habitat in the cove (Figure 5-5).

During the part of the year when it is present, surface canopy-forming bull kelp was affected by the discharge over the broadest area, and was used to delineate the maximum spatial extent of surface effects in the nearshore (Figure 5-6). Bull kelp is an annual plant that forms surface canopies from March through November. Nearly all plants are removed annually by winter storms, requiring recruitment of new individuals to form the following year's kelp population. Following power plant start-up, annual recruitment of bull kelp no longer occurred in the same shallow subtidal areas of Diablo Cove where effects were observed on subtidal benthic understory algae and subcanopy kelps. In deeper water, bull kelp plants developing beneath the discharge plume were unaffected until they grew into the surface

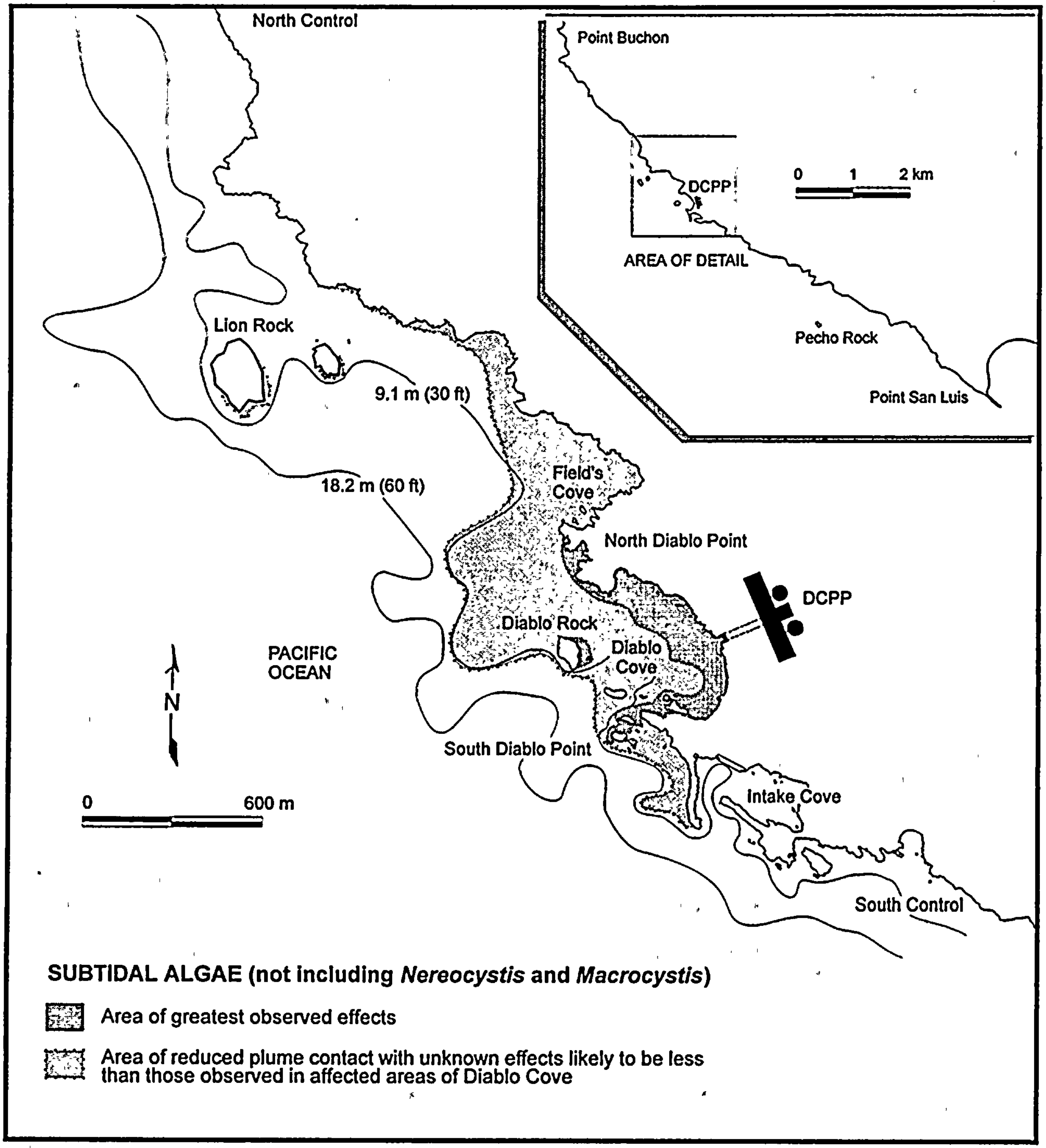

Figure 5-5. Map of the spatial extent of effects on bottom-dwelling subtidal algae. Illustration from the TEMP Analysis Report.

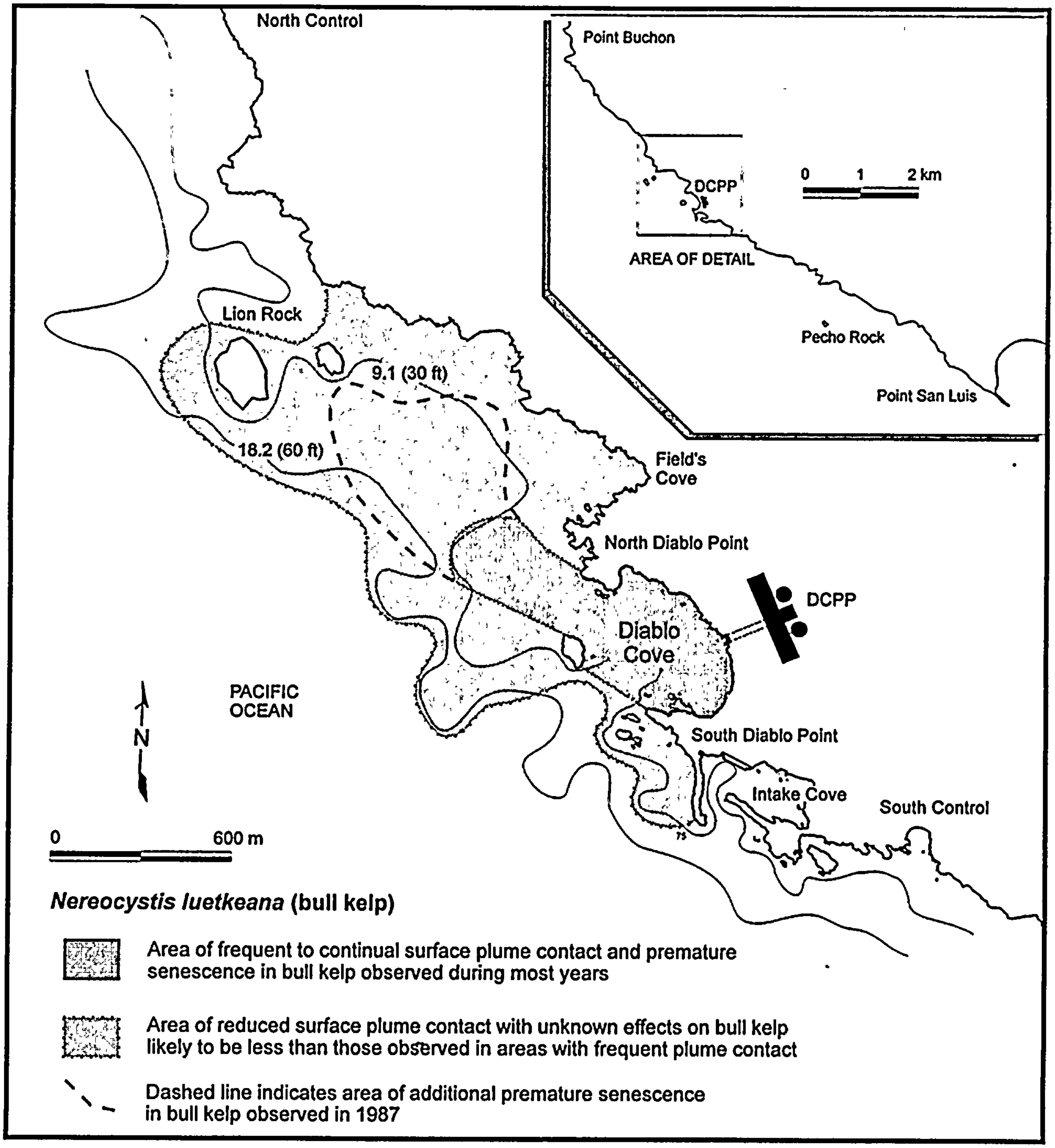

Figure 5-6. Map of the spatial extent of effects in bull kelp. Illustration from the TEMP Analysis Report.

discharge plume. When the plants came into contact with the plume, the blade tissues began to deteriorate and fall apart. Although deterioration of the blade tissue is normal following release of spores from the blades in October and November, the warmer water causes deterioration to occur 2-4 months earlier than normal, before reproductive structures fully develop. This process is referred to as premature senescence. Bull kelp was affected by power plant discharges in this manner over the largest geographic area in 1987 during an El Niño. During other years the area affected was less.

Aerial photographs of surface kelp canopy were analyzed using a geographic information system (GIS). This analysis measured actual kelp canopy coverage, rather than the geographic area of kelp habitat that could be exposed to the discharge plume. The potential area of discharge effects that included Diablo Cove and areas in Field's Cove northward to Lion Rock varied considerably in actual kelp canopy cover during the pre-operation period (from 15.9 ha [39 ac] in 1975 to less than one hectare (~1 ac) in 1981). These values represent the potential range of canopy cover in this area. At least 3.3 ha (8.2 ac) of kelp canopy were affected in 1987.

Further changes in the Diablo Cove subtidal algal assemblage occurred with the shift in the surface canopy species from bull kelp to the more heat tolerant giant kelp (*Macrocystis pyrifera*). Although present in other areas around Diablo Canyon, giant kelp was found infrequently in Diablo Cove through the early 1990's, and then increased in density in nearly all areas of Diablo Cove. The increase was statistically significant even though the average abundance of giant kelp at the Diablo Cove stations show only a small increase from the pre-operational period. This is a result of the operational mean including data from surveys before 1990 when giant kelp was absent and data from surveys after 1990 when it became abundant. Coincident with the increase in giant kelp were decreases in understory algal cover. This was presumably caused by shading effects (not temperature) as the understory species that declined were ones that had previously increased with onset of power plant operation and reduction of other kelp canopy and subcanopy species.

Ecological Significance of Observed Changes

Intertidal Habitat-Formers

The pre-operation intertidal algal assemblage was numerically dominated by large bladed forms that provided shading for other smaller, branched understory algae and habitat, shelter, and food resources for faunal assemblages of invertebrates and intertidal fishes. The current algal assemblage in Diablo Cove where the intertidal is continuously exposed to the thermal plume is largely different from the pre-operation algal assemblage as a result of reductions in bladed algal forms and increases in crustose and filamentous species. The fewer algal layers and lesser amount of algae covering rocks provide a comparatively simpler habitat for faunal assemblages. The intertidal region of Diablo Cove during operation is similar to intertidal areas of southern California that are largely dominated by invertebrates. This is the result of reductions in a few previously dominant species. Changes in other species have not been as large and as a result the community of habitat-formers in the intertidal, while different from pre-operation, is still composed of many indigenous species. The continued presence of invertebrates and fishes in the intertidal areas of Diablo Cove is evidence that the algal community still provides valuable habitat for invertebrates and fishes.

Changes to intertidal algae outside Diablo Cove involved shifts in the abundances of a few taxa. The algal community in Field's Cove and at South Diablo Point is largely indistinguishable from pre-operation conditions. The changes in these areas were generally only discernible using statistical analysis. The discharge plume contacts these areas less frequently and temperature elevations are considerably reduced from the levels in Diablo Cove.

The TEMP studies collected data on the composition and abundance of habitat-formers, invertebrates and fishes and did not include studies on the interactions among taxa within the community. The evidence for relationships between habitat-formers and faunal (invertebrates and fishes) assemblages is based on changes in composition and abundance within the same intertidal zone. Drawing conclusions on the effects of changes in habitat-formers on faunal assemblages is complicated by the fact that there are also changes in the fauna due to thermal effects (see Sections 5.3.3 and 5.3.4). Despite these limitations, some of the reductions in abundance for faunal species may be related to declines in algae. These included declines in smaller sea star species, tube-building and motile worms, chitons, snails, and certain intertidal fishes. Several faunal groups also increased. The increase in algal films on bare rock has increased the abundance of algal film-grazing limpets. Similarly, the increase in open bare rock space may have indirectly facilitated the expansion of barnacle and anemone cover.

The spatial effects on intertidal algae were largely confined to Diablo Cove. Although areas of Field's Cove and South Diablo Point were marginally affected, the algal and faunal abundances there remained within normal ranges of variation. The shoreline distance within Diablo Cove where statistically significant changes in the algae where greatest represents less than 5 percent of the coastal reach from Point Buchon to Point San Luis. If the shoreline with reduced effects is included the total is still less than 10 percent. The amount of shoreline affected by the plume remains relatively small in proportion to the total amount of unaffected adjoining rocky coastline to north and south.

The types and patterns of changes presented in community analyses in the 1997 Analysis Report show that changes in Diablo Cove that exceed the variation in natural unaffected communities will continue during plant operation. If the power plant ceased thermal discharges on a permanent basis, the return of the algal community to levels of species abundance observed before power plant start-up would begin immediately. Similar responses have been observed in control areas following El Niño-related disturbances. Species that have declined but still remain in affected areas will likely repopulate more rapidly than species that are no longer present. However, for most species, algal spores are broadly dispersed and reproductive algae in unaffected adjoining areas will contribute to recruitment. Once established, marine algae often become reproductive within their first year of growth, adding to the source of spores. The lengths of time for these processes to occur will undoubtedly vary among taxa, as a result of grazing effects, competition for space, and substrate availability. Re-establishment of surfgrass may occur over a longer time period because its seeds are not widely dispersed and it is slow to become re-established in areas where it has been removed.

Subtidal Habitat-Formers

Discharge-related changes to subtidal habitat-formers in Diablo Cove were characterized initially by shifts in dominant understory algae caused by reductions in surface bull kelp and sub-canopy oar-blade and tree kelp. Eventually giant kelp became established in Diablo Cove causing reductions in some of the understory algae. Giant kelp provides surface, mid-water, and bottom canopy structure and can be considered an equivalent habitat replacement to the losses in bull kelp and subcanopy kelp habitat in Diablo Cove. Giant kelp forests are considered among the most highly productive and complex ecosystems in the world, equivalent to tropical rain forests. Each plant of giant kelp consists of numerous blades developing along the lengths of numerous stipes. This growth pattern is morphologically more complex than bull kelp, where each plant consists of a single stipe terminating in a single bulb with attached blades. Giant kelp is the fastest growing plant species in the world, a perennial, and provides potential year-round habitat, shelter, and food resources for fishes and invertebrates. In contrast, bull kelp is an annual species, with most of each year's population removed by winter storms. Holdfasts of giant kelp consist of numerous loosely intertwined branches, that provide spaces for harboring small invertebrates, including crabs, worms, and snails. Holdfasts of bull kelp consist of more tightly adjoined branches that do not provide similar habitat for small animals. Increases in species richness for fishes (Sections 5.3.4) in some areas of Diablo Cove may provide evidence of the increased habitat value of giant kelp.

Discharge-related changes to subtidal algae have only been observed in the areas of Diablo Cove less than -4 m (15 ft) in depth, and to -7 m (25 ft) on the inshore side of Diablo Rock. No discharge-related effects on subtidal algae have been observed outside of Diablo Cove. The areas affected in Diablo Cove are small in proportion to the total amount of unaffected area to the north and south. Effects on surface bull kelp extend over a greater area, but the actual amount of bull kelp affected is highly variable from year-to-year. The effects on bull kelp have not affected its capacity to repopulate Field's Cove, and the north channel and some deeper areas of Diablo Cove. The variability of the actual amount of bull kelp affected and the high habitat value provided by the replacement giant kelp community reduce the ecological significance of this effect.

If the power plant permanently ceases thermal discharges, the return of species abundances to levels of abundance observed before power plant operation should begin immediately. Species that declined from discharge-related effects should begin increasing in abundance during the first year of shut-down. Bull kelp should repopulate areas of Diablo Cove. Giant kelp, however, may remain abundant. Discharge conditions in Diablo Cove are not a prerequisite for supporting giant kelp, since dense stands occur in closely adjoining unaffected areas (north of the power plant between Lion Rock and Point Buchon). Consequently, giant kelp may persist in Diablo Cove after the power plant has stopped operating.

5.3.3 Shellfish/Invertebrates

'Shellfish' are defined as shelled mollusks or crustaceans with commercial value. Examples of shellfish are abalone, large clams, lobster and market crabs. The 'invertebrate' category covers all other invertebrates. However, several invertebrate species not defined as 'shellfish' have commercial value (e.g., red sea urchins and market squid). Therefore, both 'invertebrates' and 'shellfish' are discussed together in the following section without differentiating the groups into these two categories. Invertebrates were sampled in both intertidal and subtidal studies as part of TEMP, and additional data on red and black abalone were collected in TEMP studies that focused on these two species.

Summary of Observed Changes

Intertidal Invertebrates

A total of 248 taxa were sampled from the horizontal band transect (HBT) study and a total of 314 taxa were sampled from the intertidal algal-faunal association study (AFAS). Of these, 139 of the most abundant taxa were statistically analyzed in the 1997 Analysis Report for changes resulting from the discharge. Statistically significant increases were detected in 38 taxa and statistically significant decreases were detected in 52 taxa. The 49 other taxa either did not change or the analysis results were inconclusive due to low statistical test power. Of the statistically significant changes detected by the BACI analysis overall, individual station comparisons between pre-operation and operation periods showed that changes were not detectable at the Field's Cove and South Diablo Point stations for several taxa.

Increases after power plant start-up of up to several hundred percent occurred in many species of herbivorous gastropods, urchins, barnacles, anemones, and tube building worms. Although increases were detected for all of these taxa groups in Diablo Cove, statistically significant increases in barnacles and some herbivorous gastropods did not occur at South Diablo Point or Field's Cove stations. Increases in these areas were also less than those observed in Diablo Cove. Statistically significant decreases in Diablo Cove occurred in brown turban snails, six-armed sea stars, black abalone, the anemone *Epiactis prolifera*, nemertean worms, the chiton *Nuttalina californica*, and the tube worm *Pista* spp. Of these taxa statistically significant decreases were detected at South Diablo Point for the six-armed sea star, and at Field's Cove for *Nuttalina californica* and tube worms. The species richness increased significantly at the upper tidal elevation of the HBT stations in Diablo Cove and Field's Cove, but there was no significant change at the lower elevation.

Before plant operation, intertidal stations in Diablo Cove were dominated by foliose algal cover. Due to the reduction of algal biomass and the increases in invertebrate abundances in the cove after plant start-up, these stations became dominated by invertebrates. Although statistically significant shifts in the abundance of some invertebrate taxa occurred in the adjoining areas of Field's Cove and South Diablo Point (where algal cover was only reduced by approximately 10 % due to plant operation) invertebrate communities in these areas are relatively similar to their pre-operation condition. The magnitude of the changes at these stations was less than the effects on the same taxa in Diablo Cove.

The spatial extent of shoreline effects on intertidal invertebrates is shown in Figure 5-7. Statistically significant changes in species abundances were greatest in magnitude in Diablo Cove. South Diablo Point and the southern shoreline of Field's Cove were the southernmost and northernmost areas, respectively, where statistically significant changes were detected. However, changes in these two areas were substantially less than the decreases recorded in Diablo Cove, indicating that effects from the discharge decreased with distance from the discharge, and would be expected to decrease in magnitude further north and south. Based on qualitative observations, no effects on intertidal invertebrates were observed south of South Diablo Point and along the northern shoreline of Field's Cove to Lion Rock where the frequency of plume contact is greatly reduced.

Black abalone with withering syndrome (WS) were first found in Diablo Cove in spring 1988. Through 1991, the disease resulted in population declines of almost 90 percent in Diablo Cove, similar to the magnitude of declines reported from the Channel Islands. Recent investigations have identified the likely cause of WS as a protozoan that infects the digestive systems of black abalone.[79] Until 1994, Diablo Cove appeared to be the only mainland area where extensive disease related-mortalities had occurred, but large population declines have now been recorded at study sites located at Point Conception and Vandenberg Air Force Base.[80] After WS was found in Diablo Cove, the sampling effort to monitor black abalone was expanded to areas north and south of the cove (Point Buchon to Stillwater Cove). Black abalone with WS have been found throughout this area, but population decreases in areas outside Diablo Cove were less than those observed in the cove (Figure 5-7). Based on recent mortalities in other areas north of Point Conception, declines in black abalone abundance in the Diablo Canyon area may have

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[79] Gardner, G.R., J.C. Harshbarger, J.L. Lake, T.K. Sawyer, K.L. Price, M.D. Stephenson, P.L. Haaker, and H.A. Togstad. 1995. Association of prokaryotes with symptomatic appearance of withering syndrome in black abalone *Haliotis cracherodii*. J. Invert. Path. 66:111-120.

[80] Altstatt, J.M., R.F. Ambrose, J.M. Engle, P.L. Haaker, K.D. Lafferty, and P.T. Raimondi. 1996. Recent declines of black abalone, *Haliotis cracherodii*, on the mainland coast of central California. Mar. Ecol. Prog. Ser. 142:185-192.

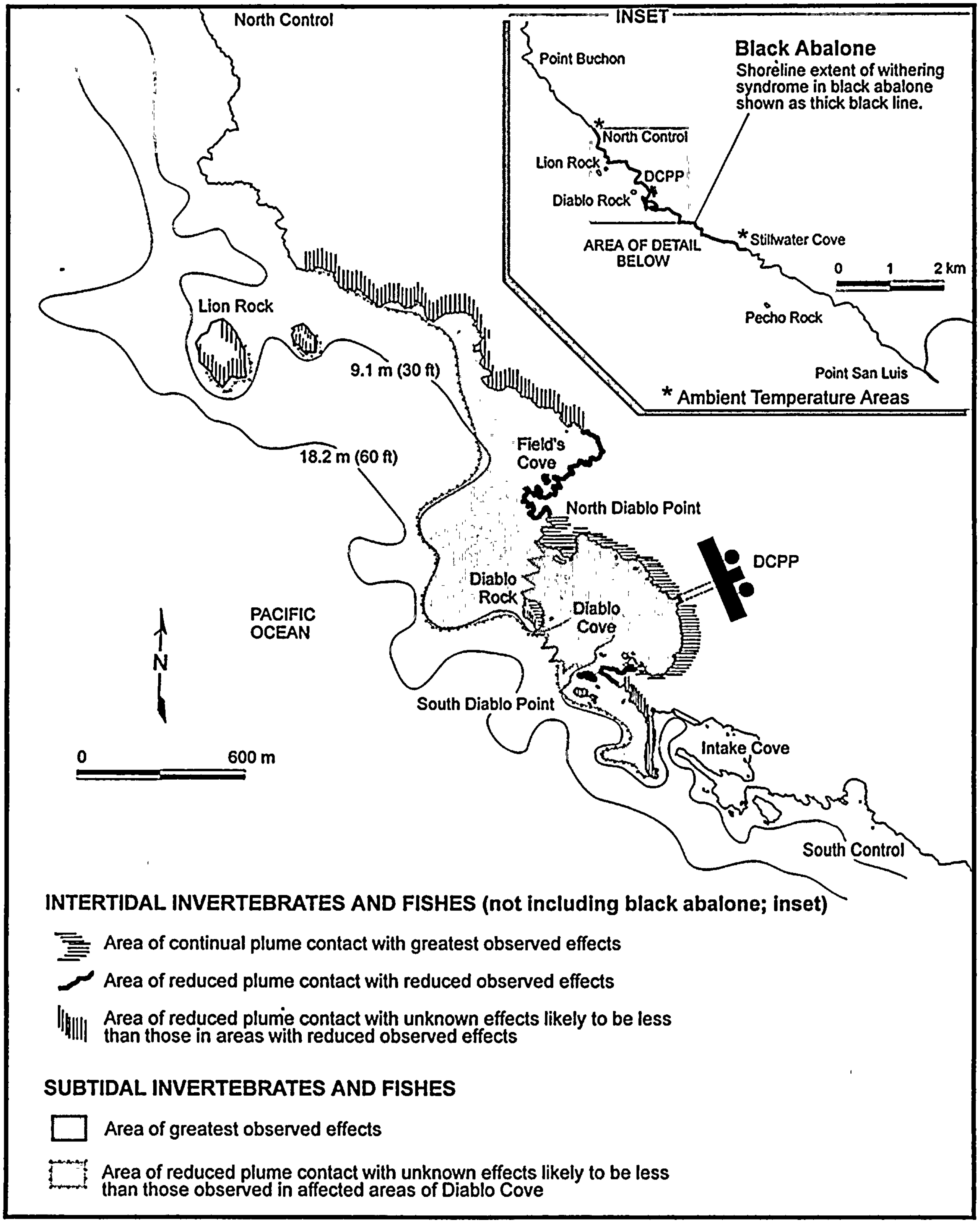

Figure 5-7. Map of the spatial extent of effects observed in intertidal and subtidal invertebrates and fishes. Illustration from the TEMP Analysis Report.

eventually occurred in the absence of the power plant, although the rate of the decline was evidently increased by the DCPP discharge.

Subtidal Invertebrates

No subtidal pre-operational data from Field's Cove were collected, therefore, the following section only discusses discharge-related changes in Diablo Cove. All discussion of changes outside Diablo Cove is based on qualitative observations before plant operation and data from Field's Cove collected during plant operation. A total of 238 taxa were sampled in two subtidal study methods during the TEMP. Of these taxa, 106 of the most abundant were analyzed in the 1997 Analysis Report. Statistically significant increases were detected in 28 taxa and statistically significant decreases were detected in 32 taxa. The remaining 46 taxa either did not change or the results were inconclusive due to low statistical test power.

Overall, the changes in relative abundance among subtidal invertebrates were variable, in contrast to the general increase in intertidal invertebrate abundances. For example, decreases were observed in some herbivorous gastropods (e.g., brown turban snails and lined chitons), while other herbivorous gastropods (keyhole and mitre shell limpets, Norris' top snail and gumboot chiton) increased. Statistically significant increases also occurred in purple sea urchins, that led to the formation of extensive 'urchin barrens' (areas with low foliose algal cover caused by heavy urchin grazing) in north Diablo Cove.

Among the more obvious qualitative observations in the shallow subtidal were increases in algal biomass and changes in algal species composition. In these areas, there are low abundances of both large-shelled herbivorous snails and bat stars. At depths below about 10 m (33 ft) bat stars are common and gumboot chitons, formerly uncommon in the entire study area, are abundant. Brown turban snails are relatively abundant in some shallow areas, but all individuals are of a small size and appear to be restricted to cryptic habitats under cobbles and in dense patches of understory algae. Some of these changes may be explained by predation upon the larger, more conspicuous shelled gastropods by the sheephead, bat rays, and leopard sharks attracted into Diablo Cove by the discharge plume.

Red abalone were not adequately sampled by the subtidal benthic studies and therefore were sampled in a separate study designed to estimate their population abundances within Diablo Cove and control areas. The results of this study showed that prior to plant operations and through 1987, red abalone were most abundant at depths shallower than 6 m (~20 ft) in Diablo Cove and appeared to be unaffected by power plant operation. A cove-wide decline in red abalone occurred between 1987 and 1990. Mean densities of red abalone decreased at all depths, but the largest declines occurred in the shallow perimeter of the entire cove and at all depths in north Diablo Cove. These are the areas of the cove where the warmest water temperatures coincided with the greatest abalone abundances. After 1991, red abalone were only abundant at depths greater than 6 m (~20 ft) in Diablo Cove; although their absolute abundance at this depth was reduced by about 50 percent from that measured in surveys prior to 1990. WS was observed affecting red abalone in Diablo Cove and probably contributed to the decline in abundance: Red abalone in Field's Cove and South Control remained abundant at all depths.

Studies on subtidal invertebrates were largely confined to permanent stations within Diablo Cove and control areas. One deep station and one shallow station were established in Field's Cove after power plant start-up. Data from these stations and qualitative observations suggest that effects of the discharge on subtidal invertebrates were restricted to subtidal depths of 10 m (~33 ft) and less within Diablo Cove (Figure 5-7). No effects have been observed outside Diablo Cove, although reduced plume contact with the bottom may cause minimal effects that could extend into Field's Cove, and southward to the west intake cove breakwater. The diminishing exposure of subtidal habitat to the plume in these areas would not likely result in any changes in species composition and abundance.

Ecological Significance of Observed Changes

Intertidal Invertebrates

The pre-operational intertidal community was characterized as being algal dominated. Decreases in algae and increases in several indigenous invertebrates resulted in an operational community dominated by invertebrates. In general, these changes affected species of lower trophic levels, as opposed to 'keystone' species of high trophic status that may exert a disproportionate influence on community structure.[81] An exception was increases in *Pisaster* sea stars, a keystone predator, found in both the intertidal and subtidal areas of Diablo Cove. Intertidal population increases included barnacles, several limpet species, purple sea urchins, sand tube worms and several species of amphipods.

Qualitative examination of the intertidal area in north Diablo Cove reveals areas of substratum that are covered with common barnacles, black turban snails and limpets. Some areas in north Diablo Cove were extensively overgrazed by purple sea urchins. Prior to plant operation these areas were covered with algae, primarily iridescent seaweed. The presence of herbivores, particularly the purple sea urchins, undoubtedly contributes to maintaining the low level of algal standing stock, but interactions among other factors such as temperature and life history aspects of the algae may be more important. The loss of intertidal algal cover provided open space for colonization by barnacles and limpets. The lack of erect algae together with the presence of warm water and abundant light enhanced the growth of the algal/bacterial film that sustains limpet populations. In many respects the appearance of the intertidal is similar to shoreline areas in southern California, except that the invertebrates that dominate the habitat in the cove are indigenous to this area.

Declines in black abalone began in 1988 after three years of plant operation. The declines occurred rapidly in Diablo Cove due to the warm water and the presence of a pathogen responsible for WS and widespread declines throughout southern California. The magnitude of the decreases in Diablo Cove were similar to those recorded at locations in southern California where water temperatures are similar to those in the cove. Outside the cove the decreases were less and appeared similar in magnitude to declines recorded in other areas of central California.

Although statistically significant increases in intertidal invertebrates have occurred outside Diablo Cove at South Diablo Point and in Field's Cove, fewer species changed in these areas and the changes are much less than those observed inside the cove. Other than control locations, areas beyond these stations have not been extensively studied, but based on the reduced frequency of plume contact few changes would be expected in these areas. The shoreline distance within Diablo Cove where statistically significant changes in invertebrates where greatest represents less than 5 percent of the coastal reach from Point Buchon to Point San Luis. If the shoreline with reduced effects is included the total is still less than 10 percent. The amount of shoreline affected by the plume is relatively small in proportion to the total amount of unaffected adjoining rocky coastline to north and south.

There is no indication that substrates have been altered in areas of Diablo Cove where substantial biological changes occurred, thereby limiting the return of the biological communities to prior states of

[81] Paine, R.T. 1974. Intertidal community structure: experimental studies on the relationship between a dominant competitor and its principal predator. Oecologia 15:93-120.

relative abundance. The rate of reversal for a specific area or habitat is expected to be related to the degree of discharge-related change. Multivariate analysis of intertidal invertebrate communities in control areas presented in the 1997 Analysis Report showed that complete reversal of 1983 El Niño abundance changes took approximately four years. Other studies have shown that areas cleared of mussels may take longer than six years for recovery.[82] Intertidal areas of Field's Cove and South Diablo Point will experience relatively rapid reversal of discharge-related changes, as the naturally-occurring species have only changed in their relative abundances, and have not declined substantially.

A primary feature of the changes in the intertidal areas of Diablo Cove has been the loss of foliose algal cover. Therefore, the return of invertebrates to pre-operation abundance conditions in Diablo Cove will be prolonged as algae slowly overgrows substrate currently occupied by invertebrates. Repopulation of taxa that decreased in abundance during plant operation will depend on their ability to recolonize affected areas. Organisms with limited dispersal that were reduced in abundance during plant operation, including the six-armed sea star, *Leptasterias* and the proliferating anemone *Epiactis*, will repopulate Diablo Cove at a relatively slow rate. Recruitment of juvenile black abalone (<2.5 cm, ~1 in) has occurred in Diablo Cove between 1991 and 1994 resulting in some recovery of the population, although large abalone remain rare and WS-affected animals are still found. These observations indicate the potential for recruitment in Diablo Cove from larval settlement in a species that may have relatively limited larval dispersal.[83] The successful reestablishment of the black abalone population will depend upon their ability to survive WS. Due to the abalone's slow growth rate, it may take many years for black abalone to attain the same size class distribution found in the population prior to the WS infections.

Subtidal Invertebrates

Discharge-related changes in subtidal invertebrate communities were characterized by shifts in the relative abundances of species present in the cove before plant start-up, and, to a lesser degree, introductions of several 'warm-water' species not common to the area. Invertebrates that increased during plant operation included both warm-water and cool-water species. Norris' top snail is a common and abundant herbivore in southern California, that was recorded once in Diablo Cove in the late 1960's. It became established and common in the cove during power plant operation. Gumboot chitons that are usually associated with cool-temperate waters further north became common in the cove following plant operation. These and other examples show that increased water temperature from the discharge was not the only factor affecting species changes in Diablo Cove. The increases did not result in any one species becoming dominant. The community still consists of a wide variety of invertebrate taxa including filter-feeders, herbivores, and predators.

Changes to subtidal invertebrates were confined to Diablo Cove areas shallower than 6-8 m (18-25 ft). Unlike intertidal black abalone that declined over a broad area, red abalone declines were also confined to Diablo Cove. No effects on subtidal invertebrates have been observed outside of Diablo Cove. The total area with observed discharge-related effects on invertebrates is relatively small in proportion to the total amount of unaffected rocky coastline to north and south.

The continued presence of many of the same species that were present before plant operation provide the potential for relatively rapid return to pre-operational patterns of abundance after the plant ceases operation. A feature of the Diablo Cove subtidal is the proximity of unaffected areas for certain taxa

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[82] Kinnetic Laboratories, Inc. 1992. Study of the rocky intertidal communities of central and northern California: Final report (Vol. 1). U.S. Dept. of the Interior, Minerals Management Service, Pacific OCS Region. Contract No. 14-12-0001-30057.

[83] P. Raimondi, U.C. Santa Cruz, Dept. of Biological Sciences (pers. comm.).

below depths of approximately 6-8 m (18-25 ft). The process of return to relative species abundances similar to pre-operational conditions in the subtidal will be assisted by recruitment and immigration from these deeper unaffected areas. Red abalone and bat stars, have declined in Diablo Cove due to disease, but have remained abundant or common at depths below 6-8 m (18-25 ft) throughout the study area. Predation by bat rays, sheephead and sea otters may have contributed to the declines in Diablo Cove populations of brown turban snails, purple sea urchins and Norris' top snail. Bat rays and sheephead, attracted by the discharge to Diablo Cove, will disperse when the discharge ceases. Repopulation of these prey species is dependent upon aspects of their life histories. Long lived, slow growing species with planktonic larvae, such as red abalone and brown turban snails, may take longer to return to pre-operation levels of abundance than shorter lived, faster growing species such as purple and red sea urchins.

5.3.4 Fishes

The proximity of Diablo Canyon to Point Conception, a major biogeographic separation between nearshore fish assemblages, results in an indigenous fauna with both northern (cool-temperate) and southern (warm-temperate) affinities. Fishes in the area include intertidal and subtidal species of bony fishes as well as sharks and rays. Fishes were primarily sampled in the subtidal as part of TEMP, although some data were collected on intertidal species. No subtidal pre-operational data from Field's Cove were collected, therefore, the following section only discusses discharge-related changes to fishes in Diablo Cove. All discussion of changes outside Diablo Cove is based on qualitative observations.

Summary of Observed Changes

Intertidal Fishes

Eleven intertidal fish taxa were analyzed in the 1997 Analysis Report for differences between Diablo Cove and the adjacent Field's Cove reference station. Statistically significant decreases were detected in five species. *Xiphister mucosus* (rock prickleback) was the most abundant taxa in Diablo Cove before plant operation and has a cool-temperate distribution from Alaska to Point Conception. This species declined after power plant start-up at both the Diablo Cove stations and the Field's Cove station used as a reference for the analyses. Decreases in this and other species were less in Field's Cove. No taxa unequivocally increased in Diablo Cove after plant start-up, although *Anoplarchus/Cebidichthys* (high cockscomb and monkeyface eel) increased in south Diablo Cove and decreased in north Diablo Cove. Periodic recruitment of juveniles in Diablo Cove during plant operation indicated that intertidal areas of the cove still provided viable habitat for many intertidal fish taxa.

Subtidal Fishes

Approximately 60 taxa of fishes were recorded on the subtidal benthic transects before plant start-up, and 65 were recorded after plant start-up. Of the 37 taxa analyzed in the 1997 Analysis Report, 13 increased, 8 decreased and for the other 16 taxa the analyses either did not detect a change or were inconclusive due to the low statistical power of the test. The changes in taxa did not significantly affect fish diversity on Diablo Cove midwater transects, although diversity decreased on bottom transects in south Diablo Cove, and was unchanged in north Diablo Cove. However, numbers of taxa increased on both midwater and bottom transects in north Diablo Cove.

The most obvious changes in fish composition following power plant start-up occurred in the near-field zone of the discharge plume, where certain species were attracted by the plume's turbulence and warm water. These species were indigenous, but uncommon, in Diablo Cove before plant start-up, and included leopard shark, bat ray, round ray, white seabass, opaleye, halfmoon, and sheephead. Similar increases in these species were seen on the inshore side of Diablo Rock and in most shallow areas throughout Diablo Cove. In contrast, some taxa that had been common before plant start-up were nearly absent in Diablo Cove after operation (e.g., kelp greenling). The temperature transition zone attracted surfperches when it was situated close to bottom habitats. In areas deeper than 7.6 m (25 ft), cool ambient temperatures prevailed; here the fish fauna was basically the same as in control areas at similar depths outside of Diablo Cove. Juvenile blue rockfish declined in abundance in north Diablo Cove during the power plant operation period, a pattern consistent with laboratory thermal avoidance studies on this species. Additional observations in Field's Cove, near Lion Rock (north of Diablo Cove), and the breakwater/Seal Haulout area (south of Diablo Cove), indicated that the fish fauna at those locations was unaffected by the power plant discharge.

Changes in the fish assemblage observed following DCPP start-up appeared to be primarily limited to the immediate vicinity of the discharge plume and other shallow (<7 m) areas within Diablo Cove. Based on a multivariate analysis of fish data from 1976-1995, and other incidental observations north and south of Diablo Cove, changes between the control and affected area diminished rapidly with distance from the discharge. Effects outside the cove were related to the attraction of some midwater fishes (e.g., topsmelt, a surface-feeding species) to the offshore surface plume.

Ecological Significance of Observed Changes

Intertidal Fishes

The assemblage of intertidal fish species in both Diablo Cove and Field's Cove prior to power plant operation was similar to that described from other central California rocky coast intertidal habitats, consisting largely of pricklebacks, sculpins, clingfish, and gunnels.[84] One of the most apparent features of the population of intertidal fishes in Diablo Cove was the seasonal recruitment of pricklebacks that was reduced in Diablo Cove after plant start-up. Pricklebacks have a cool-temperate geographic distribution that would indicate that they are less tolerant of the water temperatures in Diablo Cove than other intertidal species. Reductions in abundance for other intertidal fishes likely resulted from the statistically significant losses of intertidal algal cover in Diablo Cove after power plant start-up. Several intertidal fishes either use algae as habitat, as a food source, or feed on algal-associated invertebrates.

The total amount of rocky intertidal habitat affected in Diablo Cove was small compared to the total amount of similar rocky habitat in the coastal reach from Point Buchon to Point San Luis. In addition, most of the species were not entirely restricted to the intertidal zone and could also occupy shallow subtidal habitat. The intertidal fishes that declined in Diablo Cove were not numerous enough to significantly affect either algal populations (through herbivory) or zooplankton prey populations. It is also unlikely that they were a unique food source for any predators that may have been negatively affected by losses in intertidal fishes. Therefore, the statistically significant reductions in abundance in some intertidal fish species were not ecologically significant in terms of the local nearshore population.

Subtidal Fishes

The results of this assessment suggest that the observed changes in the fish assemblage were caused by temperature avoidance and attraction and not to direct effects on mortality and reproduction. The greatest change in the shallow water fish fauna of Diablo Cove was the statistically significant increase in bat

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[84] Yoshiyama, R.M., C. Sassaman, and R. N. Lea. 1987. Species composition of rocky intertidal and subtidal fish assemblages in central and northern California, British Columbia-Southeast Alaska. Bull. So. Calif. Acad. Sci. 86:136-144.

rays, leopard sharks and sheephead, that are all predators of benthic invertebrates. Increases in these species may have been a factor in the observed decreases in some invertebrate groups, especially shelled gastropods (*Tegula, Calliostoma* and *Lithopoma*) within Diablo Cove. However, the combined effects of foraging activities on invertebrates by bat rays, leopard sharks, sheephead and other attracted fishes were not quantified with fish gut analysis. Because of their mobility, predatory fishes may have also foraged over a wider area, including adjacent reefs and deeper sandy substrates outside of Diablo Cove, although these taxa did not commonly occur at the South Control station, less than 1 km (0.6 miles) south of Diablo Cove.

Other predatory species that increased were white seabass, kelp bass, and striped bass, that are primarily piscivorous (fish-eating) species, and these were probably attracted to Diablo Cove by a combination of warmer water temperatures and the increased numbers of forage fishes ('baitfish') such as topsmelt and anchovy. Although sheephead occur coastwide, it is mainly a southern species and prefers warmer water. Increases were also observed in certain herbivorous (algae feeding) fishes (e.g., opaleye and halfmoon) that are more common south of Point Conception. The numbers of herbivorous fishes, however, did not have an ecologically significant effect on algal standing stock, particularly giant kelp that is known to be affected by herbivorous fishes in some circumstances.[85]

Because of the proximity of Diablo Cove to Point Conception, fishes with southern affinities are occasionally found in the area, especially during warm-water years. Some of these species include sheephead, blacksmith, kelp bass, white seabass, giant kelpfish, and bluebanded gobies. These taxa, however, do not normally establish reproductive populations in the area. Most resident taxa with southern affinities tend to occur in bays, such as Morro Bay (17 km [11 mi] north of Diablo Cove - linear distance). Many of the fishes typically found north of Point Conception have adapted their reproductive strategies to minimize the offshore transport of eggs and larvae as a result of upwelling currents.[86] Surfperches, one of the most common fish families in the Diablo Canyon area, are live bearers and have effectively eliminated offshore transport. Sculpins, greenlings, gobies, pricklebacks, gunnels, and toadfishes all have adhesive benthic eggs. The larvae hatch at relatively large sizes, thus enhancing their ability to transform to the juvenile stage in nearshore areas. Rockfishes have eliminated the egg stage through live-born larvae and the extruded larvae disperse with prevailing currents.

In relation to similar habitats in the region, the area of fish habitat in Diablo Cove and Field's Cove affected by the DCPP discharge is small. Based on qualitative observations, depths below about 9 m (30 ft) were unaffected and species composition at the South Control station was basically similar between pre-operational and operational periods despite overall declines in the abundances of many species. Kelp canopy increased in all areas of Diablo Cove, providing habitat for adults and juveniles of several fish taxa. Although the plume can intermittently contact a larger area, the length of coastline with actual observed effects is much less and represents approximately 7 percent of the coastal reach from Point Buchon (north of DCPP) to Point San Luis (Figure 5-7).

All of the changes caused by the discharge are reversible because of the mobility of most adult fishes, the close proximity of unaffected habitats, and the dispersal capability of species with pelagic larvae. Return of the fish fauna in Diablo Cove to conditions more similar to pre-operational conditions would most likely occur in three concurrent phases (time scales): 1) emigration of migratory species (days); 2)

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[85] Carter, J.W., W.N. Jessee, M.S. Foster and A.L. Carpenter. 1985. Management of artificial reefs designed to support natural communities. Bull. Mar. Sci. 37:114-128.

[86] Hobson, E.S. 1994. Ecological relations in the evolution of acanthopterygian fishes in warm-temperate communities of the northeastern Pacific. Envir. Biol. Fish. 40:49-90.

immigration of fishes from adjacent unaffected areas (months); and 3) recolonization via larval transport (years). Fishes capable of long-distance movements such as white sea bass, striped bass, and leopard shark would leave the vicinity with the cessation of the warm water discharge and as concentrations of bait fishes around the discharge dispersed. This would be a relatively rapid change, as evidenced by previous observations of diminished numbers of sharks and sea bass during power plant outages. Fishes from unaffected habitats north and south of the power plant, and rocky habitats below about 9 m (30 ft) would re-occupy shallow depths in Diablo Cove over time. Recolonization would also occur as cohorts of young-of-the-year fishes settled from the plankton. Annual settlement of many fish taxa presently occurs in Diablo Cove during power plant operation. The availability of larvae is highly variable from year to year, and is affected by many factors including coastal currents and planktonic food resources. Success of individual cohorts among years is also highly variable and would lead to uncertainty about predicting the time needed for recovery via larval settlement.

5.4 Conclusions Concerning Effects on Marine Habitat

The assessment of changes to the biotic categories indicates that effects have largely been confined to Diablo Cove. Although statistically significant losses of algal diversity, species richness, and cover occurred in Diablo Cove, the localized losses do not threaten the protection of the same populations in the coastal segment between Point Buchon and Point San Luis. The area of Diablo Cove where the greatest effects have been detected occupies less than 5 percent of the shoreline area within this coastal segment. In addition, although some of the changes inside Diablo Cove were statistically significant, the changed habitat remains functionally viable for numerous indigenous species.

The ecological significance of the effects on the three biotic categories were evaluated using ERA criteria in the previous section. They are summarized below and evaluated using EPA decision criteria for assessing protection of the BIC in the coastal segment between Point Buchon and Point San Luis.

Habitat-Formers

Discharge-related changes to habitat-forming species described in the previous section were largely restricted to Diablo Cove where statistically significant reductions in intertidal algal cover, species richness, and diversity occurred. Decreases in algal cover in the cove resulted from reduced abundances of a few species. A strong gradient of declining effects away from the discharge was detected with lesser effects documented in Field's Cove and South Diablo Point. Effects to subtidal habitat-formers diminished rapidly with depth and distance from the discharge. Subcanopy kelps that declined in Diablo Cove after plant operation were replaced by giant kelp that provided a similar habitat function to the pre-operational kelp assemblage. The effects of the discharge on limiting the repopulation of surfgrass beds that had been significantly reduced by pre-operational storms were also restricted to Diablo Cove. The discharge effects observed in Diablo Cove habitat-forming species, considering their small spatial extent do not present any risk to populations in water body. The continued presence, and in some cases increases, of invertebrates and fishes, provides evidence that the trophic structure of the community has been maintained. Many invertebrates and fishes rely on habitat-formers for food and shelter. Although there are no threatened or endangered habitat-formers, invertebrates or fishes in the Diablo Canyon area, a local population of southern sea otters, a federally endangered species, continue to frequently utilize Diablo Cove as a foraging area. Sea otters are a top-level predator in the trophic structure of the central California nearshore marine community. The small spatial scale of discharge-related effects on habitat-formers and the continued maintenance of a functioning marine community in affected areas provides substantial evidence that the BIC is protected by the current discharge temperatures.

Shellfish/Invertebrates

Discharge-related effects in Diablo Cove generally resulted in increases in indigenous species of filter-feeding and herbivorous intertidal invertebrates. Effects on intertidal invertebrates in the adjoining areas of Field's Cove and South Diablo Point were considerably reduced from the changes observed in Diablo Cove. The invertebrate assemblages in these areas were essentially unchanged from their pre-operation condition. In contrast to the intertidal, discharge-related decreases occurred in the abundances of several subtidal invertebrates. Effects from the discharge were only detected in the cove at depths less than approximately 10 m (33 ft) and no effects on subtidal invertebrates were detected outside of Diablo Cove. In both the intertidal and subtidal a few of the lesser abundant species with northern biogeographic distributions decreased, and a few species with southern distributions increased in frequency. No statistically significant decreases in diversity, as measured by species richness, were detected for intertidal or subtidal invertebrates. A rich assemblage of intertidal and subtidal invertebrates has been maintained in areas where effects have been detected. The types of discharge-related changes detected provide evidence that the BIC is being protected by the current discharge temperatures.

Fishes

In general, for fishes that changed in abundance after power plant start-up, increases were more prevalent than decreases as certain species preferentially moved into areas warmed by the discharge. The warm water has attracted several species with southern biogeographic distributions. Discharge-related changes to fishes were caused by temperature avoidance and attraction and not from direct effects on mortality and reproduction. The changes in taxa did not significantly affect fish diversity on Diablo Cove midwater transects, although diversity decreased on bottom transects in south Diablo Cove, and was unchanged in north Diablo Cove. However, species richness increased on both midwater and bottom transects in north Diablo Cove. A rich assemblage of fishes has been maintained in areas where effects have been detected. No effects from the discharge have been observed outside of Diablo Cove. The discharge does not appear to exclude or block the migration of fishes from any areas, except directly in front of the discharge. The types of discharge-related changes detected provide evidence that the BIC is being protected by the current discharge temperatures.

BIC Criteria

The following criteria are provided in EPA guidance as the basis upon which a regulator would determine that the existing thermal discharge assures protection and propagation of a BIC. In the case for DCPP, these criteria further support our conclusions on the significance of the changes to the three biotic categories and the continued protection of the BIC.

There is no convincing evidence that there will be damage to the BIC resulting in such phenomena as those identified in the definition of "appreciable harm";

There is no evidence that appreciable harm has or will occur from the operation of the power plant. Within the area exposed to the plume, the marine community has not become dominated by nuisance species and is comprised of both warm-temperate and cool-temperate species characteristic of the biogeographic transition zone where DCPP is located. Decreases of formerly indigenous species in the exposed area have generally been accompanied by corresponding increases in other indigenous species, maintaining the overall complexity and richness of the assemblage. There is no evidence that the observed net reduction in intertidal algae has disrupted the trophic structure of the water body, as the overall abundance and species richness of the invertebrates and fishes at higher trophic levels has increased in the presence of the thermal discharge. There is no evidence that effects in the localized area of the plume limit the successful completion of the life cycles of indigenous populations in the remainder of the water body. The magnitude of effects decreases correspondingly with reductions in temperature and hydraulic exposure as the plume disperses with distance from the outfall. Therefore, the total portion of the extensive populations of most of the marine communities exposed to the plume is small. The area of Diablo Cove where the greatest effects have been detected occupies less than 5 percent of the shoreline area within the coastal segment (Point Buchon to Point San Luis), and the total area where any discharge effects have been observed occupies approximately 7 percent of the coastal segment.

The receiving waters are not of such quality that excessive growths of nuisance organisms will take place;

There have been no increases in species that represent a nuisance to the recreational or commercial resource.

A zone of passage will not be impaired to the extent that it will not provide for the normal movement of populations of RIS, dominant species of fishes, and economically important species of fish, shellfish, and wildlife;

There is no indication that the areas affected by the discharge fragment the community or interfere with any corridors or mechanisms required for successful migration of members of the community. The areas affected by the discharge do not represent critical spawning or nursery habitat that are not available elsewhere within the coastal water body segment. Outside of the immediate area of the discharge plume the physical habitat within Diablo Cove and its immediate vicinity has not been affected. Habitat for juvenile fishes within the water column previously provided by bull kelp and subsurface tree kelps has been replaced during power plant operation by giant kelp habitat. This finding of 'no effect' is consistent with all previous DCPP discharge assessment findings.

There will be no adverse impact on threatened and endangered species;

There are no impacts of the discharge on the beneficial use of marine habitat by threatened or endangered species in Diablo Cove and its immediate proximity. The only threatened or endangered species occurring in Diablo Cove and its immediate proximity are species of marine mammals that are not at risk from temperatures resulting from the DCPP discharge. Previous assessment found that no protected species were either expected to be, or later observed to be, affected by temperatures resulting from the DCPP discharge.

There will be no destruction of unique or rare habitat without a detailed and convincing justification of why the destruction should not constitute a basis for denial.

The thermal discharge at DCPP causes no destruction of unique or rare habitat. The area affected by the discharge is not unique or rare.

6.0 PROTECTION OF BENEFICIAL USES ASSESSMENT

6.1 Introduction

The changes caused by the Diablo Canyon Power Plant discharge temperatures to biological communities and taxa in the receiving water areas are described in Section 5. The ecological significance of these changes was also summarized for each biotic category as recommended by EPA guidance for assessment of a BIC and for criteria developed from EPA ERA guidelines. In this section, the level of protection afforded the DCPP water basin's marine habitat by the power plant's discharge temperature limit is assessed. The assessment uses the findings for each biotic category to produce an integrated evaluation of protection of marine habitat, the primary beneficial use addressed in this report.

The assessment framework to determine if the thermal discharge is protective of beneficial uses centers on the State Board's Order 83-1 in March 1983 upholding the thermal limit of 11.1°C (20°F).[87] The Order concluded that a significant alteration of water quality in Diablo Cove was not unreasonable.[88] The State Board outlined a series of factors they used in reaching their decision. The development of these factors was necessary because detailed guidance for assessing the protection of the DCPP discharge limit to receiving water beneficial uses is not available in the state Thermal Plan. These same factors are still applicable in assessing the reasonableness of the observed effects and are used in this assessment.

The assessment is then evaluated for consistency with other decisions and policies. This includes review of the finding in terms of: 1) the original predictions; 2) thermal limits at other power plants; and 3) the standard scope of study recommended by EPA.

6.2 Protection of Beneficial Uses

The 1997 Analysis Report is the latest chapter in an on-going review of the thermal discharge at Diablo Canyon. Permits addressing the thermal discharge have been issued by the Regional Board since 1969. Additionally, since the State Board Order in 1983, numerous annual reports and one comprehensive report (1988 TEMP Final Report) have been submitted to the Regional Board. These reports all provided information to the Regional Board on the magnitude and spatial extent of the discharge's thermal effects.

6.2.1 Observed Effects are not Ecologically Significant

The State Board's Order 83-1 acknowledges that some changes from the discharge are acceptable. Our evaluation of observed effects in Section 5 using EPA guidance criteria indicates that the DCPP discharge, while causing statistically significant changes in the abundances of some species, has not resulted in ecologically significant changes that affect the continued beneficial use of marine habitat in the area of DCPP. The State Board order also noted that CDF&G found that the effects of the thermal discharge would be reversible. The analysis of the TEMP data in Section 5 indicates that this conclusion remains accurate.

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[87] State Water Resources Control Board, Order No. 83-1, March 17, 1983.

[88] State Board Order No. 83-1, at p. 27.

6.2.2 Protection Based on Order 83-1 Factors

In order to determine whether the predicted effects were reasonable, the 1983 State Board decision outlined the series of factors they considered. These factors are still applicable in assessing the reasonableness of the observed effects.

Balancing Process

The State Board indicated that the decision on the reasonableness of the thermal limit must utilize a balancing process. This balancing process requires that activities that may affect the quality of the waters of the state, such as the Diablo Canyon thermal discharge, "shall be regulated to attain the highest water quality that is reasonable, considering all demands being made, and to be made, on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." Therefore, all of the beneficial uses must be considered and balanced to provide a reasonable level of protection.

The State Board found that some level of change in the vicinity of Diablo Cove is acceptable, as the area is not an Area of Special Biological Significance. This remains true today. The overall absence of ecologically significant effects, coupled with the fact that the observed effects are reversible, supports the conclusion that beneficial uses are reasonably protected.

Permitting History

The State Board also reviewed DCPP's permitting and reporting history in Order 83-1. First, it was noted that the plant has been issued permits since 1969, allowing a once-through cooling water discharge. The Regional Board has continued to receive information on the TEMP program since the 1983 decision, most importantly the 1988 TEMP Final Report. These studies have produced one of the largest sets of data on thermal effects in the marine environment in the U.S. and have provided an on-going understanding of the changes in the vicinity of Diablo Cove. Diablo Canyon's NPDES permit was renewed in 1985 and again in 1990. It was also noted that PG&E submitted a report that examined the economic and environmental benefits of alternatives to a once-through cooling system (Alternatives Report). This report indicated that any alternative to the existing system would be either cost prohibitive, have adverse environmental consequences, or both. The analysis in the Alternatives Report remains applicable today.

Importance of Agency Involvement and Multi-agency Workgroup

The State Board also noted the importance of the role of CDF&G in the study. CDF&G, as well as U.S. EPA, remain involved in the environmental study process at Diablo Canyon. Additionally, the use of the multi-agency workgroup, that included both government agencies and the public, in the development and review of the 1997 Analysis Report is indicative of the current strength of the external review process. In preparing the data for analysis, a number of decisions had to be made about the scope and approach of the analyses, taking into account changes in sampling design and methods over the monitoring period. The approach and selection of methods was accomplished with the close advice and direction of the Regional Board's appointed independent experts, Drs. Foster and Schiel, the Regional Board technical working group and the Regional Board staff. Data were carefully reviewed and scrutinized before inclusion in the analysis. A quality assurance audit of the data was conducted under the review and supervision of Drs. Foster and Schiel. The results of the audit and the final data sets are fully documented and archived in a composited CD format accompanying the 1997 Analysis Report.

Working closely with the Regional Board's independent experts, a statistical approach was selected based on a general format of 'before and after' effects compared among impact and control areas. The analytical technique know as the BACI method provides an excellent basis to detect changes due to the discharge taking into account changes that are natural and variable through time. The study design must also ensure that the control and affected areas are reasonably similar in species composition and habitat and that they respond similarly to regional changes. In cases of non-parallel responses to natural changes between control and affected areas, it is possible that a small decline in the affected areas would be detected as an increase, if a larger decline occurred in the control area. To avoid drawing an erroneous conclusion in such a case, it is important that other statistical and graphical techniques be employed. To this end, a broad range of statistical and graphical techniques were applied to the DCPP monitoring data in preparing the 1997 Analysis Report.

State Board Plans and Policies

The 1983 decision noted the State Board's policy preference for the ocean-siting of power plants. This policy remains in effect and when reviewed, it is clear that the environmental concerns cited in the policy are still true today. The State Board also compared the Thermal Plan requirements for new dischargers to those for existing dischargers and reviewed the thermal limits of comparable coastal-sited power plants. The results of their review and analysis remain applicable to Diablo Canyon. There have been no changes to the Thermal Plan since 1983 (and none since 1975), and thus, it is still reasonable to infer that an existing discharger would be subject to a less stringent standard than a new discharger. Diablo Canyon's thermal limit of 22°F above ambient is not only reasonable when compared to the 20°F limit allowed for a new discharger, it remains comparable to the thermal limits established at other power plants in California and elsewhere (Table 6-1).

6.2.3 Conclusion on Protection of Beneficial Uses

A finding of protection of beneficial uses (POBU) is reasonable based on the absence of any ecologically significant effects (as defined by EPA criteria for evaluating a BIC and ERA factors). This finding is further supported by our review of the factors considered by the State Board decision upholding the original thermal limits. These factors are still applicable in an evaluation of the protection afforded beneficial uses by the discharge thermal limits. The basis of the State Board's conclusion in Order 83-1 is further supported by the additional information provided in the current assessment.

6.3 POBU Finding is Consistent with other Decisions and Policies

Further support for a finding that beneficial uses are protected is found by examining three other factors. They are: 1) a comparison of the predicted effects used in the decision to observed effects; 2) a comparison of the DCPP discharge with other ocean-sited power plants; and 3) a discussion of the scope of the DCPP thermal studies.

Table 6-1. Ocean-sited power plants in the continental U.S.

	Capacity (Mwe)	Ambient Temperature Range (°F)	Condenser Delta T° (°F)	Cooling Water (CFS)	Heat Treatment Maximum Temperature (and/or maximum Delta T°) (°F)	Receiving Water Body	Discharge Type	Discharge Depth (feet)	Distance from Shore (feet)
Alamitos	2,097	50 - 70	18	1,967	110	Tidal prism of San Gabriel River/ Pacific Ocean	Shoreline	Surface	—
Diablo Canyon†	2,269	48 - 69	22	3,930	50 delta T°	Pacific Ocean	Shoreline	Surface	—
El Segundo	1,020	50 - 70	22	978	125	Pacific Ocean	Offshore Sngl Port	16	2,100
Encina	937	50 - 76	20	1,225	60 delta T°	Pacific Ocean	Shoreline	Surface	—
Harbor	240	50 - 70	—	172	120	Pacific Ocean	Shoreline	Surface	—
Haynes	1,625	50 - 70	20	1,513	115 65 delta T°	Pacific Ocean	Shoreline	Surface	—
Huntington Beach	870	53 - 71	26	798	130	Pacific Ocean	Offshore Sngl Port	20	1,500
Mandalay	430	53 - 73	22	395	125	Pacific Ocean	Shoreline	Surface	—
Millstone 1 & 2†‡	1,522	34 - 75	23	2,275	105	Long Island Sound	Shoreline	Surface	—
Millstone 3†‡	1,150	—	18	2,000	—	Long Island Sound	Shoreline	Surface	—
Morro Bay	1,002	50 - 60	30	1,118	35 delta T°	Pacific Ocean	Shoreline	Surface	—
Moss Landing 6 & 7	1,500	50 - 60	28	1,337	40 delta T°	Pacific Ocean	Offhsore Sngl Port	20	700
Ormond Beach	1,500	56 - 62	30	1,063	125	Pacific Ocean	Offshore Sngl Port	20	1,350
Pilgrim†‡	655	34 - 60	32	789	102	Atlantic Ocean	Shoreline	Surface	—
Redondo Beach 5 & 6	350	50 - 70	27	713	125	Pacific Ocean	Offshore Sngl Port	25	1,600
Redondo Beach 7 & 8	960	—	27	1,042	125	Pacific Ocean	Offshore Sngl Port	20	300
San Onofre 2 & 3	2,254	55 - 72	20	3,627	—	Pacific Ocean	Offshore Diffuser	40 - 50	8,350, 6,020
Scattergood	818	50 - 70	16	760	135	Pacific Ocean	Offshore Sngl Port	15	1,200
Seabrook†‡	2,300	34 - 61	39	1,047	120	Atlantic Ocean	Offshore Diffuser	50 - 60	5,200
St. Lucie 1†‡	850	60 - 85	30 - 32	1,150	117	Atlantic Ocean	Offshore Y-Port	30	1,200
St. Lucie 2†‡	850	—	30 - 32	1,150	—	Atlantic Ocean	Offshore Diffuser	30 - 40	2,000

† Nuclear power plant.
‡ East Coast plant site.

6.3.1 *Comparison to Predicted Effects*

The decision to allow the discharge of heat by DCPP was based on the State Board's acknowledgment that some changes caused by the discharge were acceptable. The predicted changes were described in the TDAR and submitted to the Regional Board in 1982. An analysis of the differences between the predicted and observed discharge effects provides additional information for evaluating the reasonableness of protection of beneficial uses. Comparisons of the effects predicted in the TDAR with observed effects are presented in Tables B-1, B-2 and B-3 and summarized below with a discussion of the limitations of those comparisons.

Limitations of Comparisons

Several factors must be taken into account when making comparisons between the anticipated discharge effects reported in the 1982 TDAR and effects reported in the 1997 Analysis Report.

- The predictions in the TDAR were based on laboratory experiments that could not simulate actual field conditions. The laboratory experiments ranged in duration from 4 to 120 days. Discharge effects reported in the 1997 Analysis Report were based on analyses of data collected over a 10-year period of power plant operation. Many of the effects may have been due to long-term chronic temperature exposures that were not studied in the laboratory.

- The conditions simulated in the laboratory did not include El Niño conditions that result in warmer ambient temperatures and warmer absolute discharge temperatures.

- The changes observed in species distributions and abundances during power plant operation may have resulted from factors other than temperature, such as habitat availability and competition for space, as well as predation and grazing. Specific predictions on these types of changes were not made in the TDAR.

- The physical model used in the TDAR was only designed to predict temperatures inside Diablo Cove. Consequently, no specific predictions were presented for areas outside the cove, although several risk maps in the TDAR showed areas where physical model data did not exist to determine the precise boundaries of plume effects.

- In some cases, different units of measurement were used to describe the spatial extent of predicted versus observed effects. The spatial areas of effects in the predictions reported in the TDAR were expressed as percentages of cove area estimated to be affected. The 1997 Analysis Report presented estimates of affected areas in units of acres or hectares. For the comparisons in this report, TDAR percentages were converted to acres by multiplying by 40 acres, the estimated surface area of the cove.

- The estimates of area reported in TDAR cannot be compared to shoreline distances estimated in the 1997 Analysis Report using GIS techniques.

Summary Comparison of Predicted versus Observed Thermal Discharge Effects

The presentation of predicted biological effects in the TDAR used data on plume distribution and temperature from a physical model of the discharge to develop maps of anticipated effects. The data from the model on expected seawater temperature increases due to the discharge generally agreed with observed temperatures. The actual behavior and distribution of the plume were different from predicted patterns. The plume was found to generally spread throughout Diablo Cove with the largest temperature increases occurring in north Diablo Cove. This is in contrast to the predictions that the largest temperature increases would occur in south Diablo Cove. It was also predicted that the plume would exit the south entrance to the cove and spread out offshore. The observed tidal variations in plume direction actually resulted in some volume of heated water being directed out the north cove entrance causing the plume to contact areas of Field's Cove that were not anticipated in earlier predictions. The frequency of plume contact is reduced in the area of North Diablo Point and Field's Cove from that observed in Diablo Cove. This results in a temperature difference in these areas that is less than the temperature increases measured in Diablo Cove. These differences were recognized after the plant began operating and the physical model was reconfigured to better match observed plume behavior.

Many of the differences between the predicted and observed biological effects shown in Tables B-1, B-2 and B-3 resulted from the behavior and distribution of the plume observed upon start-up of the power plant. The predicted spatial extent of biological effects did not account for the spread of the plume throughout Diablo Cove and northward into Field's Cove (Table B-2). The spatial extent of early seasonal senescence of bull kelp surface fronds to the north of Diablo Cove in 1987, reported in the 1988 TEMP Final Report, remains the greatest distance effects have been observed. These effects probably resulted from the coincidence of DCPP two-unit discharge temperatures combined with El Niño conditions. Effects were not predicted to occur outside Diablo Cove but effects were observed in the intertidal habitat of Field's Cove immediately north of Diablo Cove. The decreased magnitude of the discharge-related effects in this area reported in the 1997 Analysis Report were first reported in the 1990 TEMP Annual Report after submittal of the 1988 TEMP Final Report. Although effects on iridescent seaweed were predicted in the TDAR in areas of potential thermal risk to the south of Diablo Cove, the timing or scale of effects were not predicted. The changes in Field's Cove for iridescent seaweed were less than the 50% mortality level from the thermal effects laboratory results used in developing the TDAR risk maps.

The nature and magnitude of the changes to intertidal communities in Diablo Cove, and to a lesser degree in areas outside the cove less frequently contacted by the plume, are another area of general disagreement between predicted and observed effects (Table B-2). It was originally predicted that few changes would occur in the intertidal as diurnal warming and tidal changes subject it to a wide range of air and seawater temperatures. The effects of the loss of iridescent seaweed, that provided a lush, abundant algal overstory in the intertidal, on the other components of the intertidal community could not have been predicted. The change in the intertidal to a algal grazer/filter feeder/algal turf-dominated community is likely the result of increased species interactions resulting from the loss of iridescent seaweed and increased availability of open space for recruitment. Subtidally, the loss of overstory and understory kelp species predicted in the TDAR and reported in the 1988 TEMP Final Report resulted in increased abundances of understory algae, not predicted in the TDAR. Many of the changes in invertebrate abundances in the subtidal were probably a result of increased predation pressures by fishes that increased after plant start-up. In contrast to predicted effects, affected areas did not become populated with large numbers of warm-water tolerant species.

The predictions reported in the TDAR were generally based on only individual species responses and did not include the types of effects caused by species interactions. Predictions of how individual species would respond to the increased water temperatures discharge were accurate for 16 of the 25 taxa listed in Table B-3. Predictions on four of the remaining taxa were unable to be verified because no changes were detected for them. Of the other five taxa, black abalone only began declining in 1988 after three years of plant operation as a result of withering syndrome disease-related mortalities. The causes of the differences between predicted and actual responses for black abalone and the other four taxa were all related to more complex ecological changes not directly related to increased seawater temperatures. The long-term nature of the monitoring data provided an opportunity to document the complexity of many of these ecological changes and adjustments within the areas affected by the DCPP discharge.

6.3.2 Other Ocean-Sited Power Plants

The conclusion that beneficial uses are protected by the DCPP thermal limit is consistent with the low impact potential ascribed to thermal discharges from ocean-sited power plants. The preference for ocean siting emerged from appraisals of the major potential impact of waste heat discharges that took place early in the history of thermal discharge regulation. During the early 1960's, a rapid rate of increase in electrical demand was projected to continue indefinitely. Larger generating units with increased cooling water flows were being built to meet this increasing demand. Early studies found that some of these were being built along streams that were too small to assimilate the thermal discharge without major ecological impacts. As a result waste heat was defined as a pollutant in the Federal Water Pollution Control Act of 1965. The major concerns that led to the inclusion of heat as a pollutant are reflected in federal water quality criteria documents issued for guidance to the States and other interested parties. In 1968, the National Technical Advisory Committee (NTAC) and in 1972, the National Academy of Sciences (NAS), identified four major concerns: blockage of the migration and free movement of species for spawning and other purposes, large mixing zones that damage the receiving water basin ecosystem, cold shock mortality of discharge-resident species from sudden temperature drops during power plant shutdown, and evaporative losses of water in areas of limited fresh water resources. A summary of information on ocean-sited power plants is presented in Table 6-1.

These theoretical considerations were supported by findings from early studies on the effects of thermal discharge conducted at operating power plants through the early 1970's. By 1975, the State Board adopted a policy preference for the ocean siting of power plants that is still in effect. The State Board based this preference in part on the apparent lower susceptibility of the coastal marine environment, relative to inland waters, to water quality impacts associated with power plant cooling. As the number of studies expanded through the mid- and late-1970's, the Utility Water Act Group funded a review of the effects of thermal discharges at ocean-sited power plants.[89] This report summarized the results of studies conducted at 17 ocean-sited plants with once-through cooling systems to determine impacts on the marine biota. The report concluded that:

- there were no significant adverse impacts on marine phytoplankton and zooplankton because the thermal discharge does not cause a shift toward nuisance plankton species nor does it alter the community structure and abundance;
- local reductions of attached habitat-forming organisms occurring in the immediate discharge area due to physical and thermal effects of the plume cause no harm to the balanced indigenous community, since habitat-formers outside this area were unaltered;
- there were no adverse impacts on marine shellfish/invertebrates since thermal plumes are buoyant in the ocean, thereby limiting the slight effects on these bottom dwelling organisms to the immediate discharge area;

[89] Yankee Atomic Electric Company. 1982. Effects of thermal discharges from ocean-sited power plants. Yankee Atomic Electric Company, Framingham, MA.

- there were no adverse impacts on fishes since discharge effects were limited to attraction and avoidance. There was no blockage of migration, and lethal effects were infrequent and inconsequential to the fish populations as a whole; and

- there were no adverse impacts to marine vertebrate wildlife since the areas of discharge at ocean-sited plants do not represent a limited or unique habitat for marine birds, reptiles or mammals, and discharges were not found to expose large populations of these species or act as a barrier to their migrations.

The findings from numerous studies at other operating power plants confirm the rationale for preferring the use of ocean discharges as a means of minimizing environmental impact.

6.3.3 Scope of Thermal Effects Studies

The conclusion that DCPP's thermal limits protect beneficial uses is also supported by an evaluation of the Diablo studies in reference to EPA guidance. The EPA drafted interagency technical guidance in 1974, 1975, and 1977 to assist dischargers in developing the necessary studies to assess the protection of BIC and to coordinate the environmental assessments required by the NRC under NEPA and by the EPA under the Clean Water Act.

Duration of DCPP Environmental Studies

The DCPP thermal effects studies were originally designed in accordance with the 316(a) guidance described above. The studies analyzed in this assessment span a period of almost 20 years, including 10 years of post-operational thermal effects monitoring. They are apparently the longest continuously conducted thermal effects studies at any power plant in the United States. In contrast to the majority of power plants across the United States, the regulatory determination of appropriate thermal limits at DCPP has been based on a series of assessments that progressively increased the level of assurance for the decision makers (Figure 6-1).

The assessment framework and methodology provide multiple sources of assurance to our finding that the DCPP water basin's beneficial uses have been protected from appreciable harm. Investigations of the DCPP discharge effects have followed a logical progression of discharge effects predictions (hypothesis), laboratory and field observations (testing), and analysis and assessment (hypothesis acceptance or rejection). In an applied sense, the weight of evidence from this scientific approach, as seen in the sequence of studies and assessments at DCPP (Figure 6-1) has facilitated a sequence of forecasting effects, regulatory decision-making, and monitoring effects to verify the forecast. Ecology remains an inexact science as a result of the enormous number and combinations of complex interactions of species and their environments. The predictive DCPP thermal impact assessments in the 1973 FES for the AEC and in the 1982 TDAR for the Regional Board provided sufficient basis for the Regional Board to conclude (and the State Board to uphold the decision) that marine habitat would be reasonably protected and to re-issue the DCPP NPDES permit.

In 1988, following start-up of DCPP, a third thermal impact assessment was made based primarily on effects from 1.5 years of plant operation. This assessment further increased the level of assurance by providing direct evidence of the type and extent of biological effects observed from the TEMP studies. The assessment once again provided a sufficient basis for the Regional Board to re-issue the DCPP NPDES permit, with a requirement for more monitoring data to provide continuing validation

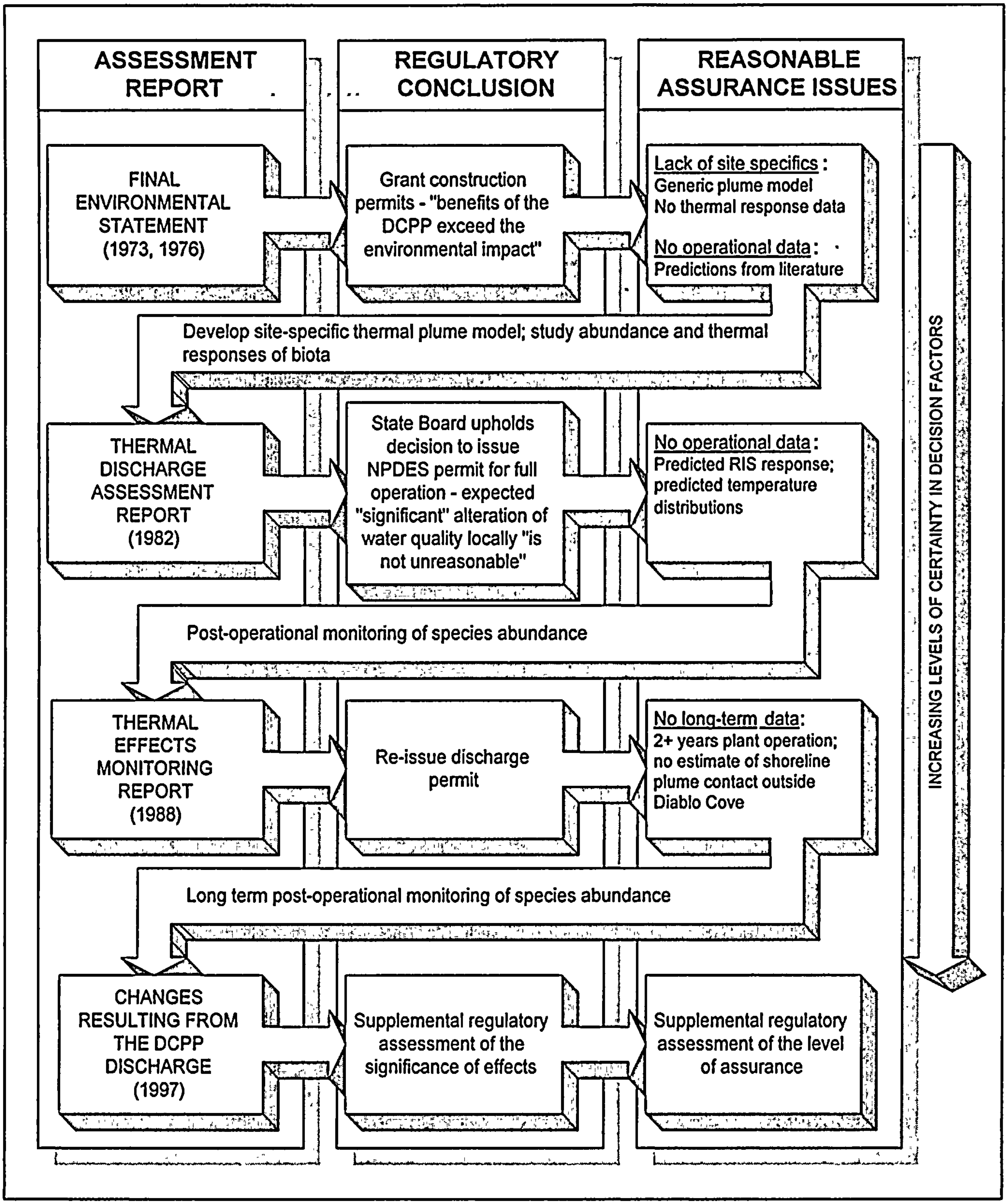

Figure 6-1. The progressive development of regulatory compliance assessments for the DCPP thermal discharge.

that the type and extent of effects from the plume do not threaten the beneficial use of marine habitat.

The current assessment is based on observed operational effects from DCPP monitored over a period of nearly one-third of the projected operational life of the plant, a study duration 5 to 6 times longer than typically required. The conclusions regarding the protection of beneficial use presented in this assessment provide a reasonable level of assurance for the compliance decision because:

- the major findings throughout the history of DCPP thermal discharge impact assessments are internally consistent (Section 6.3.1); and
- the issues of uncertainty raised by the Regional and State Boards have been progressively addressed in each stage of the assessment history described above.

DCPP Environmental Studies Exceed Requirements

The DCPP thermal discharge studies, beginning in the early 1970's with investigations of bull kelp temperature tolerance, have created one of the nation's most complete databases concerning thermal discharge effects in the marine environment. EPA 316(a) guidance for thermal effects studies identified three types of categorical study approaches and rationales (Type I, II and III), each related to various stages of power plant design, construction and operation. Since thermal discharge studies at DCPP have spanned all three facility-stages, the range and scope of DCPP thermal studies have exceeded the EPA's recommendations many times over. The EPA Type I demonstration is based almost entirely on empirical results from field studies that involve hydrothermal studies to determine the thermal characteristics of the mixing zone and biological sampling both in the area occupied by the thermal plume and at control stations to determine the actual effects of the plume. Typically the duration of these studies is one to two years. The Diablo studies combined EPA Type II and Type III demonstrations.

Type III predictive studies, as a part of DCPP early site selection and plant design efforts, modeled the discharge plume temperatures and behavior using state-of-the-art mathematical models. The inability of these mathematical models to accurately represent the complex shoreline discharge and nearshore environment led to the construction of a 1 to 75 scale physical model in a football field sized UC Berkeley hydraulic laboratory. During the same period, an onsite thermal-effects laboratory facility of similar dimensions was constructed to test the temperature tolerances of indigenous species using specimens obtained from the proposed discharge zone. The studies eventually examined the temperature tolerance of approximately 40 species; EPA guidance recommended targeting 3 to 5 representative, important species (RIS). The onsite laboratory investigations of many species included studies of temperature effects on reproduction, growth and developmental life stages, behavioral responses of temperature avoidance and attraction, and food selection and nutrition.

Type II field studies were conducted in discharge and reference areas to collect data on the abundance and distribution of the laboratory test species and associated marine habitat. These studies, that continue today as a part of the power plant's receiving water monitoring program, collected habitat specific information on a seasonally frequent basis for nearly 1,000 taxa. EPA guidance recommended that the discharger investigate a relatively small number of RIS, 3 to 5 species, in field studies to document pre-discharge baseline conditions.

The protracted DCPP licensing period extended the baseline survey period to nearly ten years from 1975 to commercial startup of Units 1 and 2 in 1985 and 1986, respectively. Analysis of the DCPP database allowed the statistical detection of relatively low-level population changes at a higher level of statistical confidence than monitoring studies with shorter durations. The size of the DCPP pre-operation baseline and operational data sets exceed EPA guidance for Type I assessment of existing thermal discharges. Data on continuing changes is still being collected.

Standards of Reasonable Assurance

The performance standard used by the EPA for implementation of guidelines for assessing BIC is that the best information and methods reasonably available should be used. Neither scientific certainty nor statistical precision is required, but data limitations are to be described and the resulting uncertainty described. It is generally accepted that scientific certitude is not possible when quantifying environmental impacts. Thus, EPA looks to 'reasonable assurance' as the basic standard of proof necessary to demonstrate compliance with the federal variance standard of protecting a balanced, indigenous community.[90] Further, EPA decisions support the premise that decisions on thermal discharges are to be made based on the "...best information reasonably obtainable..." and that the available information is sufficient if "...substantial uncertainty is avoided."[91] This approach may be summarized as requiring the discharger to present all relevant and reasonably obtainable data, account for any significant deficiencies, use available methodologies effectively, and provide a reasonable and well articulated basis for biological conclusions drawn by qualified scientists. Using EPA standards of 'reasonable assurance' the marine studies at DCPP provide the information necessary to support a finding of protection of beneficial uses.

6.4 Conclusions

The conclusion that the existing temperature limits of the DCPP discharge are protective of the receiving water's beneficial uses is based on the absence of ecologically significant discharge-related changes, the consistency of the findings with factors considered as part of the State Board's Order 83-1 and the consistency of the findings with other policies and decisions.

Absence of Ecologically Significant Changes

Although a number of discharge-related changes in the abundance and distribution of indigenous species has been observed, all of the changes are confined to Diablo Cove and its immediate vicinity. The majority of these changes were forecast as part of the power plant's history of licensing and permitting proceedings. Many of these predictions were confirmed in the previous 1988 assessment of discharge effects. A multi-agency review of the assessment's findings in 1989 concluded that more operational monitoring data was needed. The nearly eight years of additional monitoring data included in the 1997 Analysis Report provides further evidence that the power plant's discharge temperature limits are protective of the water basin's designated beneficial uses.

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[90] See e.g., Seacoast Anti-Pollution League v. Costle, 597 F.2d 306, 310 (1st Cir. 1979); Public Service Company of New Hampshire (Seabrook Station Units 1 and 2), NPDES Appeal No. 76-7 (Decision of Administrator), June 1977 ("Seabrook I); Public Service Company of New Hampshire (Seabrook Station Units 1 and 2), NPDES Appeal No. 76-7 (Decision of Administrator), August 1978 ("Seabrook II).

[91] Proposed NPDES Permit No. MA 0025135, Opinion of the Region I Administrator, March 1977 (Boston Edison, Pilgrim Units 1 and 2). The EPA Administrator refused to grant review in August of 1978.

The water basin used in the assessment is the coastal segment of Point Buchon to Point San Luis where DCPP is located. Based on comparisons with assessments at other power plants the selection of this area is very conservative. Our assessment determined that the beneficial uses within this coastal segment are fully protected by the power plant's discharge temperature limits based on the following evidence:

- There is no evidence of effects representing risk of impact to the beneficial uses identified in this assessment. The lack of ecologically significant effects in the area beyond Diablo Cove and its immediate vicinity is the primary evidence.
- Discharge effects in Diablo Cove, though somewhat more extensive than originally predicted, both in magnitude and extent, have not impacted the beneficial uses of the water basin.
- The observed discharge effects decline rapidly outside Diablo Cove. Most of the statistically significant effects in Field's Cove are substantially less than the 50% change used in the TDAR to identify possible effects. For example, the changes in percentage cover of algae in Field's Cove were approximately 10%.
- The discharge effects found in Diablo Cove and its immediate vicinity have not caused appreciable harm to the uses or services provided by its marine habitat.
- Losses of habitat-forming bull kelp in Diablo Cove have been compensated by increases in giant kelp, another species indigenous to the area.
- A wide variety of marine invertebrate taxa occupy space in Diablo Cove formerly occupied by intertidal algae.
- The diversity and abundance of fishes have increased in the presence of the discharge.
- Field observation and studies of the natural history of some of the indigenous species indicate that redundancy and resiliency in community components and function have been maintained.

Once the DCPP discharge source of heat is removed, receiving water temperatures in Diablo Cove and proximity will be immediately restored to ambient conditions, unlike other pollutants that remain in the environment (e.g. domestic waste discharges). Heat is recognized as a 'special pollutant' because of its non-conservative, non-toxic nature.

The results from TEMP studies have included the effects of several El Niño ocean-warming events that have documented the impact of natural temperature increases along the DCPP coastline. Although the re-establishment of populations in Diablo Cove and other areas following the cessation of the DCPP discharge is not certain, evidence from the El Niño events in the area of the discharge indicate that the process would take several years. Depending on the season and species affected, some restoration would begin immediately.

Consistency with Order 83-1

In 1983 the State Board issued a decision upholding the thermal discharge limits. The decision concluded that although some changes due to the discharge were predicted to occur, the predicted changes were not unreasonable. The decision utilized a balancing process in reaching its conclusion that was based on several factors that are still applicable when considering the reasonableness of the thermal limits. In reconsidering these factors we found that:

- The findings of the 1982 Alternatives Report are still valid that any alternative to the existing discharge would be either cost prohibitive, have adverse environmental consequences, or both.
- The area is not an Area of Special Biological Significance and therefore some level of change is acceptable.
- DCPP has been issued permits since the 1983 decision. During this period PG&E has continued to provide the Regional Board with information on the effects of the discharge
- CDF&G, the EPA, other government agencies and the public have been involved in the development and review of the 1997 Analysis Report.
- The discharge complies with the State Board's policy preference for the ocean-siting of power plants.
- The thermal limits are reasonable, when compared to the 20°F limit allowed for a new discharger, and are comparable to the thermal limits established at other power plants.

The balancing process required in the State Board's original decision must still be used in weighing these factors against the observed effects of the discharge. A reasonable balancing suggests that the thermal limits are still valid, because the effects do not threaten the protection of beneficial uses in the water body used for comparison and the effects are small compared to the economic value of Diablo Canyon's electrical power.

Consistency with Other Policies and Decisions

Several of the factors were evaluated in reaching the conclusion that beneficial uses are protected by the current discharge thermal limits. The additional information on these factors was provided to ensure that any decision regarding the discharge limits met the test of "reasonable assurance". These factors are a comparison of the predicted to observed effects; a comparison of the DCPP discharge to other ocean-sited power plants; and a discussion of the scope of the DCPP thermal studies.

The decision was partially based on the State Board accepting that the predicted effects of the discharge on marine communities were reasonable. Our analysis points out that the predictions on individual species responses were reasonably accurate, while the magnitude and spatial scale of the effects were not entirely accurate. The differences were primarily the result of inaccuracies in the predicted direction of the thermal plume that in turn affected the predicted magnitude and location of plume shoreline and bottom contact. The effects that have been detected in the intertidal areas outside Diablo Cove as a result of the differences in plume direction are much reduced from those observed in Diablo Cove. In many cases these effects were less than the 50% mortality level used in the thermal effects laboratory studies. The temperatures that resulted in 50% mortality were used in development of the TDAR risk maps. More importantly, our analysis shows that the ecological significance of the observed effects is small and does not threaten the protection of a BIC in the water body. This conclusion is supported by numerous studies at other power plants showing the absence of large adverse impacts on water quality as a result of thermal discharges to open coast marine environments.

The DCPP environmental studies used in supporting these conclusions far exceed EPA 316(a) guidance. The duration of the studies is 5 to 6 times longer than recommended. The studies have also been conducted under the review of the Regional Board staff and CDF&G and the current assessment process is conducted through a multi-agency committee consisting of representatives from federal, state and local agencies and the public. The Regional Board has also appointed two independent experts to assist in the development and review of the assessment reports. The strength of the current and past assessments contribute to providing the reasonable level of assurance required for concluding that the current DCPP discharge thermal limits protect the beneficial uses of the receiving waters.

This protection of beneficial uses conclusion is based on the fact that the observed effects are limited to Diablo Cove and its immediate vicinity and do not pose any ecological risk to the balanced indigenous community. The conclusion is further supported by an analysis of the factors used by the State Board in assessing the reasonableness of the thermal limits in Order 83-1. Additional information on observed effects, thermal limits at other power plants and the strength of the DCPP marine studies compared to other sites provides further evidence that the decision in 1983 upholding the existing thermal limits at DCPP was correct, and that the same decision is valid today.

APPENDIX A

Bibliography of DCPP Marine Environmental Studies, 1966-1998

The following is a bibliography of field and laboratory reports pertaining to marine environmental studies at DCPP. The reports are arranged by subject or by the publishing organization. Status reports of some studies were prepared on a quarterly basis, with the results compiled in final or annual reports. These quarterly reports are not included in this bibliography.

A.1 Thermal Effects Monitoring Program Reports

Thermal Effects Monitoring Program (TEMP) reports include reports done under various program titles including: 316(a) Demonstration, Marine Environmental Monitoring Program (MEMP), Ecological Monitoring Program (EMP), Thermal Effects Monitoring Program (TEMP) and Receiving Water Monitoring Program (RWMP). All reports below were submitted to the Regional Water Quality Control Board, as part of the DCPP NPDES marine monitoring requirements. The reports are listed chronologically.

Lockheed Marine Biology Laboratory. 1976. Diablo Canyon study report: field biological studies, a nine month report to Kaiser Engineers, Inc. October 1976.

PG&E. 1978. Pacific Gas and Electric Company 316(a) demonstration program field biology preoperational phase database summary, Vols. 1 and 2. Prepared by Lockheed Center for Marine Research, Carlsbad, CA. for Kaiser Engineers, Inc. April 1978.

PG&E. 1978. Diablo Canyon Power Plant 316(a) demonstration. Nine month progress report. Prepared by TERA Corp., Berkeley, CA. May 1978.

PG&E. 1979. Diablo Canyon Power Plant 316(a) demonstration. Nine month progress report. Prepared by TERA Corp., Berkeley, CA. February 1979.

1980 - No monitoring report published.

1981 - No monitoring report published.

1982 - No monitoring report published. Instead, the "Thermal Discharge Assessment Report" (PG&E 1982) was produced.

PG&E. 1983. Thermal effects monitoring program. 1982 Annual report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. January 1983.

PG&E. 1984. Thermal effects monitoring program. 1983 Annual report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. January 1984.

PG&E. 1985. Thermal effects monitoring program. 1984 Annual report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. March 1985.

PG&E. 1986. Thermal effects monitoring program. 1985 Annual report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. April 1986.

PG&E. 1987. Thermal effects monitoring program. 1986 Annual report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. May 1987. DCL-87-087.

PG&E. 1988. Thermal effects monitoring program. Final report. Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. April 1988. DCL-88-108.

PG&E. 1989. Diablo Canyon Power Plant. Marine environmental monitoring program. 1988 Annual report. Pacific Gas and Electric Company, San Francisco, CA. April 1989. DCl-89-119.

PG&E. 1990. Thermal effects monitoring program. 1989 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. April 1990. DCL-90-111.

PG&E. 1991. Thermal effects monitoring program. 1990 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. March 1991. DCL-91-069.

PG&E. 1992. Thermal effects monitoring program. 1991 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. March 1992. DCL-92-070.

PG&E. 1993. Thermal effects monitoring program. 1992 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. March 1993. DCL-93-067.

PG&E. 1994. Thermal effects monitoring program. 1993 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. March 1994. DCL-94-062. Addendum, DCL-94-081.

PG&E. 1995. Thermal effects monitoring program. 1994 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. March 1995. DCL-95-062.

PG&E. 1996. Ecological monitoring program. Summer/fall 1995 status report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, San Francisco, CA. February 1996. DCL-96-046.

PG&E. 1996. Ecological monitoring program. Status report. Winter 1995 and spring 1996 surveys. Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, San Francisco, CA. July 1996. DCL-96-544.

PG&E. 1997. Receiving water monitoring program. 1996 semi-annual status report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, San Francisco, CA. February 1997. DCL-97-513.

Tenera, Inc. 1997. Diablo Canyon Power Plant thermal effects monitoring program analysis report. Chapter 1. Changes in the marine environment resulting from the Diablo Canyon Power Plant thermal discharge. Prepared for Pacific Gas and Electric Company, San Francisco, CA. December 1997. DCL-97-600.

Tenera, Inc. 1998. Diablo Canyon Power Plant. Receiving water monitoring program. 1998 Winter-spring report. Prepared for Pacific Gas and Electric Company, San Francisco, CA. July 1998. DCL-98-557.

Tenera, Inc. 1998. Diablo Canyon Power Plant. Receiving water monitoring program. 1995-1997 progress report. Submitted to Pacific Gas and Electric Company, San Francisco, CA. August 1998. DCL-98-561.

A.2 Predictive Analyses and Evaluation Reports

The reports in this category were prepared by various organizations and are listed chronologically.

PG&E. 1971. Environmental report, units 1 and 2, Diablo Canyon site. AEC dockets 50-275, 50-323. July 1971; PG&E, environmental report supplement nos. 1-8 (1971-76).

United States Atomic Energy Commission Directorate of Licensing. 1973. Final Environmental Statement related to the nuclear generating station Diablo Canyon units 1 & 2, May 1973 (docket nos. 50-275 and 50-323); NRC Office of Nuclear Reactor Regulation, addendum to the final environmental statement for the operation of the Diablo Canyon Nuclear Plant units 1 and 2 (May 1976) (docket nos. 50-275 and 50-323).

Brown, C.A., R.A. Molina, G.A. Jacoby, and P.M. Maroney. 1974. Effluent control systems. Diablo Canyon Nuclear Power Plant. Preliminary study based on EPA's proposed effluent limitation guidelines and standards of March 4, 1974. Kaiser Engineers. Prepared for Pacific Gas and Electric Company. July 1974.

PG&E. 1982. Thermal discharge assessment report. Diablo Canyon Power Plant. Prepared by TERA Corp., Berkeley, CA. March 1982.

PG&E. 1982. Assessment of alternatives to the existing cooling water system. Diablo Canyon Power Plant. Prepared by TERA Corp., Berkeley, CA. April 1982.

PG&E. 1985. Environmental evaluation of heat treatment thermal discharges. Diablo Canyon Power Plant. Prepared by TERA Corp., Berkeley, CA. July 1985.

A.3 NPDES Influent/Effluent Monitoring Reports

DCPP influent/effluent monitoring reports are submitted to the Regional Water Quality Control Board as required in the power plant's NPDES permit. All reports are prepared by PG&E and are titled "Discharge Monitoring and Reporting Program, Diablo Canyon Power Plant - NPDES No. CA0003751". The first Waste Discharge Requirements for DCPP were issued in October 1969. The first monthly report was submitted in February 1975. From 1983 to 1990 the NPDES reports were submitted monthly with an annual summary. From 1991 to 1998 the reports were submitted quarterly with an annual summary. The reports contain data on intake and discharge temperatures, discharge flows, and sampling results for discharge constituents, which includes heavy metals, ammonia, pH, chlorine, toxicity, oil and grease, suspended solids, and settleable solids. Sampling frequency and sampling locations have changed over time in accordance with influent and effluent monitoring requirements in the NPDES permit. The reports also included Receiving Water Monitoring information (e.g. stratified water temperatures, pH, dissolved oxygen measurements, surface thermal plume mapping, and status of completions of kelp overflight photographic surveys). Sampling frequency, sampling locations, and duration of these tasks changed over time in accordance with Receiving Water Monitoring requirements in the NPDES permit. As of 1995, all Receiving Water Monitoring results have been reported separately in Receiving Water Monitoring reports submitted to the Regional Water Quality Control Board.

A.4 Annual Environmental Operating Reports

Annual Environmental Operating Reports are submitted to the Nuclear Regulatory Commission (NRC) as required in the power plant's operating license. Reports are prepared by PG&E and are titled "[Year] Annual Nonradiological Environmental Operating Report." The first report was submitted in 1981. The reports include summaries of receiving water and NPDES monitoring, terrestrial monitoring, archaeological resources preservation activities, unusual or important environmental events, power plant design changes, and non-routine environmental reports. Additionally, though not required by the NRC, the reports contain results from the DCPP Endangered Species Monitoring Program. The species include sea otters, gray whales, peregrine falcons, brown pelicans, and elephant seals. Gray whale monitoring was discontinued in 1995, after this species had been removed from the list of federally endangered species and placed on the list of protected species. Sea turtles have been reported as unusual occurrences of a species protected under the Endangered Species Act.

A.5 Wheeler J. North Studies

Dr. Wheeler J. North and associates conducted marine biological studies at DCPP from 1967 to 1987. Periodic status reports of the monitoring studies were published in the Environmental Investigations at Diablo Canyon reports prepared by PG&E and submitted to the Regional Water Quality Control Board (see Section A.10).

North, W.J. 1969. An evaluation of the marine flora and fauna in the vicinity of Diablo Cove, California. Marine Advisors, La Jolla, CA. p. 1097-1128.

North, W.J. and E.K. Anderson. 1973. Anticipated biological effects from heated effluents at Diablo Cove. Dept. Eng. Res., Pacific Gas and Electric Company, San Francisco, CA.

North, W.J., E.K. Anderson, and F.A. Chapman. 1989. Wheeler J. North ecological studies at Diablo Canyon Power Plant. Final Report, 1967-1987. Pacific Gas and Electric Company, San Francisco, CA.

A.6 California Department of Fish and Game Reports

The earliest marine investigations in the vicinity of Diablo Canyon were conducted by the California Department of Fish and Game (CDF&G) (Ebert, 1966). Additional monitoring studies of intertidal and subtidal biota were conducted from 1973 to 1982. Results from the monitoring studies were included as chapters, compiled by PG&E in the Environmental Investigations at Diablo Canyon reports (Section A.10). All Environmental Investigations at Diablo Canyon reports were submitted to the Regional Water Quality Control Board. Results from the CDF&G monitoring studies were reported in two comprehensive reports (Gotshall, et al., 1984, 1986). The state mussel watch program for trace metal monitoring at DCPP has been conducted from 1984 to present (see Martin, et al., 1985, for example report).

Ebert, E.E. 1966. An evaluation of marine resources in the Diablo Canyon area, May 2-4, 1966. MRO Ref. No. 66-10. Calif. Dept. Fish Game, Special Study.

Burge, R.T. and S.A. Schultz. 1973. The marine environment in the vicinity of Diablo Cove with special reference to abalone and bony fishes. Calif. Dept. Fish Game, Mar. Res. Tech. Rpt. No. 19.

Martin, M.M., D. Stephenson, and J.H. Martin. 1977. Copper toxicity experiments in relation to abalone deaths observed in a power plant's cooling waters. Calif. Dept. Fish Game 63:95-100.

Gotshall, D.W., L.L. Laurent, S.L. Owen, J. Grant, and P. Law. 1984. A quantitative ecological study of selected nearshore marine plants and animals at the Diablo Canyon Power Plant site: a pre-operational baseline: 1973-1978. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 48.

Martin, M., M. Stephenson, D. Smith, J. Linfield, G. Ichikawa, J. Goetzel, J. Bennett, S. Eastman, and M. Manera. 1985. Diablo Canyon Nuclear Power Plant outfall monitoring report. State Mussel Watch Progr. Prelimin. Data Rpt. 1984-1985. Calif. Dept. Fish Game. 19 pp.

Gotshall D.W., J.R.R. Ally, D.L. Vaughn, B.B. Hatfield, and P. Law. 1986. Pre-operational baseline studies of selected nearshore marine biota at the Diablo Canyon Power Plant site: 1979-1982. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 50.

A.7 DCPP Thermal Effects Laboratory Reports

Laboratory thermal tolerance studies for over 30 marine species of algae, invertebrates, and fish were conducted by Tenera Environmental Services (previously TERA Corp.). Numerous status reports were published that included experimental results, methods, and quality assurance.

PG&E. 1979. Diablo Canyon Power Plant 316(a) demonstration. Nine month progress report. Prepared by TERA Corp., Berkeley, CA. February 1979.

PG&E. 1979. Diablo Canyon Power Plant 316(a) demonstration. Nine month progress report. Prepared by TERA Corp., Berkeley, CA. November 1979.

PG&E. 1980. Diablo Canyon Power Plant 316(a) demonstration. Nine month progress report. Prepared by TERA Corp., Berkeley, CA. August 1980.

PG&E. 1982. Compendium of thermal effects laboratory studies, Vols. 1, 2, and 3. Pacific Gas and Electric Company Rep. B-81-403, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. April 1982.

A.8 Plume Modeling and Oceanographic Reports

Thermal plume modeling and oceanographic studies were conducted by PG&E's Department of Engineering Research to describe hydraulic characteristics of the DCPP discharge plume in relation to local oceanographic conditions. Bathythermograph surveys were also conducted to map the extent of surface plume isotherms as part of the plant's NPDES permit. Surveys were conducted bi-monthly from August 1986 to April 1990. Results from the surveys were submitted in quarterly and annual influent/effluent monitoring reports to the Regional Water Quality Control Board. Aerial infra-red photographic surveys of the surface thermal plume were conducted for thermal verification of the physical model and the far-field numerical model, as part of an NRC requirement. Results from the aerial infra-red surveys were also used to verify dilution factor and bathythermograph studies of the plume. Several physical oceanographic reports not listed in this section appear in Section A.10, Environmental Investigations at Diablo Canyon.

Babcock, J.D., P.J. Ryan, S.W. Tu, and V. Wyman. 1987. Hydraulic model study quality assurance requirements. Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.17. May 1987.

Borgman, L.E. 1982. Extremal analysis of wave hindcasts for the Diablo Canyon area, California made by Mr. R. Rea Strange III. Oceanweather, Inc. Prepared for Omar J. Lillevang, Whittier, CA. December 1982. 130 pp. and appendices.

Borgman, L.E. 1982. Extremal analysis of wave hindcasts for the Diablo Canyon area, California made by Dr. Don Resio. A companion report to Extremal analysis of wave hindcasts for the Diablo Canyon area, California made by Mr. R. Rea Strange III.: Oceanweather, Inc. Prepared for Omar J. Lillevang, Whittier, CA. December 1982. 142 pp.

Findikaki, I.T. 1986. Documentation and user's manual of the software for the statistical analysis and comparative evaluation of field and hydraulic model temperature data in the vicinity of the Diablo Canyon thermal outfall. Submitted to Bechtel Inc., San Francisco, CA. Prepared for Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. February 1986.

Findikaki, I.T. 1986. Statistical analysis and comparative evaluation of field and hydraulic model water temperature data in the vicinity of the Diablo Canyon thermal outfall. Submitted to Bechtel Inc., San Francisco, CA. Prepared for Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. February 1986.

Leighton, J.P. 1988. Comparison of the effects of heat treatment and full load operation on receiving water temperatures. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.760. January 1988.

Leighton, J.P. 1988. Comparison of the effects of heat treatment and full load operation on receiving water temperatures at Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420DC-87.760. January 1988.

Leighton, J.P. 1988. Estimation of the dilution factor for the Diablo Canyon Power Plant thermal discharge plume. Technical and Ecological Services, Report No. 028.282-88.2, Pacific Gas and Electric Company, Technical and Ecological Services, San Ramon, CA. February 1988.

Leighton, J.P., C.O. White, and S.W. Tu. 1990. Far-field stratification of a buoyant jet. pp. 137-144 *in* Huatong, W., W. Jingyong, and D. Hua (eds.), Physics of shallow seas. China Ocean Press, Beijing, China.

Leighton, J.P., S.W. Tu, A.A. Petroccitto and L.K. Eastman. 1986. Characterization of receiving water temperatures during power ascension testing of Unit 1, Diablo Canyon Power Plant. Report No. 420-85.748. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. March 1986.

Meek, R.P. 1988. Diablo Canyon continuous current measurements, July 1986 through June, 1987. Prepared by Robert P. Meek, ECOMAR, Inc., Goleta, CA.

Resio, D.T. 1982. Report on wave climatology for Diablo Canyon, California. Oceanweather, Inc. June 1982. 97 pp.

Ryan, P.J. S.W. Tu, J.P. Leighton, and R.L. Wiegel. 1986. Hydraulic model verification tests for unit 1 Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-86.557. November 1986.

Ryan, P.J., N. Ismail, R. Lou, S.W. Tu, and R.L. Wiegel. 1987. Hydraulic model verification tests for units 1 and 2 Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.15. April 1987.

Ryan, P.J., N. Ismail, R.C.H. Lou, S.W. Tu, and R.L. Wiegel. 1987. Hydraulic model verification tests for Units 1 and 2, Diablo Canyon Power Plant. Tech. Rpt. HEL 27-17, HEL, UCB.

Ryan, P.J., R. Kloepper, N. Ismail, S.W. Tu, and R.L. Wiegel. 1987. Hydraulic model tests for heat treatment conditions at Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.16. April 1987.

Safaie, B. 1986. Study of nearshore current in the vicinity of Diablo Canyon, California. Prepared for Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. June 1986.

Strange, R.R.III. 1982. A hindcast of severe storm waves at Diablo Canyon, California. Pacific Weather Analysis. Prepared for O.J. Lillevang. 43 pp.

Tu, S. 1990. Diablo Canyon Power Plant offshore thermal plume numerical model study, a video report. Pacific Gas and Electric Company, Technical and Ecological Services, San Ramon, CA. February 1986.

Tu, S.W. 1989. Numerical model simulation of Diablo Canyon Power Plant far-field thermal plume. Pacific Gas and Electric Company, San Ramon, CA. Report 420-DC-89.441. August 1989.

Tu, S.W. and D.S. Trent. 1989. Verification of Diablo Canyon Power Plant far-field thermal plume numerical model. Pacific Gas and Electric Company, San Ramon, CA. Report 420-DC-89.303. August 1989.

Tu, S.W., J.P. Leighton, C.O. White, and C.C. Hsu. 1986. Surface buoyant jet characteristics of the thermal discharge plume at Diablo Canyon Power Plant. A field study of power ascension testing of unit 2 and full load operation of unit 1. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-86.475. November 1986.

Wiegel, R.L. and M.J. Doyle. 1987. Cooling by ocean water: model/field comparison. Shore and Beach. July-October 1987. pp. 38-53.

Wiegel, R.L., V.W. Harms, B. Safaie, J.D. Cumming, R.P. Della, C.B. Leidersdorf, and C. Young. 1976. Report on model study of cooling water system of Pacific Gas and Electric Company Nuclear Power Plant at Diablo Canyon, California. Report no HEL 27-2, Hydraulic Engineering Lab., University of California at Berkeley, California.

Wiegel, R.L., V.W. Harms, B. Safaie, R.P. Della, and C.B. Leidersdorf. 1975. A preliminary report on model study of cooling water system of Pacific Gas and Electric Company Power Plant located at Diablo Canyon, California. Hydraulic Engineering Lab., University of California at Berkeley; also PG&E docket no. 50-275-02 and 50-323-02, Supplement no. 7.

A.9 316(b) Demonstration Studies

Entrainment and impingement studies have been conducted at DCPP as part of the Section 316(b) requirement. Studies focusing on larval fishes, crabs, and sea urchins are continuing.

PG&E. 1988. Cooling water intake structure 316(b) demonstration. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. April 1988.

Russell, B. and C.H. Hanson. 1988. Seasonal abundance and distributional patterns of larval fish in the vicinity of the Diablo Canyon Power Plant, 1986-1987. Prepared for Pacific Gas and Electric Company, San Francisco, CA. June 1988.

Tenera, Inc. 1997. Diablo Canyon Power Plant 316(b) demonstration study: phase 1-entrainment study design, part I-sampling location. Prepared for Pacific Gas and Electric Company, San Francisco, CA. DCL-97-568.

Tenera, Inc. 1997. Diablo Canyon Power Plant 316(b) demonstration study: phase 1-entrainment study design, part II- selection of target organisms, sampling methods, and gear testing. Prepared for Pacific Gas and Electric Company, San Francisco, CA. DCL-97-601.

Tenera, Inc. 1997. Diablo Canyon Power Plant 316(b) demonstration study: quarterly report - January 1, 1998. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera, Inc. 1998. Diablo Canyon Power Plant 316(b) demonstration study: quarterly report - April 1, 1998. Prepared for Pacific Gas and Electric Company, San Francisco, CA. DCL-98-525.

Tenera, Inc. 1998. Diablo Canyon Power Plant 316(b) demonstration study: quarterly report - 2nd quarter 1998. Prepared for Pacific Gas and Electric Company, San Francisco, CA. DCL-98-543.

Tenera, Inc. 1998. Diablo Canyon Power Plant 316(b) demonstration study: quarterly report - third quarter 1998. Prepared for Pacific Gas and Electric Company, San Francisco, CA. DCL-98-571.

A.10 Environmental Investigations at Diablo Canyon

Environmental Investigations at Diablo Canyon is a series of 18 reports produced by PG&E's Department of Engineering Research. Each report contains chapters that describe results from various DCPP marine field and laboratory studies conducted by PG&E from 1969 to 1987.

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Waters, B.F. 1972. Abalone transplants. Chapter IV *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

Warrick, J.W. 1972. Radiological collections. Chapter V *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

Warrick, J.W. 1972. Biological Studies by California State Polytechnic College. Chapter VI *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

CDF&G. 1972. Diablo Canyon ecological survey. Chapter VII *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

North, Dr. W.J. and J.R. Adams. 1974. Studies planned for 1972. Chapter VIII *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

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Warrick, J.W. 1974. Bull Kelp Studies. Chapter IV *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Icanberry, J.W. and J.R. Adams. 1974. Zooplankton Studies. Chapter V *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Adams, J.R. and D.G. Price. 1974. Thermal shock tolerances of larval red abalone (*Haliotis rufescens*). Chapter VI *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Adams, J.R. 1974. Thermal tolerance of adult red abalone. Chapter VII *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Hurley, J.F. 1974. Abalone: An annotated bibliography. Chapter VIII *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Fairbrother, K. 1974. Diablo Canyon breakwater studies. Chapter IX *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

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A.11 Additional Reports and Publications

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APPENDIX B

Synopsis of Comparisons of Predicted and Observed Biological Effects

Table B-1. Synopsis of comparisons of predicted and observed biological effects: community overview.

Subject	Zone	Predicted Effects	Observed Effects	Comments
Community Overview	Intertidal and Subtidal:	All changes confined to Diablo Cove Most effects in the subtidal Certain algae, invertebrates, and fishes expected to decline Replacement by warm-water tolerant forms	Most intertidal effects confined to Diablo Cove Algal cover and diversity decreased, and grazers and bare space increased (not predicted) Diminishing intertidal effects outside Diablo Cove at South Diablo Point and in Field's Cove (not predicted) Most subtidal effects confined to Diablo Cove Main algal change was decrease in bull kelp and increase in giant kelp (predicted) Algal changes confined to Diablo Cove, except for bull kelp effects that could extend to Lion Rock (predicted) Invertebrates with southern California distributions became more common (predicted) Urchin barrens formed in Diablo Cove (not predicted) Fish diversity increased with the introduction of warm water forms and increases occurred in bat rays and leopard sharks (not predicted)	Observed changes generally matched predictions in terms of species effects, but areas of effects were larger than predicted Intertidal effects involved more species over larger areas than predicted, and resulted in a more simplified intertidal community in Diablo Cove Subtidal community complexity largely maintained despite changes in species abundances due to the discharge Transition zones of diminishing effects for algae were more apparent than effects for invertebrates and fishes Changes were observed in a greater number of species than considered in predictions, but predictions included general types of changes applicable to many species (e.g. changes in ecologically functional groups) Changes are likely to continue as species in the replacement community interact

Table B-2. Synopsis of comparisons of predicted and observed biological effects: community characteristics and spatial extent.

Attribute	Zone	Predicted Effects	Observed Effects	Comments
Types of Species	Intertidal and Subtidal	Loss of some cold water forms and increase in some warm water forms Filter feeding invertebrates expected to increase in Diablo Cove	Loss of some cold water forms and increase in eurythermal forms, plus increase in some extant warm water forms Intertidal barnacles increased (one ecological component of filter feeder trophic guild)	Most changes involved shifts in the distribution and abundance of species already living in Diablo Cove Increases in some invertebrates and fishes that are more common in southern California increased Predicted change from cool-temperate community to warm-temperate community did not occur
Areas Affected	Intertidal	Effects expected along southern shoreline of Diablo Cove - a distance of ~ 1.1 km*	Effects spread over total shoreline of Diablo Cove: 2.2 km** Reduced effects over shorelines immediately north and south of Diablo Cove (South Diablo Point and Field's Cove): 1.5 km**	Description of thermal regimes and potential effects outside Diablo Cove were not included in modeling and predictive studies An additional 3.0 km of shoreline north and south is intermittently contacted by the discharge. No effects have been observed in these areas **
Areas Affected	Subtidal	Effects expected primarily in south Diablo Cove - an area of 4-6 ha*	Effects spread throughout Diablo Cove Algae: 8.1 ha (the area in Diablo Cove with depths < 7 m)** Invertebrates and fishes: 16.4 ha (the entire area of Diablo Cove)**	Transition areas with reduced effects were fairly well defined for algae (i.e., effects appeared to be confined to Diablo Cove) Additional area of possible effects that would be reduced in comparison to effects in Diablo Cove Algae: 39.5 ha (includes deeper areas of Diablo Cove and areas to the north) where plume contact can occur** Invertebrates and fishes: 31.1 ha (mainly areas to the north of Diablo Cove) where plume contact can occur **
Magnitude of Impact	Intertidal	Few changes expected in Diablo Cove	Community change throughout Diablo Cove that consisted of a shift from a foliose algal community to a grazer/turf algae/bare space community Effects to algae diminished outside Diablo Cove (South Diablo Point and Field's Cove)	More changes occurred in the intertidal than predicted Basis of prediction was that intertidal species would be tolerant of plume temperatures (vs. subtidal species)
Magnitude of Impact	Subtidal	Shift to community dominated by warm water species	Algae: Shifts involved changes in abundance of species already present in Diablo Cove and not the introduction of new species Shift in kelp dominance from bull kelp to giant kelp. Bull kelp affected outside Diablo Cove Invertebrates: More frequent occurrences of species common to southern California Fishes: Redistribution of species in Diablo Cove from avoidance and attraction to warm water and greater incidence of species common to southern California	The changes in species composition were not so extensive that the cool-temperate marine community was completely replaced by a warm-temperate marine community Algae: effects diminished immediately outside Diablo Cove except for bull kelp Invertebrates and fishes: transition zones of effects not identified

* - shoreline distances and areas estimated from TDAR risk maps; these are estimates of habitat and not the distribution of a species
** - shoreline distances and areas from 1997 TEMP Analysis Report; these are estimates of habitat and not the distribution of a species

(Table Continued)

Table B-2 (continued). Synopsis of comparisons of predicted and observed biological effects: community characteristics and spatial extent.

Attribute	Zone	Predicted Effects	Observed Effects	Comments
Number of Species Impacted	Intertidal and Subtidal	Not predicted	Of 370 species analyzed, statistically significant increases and decreases in abundance were detected in 63% in areas affected by the discharge	The total number of species analyzed included taxa groups that combined data from several species Some species and taxa may have been analyzed in both the intertidal and subtidal data sets and from more than one sampling method Most changes occurred in Diablo Cove, but: Intertidal: some effects were detected in Field's Cove and at South Diablo Point Subtidal: effects outside Diablo Cove where plume contact can occur where not statistically analyzed due to the absence of data in those areas
Temporal Change	Intertidal and Subtidal	Changes expected to continue for several years	Changes in Diablo Cove continued throughout study	Areas outside Diablo Cove not analyzed for continuing community changes
Productivity	Intertidal and Subtidal	Seaweed production may increase	Not studied	May have increased due to increases in giant kelp

Table B-3. Synopsis of comparisons of predicted and observed biological effects on 25 common species of algae, invertebrates and fishes.

Algae

Species	Zone	Predicted Effects	Observed Effects	Comments
Iridescent Seaweed	Intertidal	Decrease: An area of 1.4 ha mainly in south Diablo Cove* Possible effects in 0.5 ha outside Diablo Cove (to the south) where physical model data was not available*	Decreased: 2.2 km (decreased to absence along entire shoreline of Diablo Cove)** 1.5 km (reduced effects along shoreline immediately north and south of Diablo Cove)**	This alga is considered to be the best indicator for delineating areas of intertidal effects An additional 3.0 km of shoreline north and south is intermittently contacted by the discharge. No effects have been observed in these areas **
Surfgrass	Intertidal and Subtidal	Decrease: 1.1 ha mainly in south Diablo Cove*	Decreased: 1.9 ha (the estimated area of surfgrass loss in Diablo Cove)	Intertidal and subtidal stations monitored the upper and lower fringes of the surfgrass zone Observed effects based on special surveys and results presented as a supplemental report to the Analysis Report
Bull Kelp	Subtidal	Population decrease: 0.6 ha (directly in front of outfall)* 11.3 ha (portion of Diablo Cove)* possible effects in 2.5 ha outside Diablo Cove where physical model data do not exist* Canopy decrease: 0.7 ha (directly in front of outfall)* 15.5 ha (remainder of Diablo Cove)* possible effects in 4.5 ha outside Diablo Cove where physical model data do not exist*	Population decreased: 8.1 ha (subtidal area of Diablo Cove and north Diablo Point shallower than 4 m)** Canopy decreased: 23.0 ha (includes population losses in Diablo Cove [8.1 ha] in addition to 14.9 ha of canopy losses to the north under typical ocean temperature conditions)** 19.3 ha (additional area to the north during warmer temperatures during 1987 El Niño)**	Annual recruitment in Diablo Cove and north Diablo Point headland restricted to depths > 7 m Subtidal bull kelp plants growing into warm surface waters are affected by 'premature senescence', characterized by early canopy (frond) losses Relationship between early canopy losses and population abundance (remaining plant material and recruitment) not studied Additional area of intermittent surface plume contact where reduced effects could occur: 68.7 ha**
Giant Kelp	Subtidal	Increase: No risk map in TDAR, but predicted to increase	Increased: 17.5 ha (all of Diablo Cove)**	Largest change in subtidal algae in Diablo Cove was the replacement of bull kelp, tree kelp, oar-blade kelp, and bladder chain kelp with giant kelp
Oar-blade Kelp	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Decreased: 8.1 ha (the subtidal area in Diablo Cove with depths of < 7 m)*	No observed effects in Diablo Cove at depths > 7 m The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 39.5 ha**

* - shoreline distances and areas estimated from TDAR risk maps; these are estimates of habitat and not the distribution of a species
** - shoreline distances and areas from 1997 TEMP Analysis Report; these are estimates of habitat and not the distribution of a species

(Table Continued)

Table B-3 (continued). Synopsis of comparisons of predicted and observed biological effects on 25 common species of algae, invertebrates and fishes.

Algae

Species	Zone	Predicted Effects	Observed Effects	Comments
Tree Kelp	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Decreased: 8.1 ha (the subtidal area in Diablo Cove with depths of < 7 m)**	No observed effects in Diablo Cove at depths > 7 m The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 39.5 ha**
Bladder Chain Kelp	Subtidal	Increase	Decreased: 8.1 ha (the subtidal area in Diablo Cove with depths of < 7 m)**	Plants decreased on the stations, but remained abundant in many other areas of Diablo Cove The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 39.5 ha**
foliose red alga *(Cryptopleura rupretchiana)*	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Decreased: 8.1 ha (the subtidal area in Diablo Cove with depths of < 7 m)**	Formerly referred to as *Botryoglossum farlowianum* No observed effects at depths >7 m in Diablo Cove Species replaced in affected habitat by *C. violacea* The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 39.5 ha**
foliose red alga *(Mazzaella lilacina)*	Subtidal	Recruitment impaired: No risk map in TDAR, but expected to be affected in an area of 5.5 ha in Diablo Cove	Recruitment not measured or analyzed Test results on adults inconclusive	Formerly referred to as *Iridaea cordata*

Invertebrates

Species	Zone	Predicted Effects	Observed Effects	Comments
Black Abalone	Intertidal	Not at risk	Decreased (from withering syndrome): Shoreline distance of main incidence of WS: 3.9 km (shoreline distance from the outfall)** Shoreline distance of reduced incidence of WS: 8.8 km**	WS found at Channel Islands, Vandenberg, and Cayucos, CA, unrelated to power plant operation Recruitment in the study area has been observed, but no information on how long recruits live in areas with WS FES predicted losses of 110,000 black abalone as a result of decreases in algae and increases in sea urchin grazing

* - shoreline distances and areas estimated from TDAR risk maps; these are estimates of habitat and not the distribution of a species

** - shoreline distances and areas from 1997 TEMP Analysis Report; these are estimates of habitat and not the distribution of a species

(Table Continued)

Table B-3 (continued). Synopsis of comparisons of predicted and observed biological effects on 25 common species of algae, invertebrates and fishes.

Invertebrates

Species	Zone	Predicted Effects	Observed Effects	Comments
Red Abalone	Subtidal	Decrease: 4.2 ha (mainly in south Diablo Cove near the discharge)**	Decreased 11.5 ha (the subtidal area in Diablo Cove with depths of ≤ 8 m)**	Decreases related to WS No observed effects outside Diablo Cove FES addendum stated that Diablo Cove would not be a viable habitat where the thermal plume remains in contact with the bottom Possible reduced effects at depths > 8 m in Diablo Cove: 4.9 ha**
Purple Sea Urchin	Intertidal and Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-third of Diablo Cove, an intertidal shoreline distance of 0.7 km and an area of 5.5 ha in the subtidal	Increased: Intertidal: 2.2 km (entire shoreline of Diablo Cove)** 1.5 km (shoreline distance of South Diablo Point and Field's Cove)** Subtidal: 16.4 ha (entire subtidal area of Diablo Cove)** Urchin barrens in 0.9 ha in Diablo Cove that covered low-intertidal / shallow-subtidal**	One of three species that did not respond as predicted Increases resulted in formation of urchin barrens in north Diablo Cove An additional 3.0 km of shoreline north and south is intermittently contacted by the discharge. No effects have been observed in these areas ** The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 31.1 ha**
White-cap Limpet	Intertidal and Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-third of Diablo Cove, a shoreline distance of 0.7 km and an area of 5.5 ha in the subtidal	Increased: Intertidal: Unknown Subtidal: Increased: 16.4 ha (entire subtidal area of Diablo Cove)**	Intertidal abundances not analyzed due to low abundance in the pre- and operation study periods One of three species that did not respond as predicted Increases extrapolated to all of subtidal Diablo The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 31.1 ha**
Lined Chiton	Intertidal and Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-third of Diablo Cove, a shoreline distance of 0.7 km and an area of 5.5 ha in the subtidal	Intertidal: not analyzed Subtidal: no significant change	Intertidal abundances not analyzed due to low abundance in the pre- and operation study periods
Brown Rock Crab	Subtidal	Decrease: 1.2 ha (an area in front of the discharge and in south Diablo Cove)*	Benthic monitoring data inconclusive Rock crabs were studied under a special crab trapping study which showed that this species decreased in shallow areas of Diablo Cove after power plant start-up (PG&E 1988)	Crab trapping study ended in 1987

* - shoreline distances and areas estimated from TDAR risk maps; these are estimates of habitat and not the distribution of a species
** - shoreline distances and areas from 1997 TEMP Analysis Report; these are estimates of habitat and not the distribution of a species

(Table Continued)

Table B-3 (continued). Synopsis of comparisons of predicted and observed biological effects on 25 common species of algae, invertebrates and fishes.

Invertebrates

Species	Zone	Predicted Effects	Observed Effects	Comments
Kelp Crab	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Decreased: 16.4 ha (all of Diablo Cove)**	Decreases extrapolated to all of Diablo Cove The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 31.1 ha**
Brown Turban Snail	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Decreased: 16.4 ha (all of Diablo Cove)**	Decreases extrapolated to all of Diablo Cove The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 31.1 ha**
Sunflower Star	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Decreased: 16.4 ha (all of Diablo Cove)**	Decreases extrapolated to all of Diablo Cove The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 31.1 ha**

Fishes

Species	Zone	Predicted Effects	Observed Effects	Comments
Rock Prickleback	Intertidal	Decrease - No risk map in TDAR, but expected to be affected in less than half of Diablo Cove, a shoreline distance of 1.1 km	Decreased: 2.2 km (entire shoreline of Diablo Cove)** 1.5 km (shoreline distance of South Diablo Point and Field's Cove)**	Reference 'control' station used in analysis was located in Field's Cove, an area intermittently contacted by the plume An additional 3.0 km of shoreline north and south is intermittently contacted by the discharge. No effects have been observed in these areas **
Cabezon	Subtidal	Adult decrease: 1.6 ha (portion of Diablo Cove)* Nest area decrease: 0.6 ha (portion of Diablo Cove)*	Adults decreased: 8.2 ha (the subtidal area of Diablo Cove < 7 m in depth)** Nest area effects not reported	One target species of the local live rockfish fishery
Blue Rockfish	Subtidal	Decrease: 0.6 ha	Test results inconclusive for young-of-year (YOY) Adult abundances increased in south Diablo Cove, but results based on limited abundance data	Long-term decreases in population occurred in both Diablo Cove and control areas
Olive Rockfish	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Increased: 8.2 ha (the subtidal area of Diablo Cove < 7 m in depth)**	The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 31.1 ha**

* - shoreline distances and areas estimated from TDAR risk maps; these are estimates of habitat and not the distribution of a species
** - shoreline distances and areas from 1997 TEMP Analysis Report; these are estimates of habitat and not the distribution of a species

(Table Continued)

Table B-3 (continued). Synopsis of comparisons of predicted and observed biological effects on 25 common species of algae, invertebrates and fishes.

Fishes

Species	Zone	Predicted Effects	Observed Effects	Comments
Black-and-Yellow Rockfish	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Decreased: 8.2 ha (the subtidal area of Diablo Cove < 7 m in depth)**	Adults decreased, but no changes in 'young-of-the-year' recruits Species caught in the local live rockfish fishery The plume can intermittently contact depths >7 m in Diablo Cove and shallower areas mainly north of Diablo Cove: 31.1 ha**
Gopher Rockfish	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Unknown; discharge effects could not be tested statistically	Not abundant in depths shallower than 7 m in pre-and operation study period Species caught in the local live rockfish fishery
Black Surfperch	Subtidal	Decrease - No risk map in TDAR, but expected to be affected in less than one-half of Diablo Cove, an area of 8.2 ha	Re-distributed in Diablo Cove resulting in no overall discharge effect	Significant increases were detected in north Diablo Cove and significant decreases detected in south Diablo Cove

* - shoreline distances and areas estimated from TDAR risk maps; these are estimates of habitat and not the distribution of a species
** - shoreline distances and areas from 1997 TEMP Analysis Report; these are estimates of habitat and not the distribution of a species