CALIFORNIA ENERGY COMMISSION

ISSUES AND ENVIRONMENTAL IMPACTS ASSOCIATED WITH ONCE-THROUGH COOLING AT CALIFORNIA'S COASTAL POWER PLANTS

Staff Report

In Support of the
2005 Environmental Performance Report
and
2005 Integrated Energy Policy Report
(Docket 04-Iep-1)

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Arnold Schwarzenegger, *Governor*

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EXECUTIVE SUMMARY

The purpose of this California Energy Commission (Energy Commission) staff report is to assess issues associated with once-through cooling impacts in the context of growing scientific and public policy concerns about the viability of California's coastal bay and estuarine ecosystems. California marine and estuarine environments are in decline and the once-through cooling systems of coastal power plants are contributing to the degradation of our coastal waters. Over the past several years, the Energy Commission has reviewed five coastal power plant applications and been faced with the challenge of how to determine the impacts of proposed new or repowered power plants that use once-through cooling and what should be done to mitigate the impacts. Given the widespread public and government agency concerns about the impacts to coastal ecosystems from California's coastal power plants that use once-through cooling and the difficulty in determining the economic and ecological costs of these systems, the Energy Commission may want to consider potential policy options to address these issues.

The biological resources of the world's oceans and California's coast in particular are in serious decline. Up to 30 percent of fish stocks are overexploited, the size and water quality of estuaries have been greatly reduced, toxins and plastic wastes have become ubiquitous constituents of the world's oceans, harmful algal blooms appear to be more frequent, increased shipping has led to increases in invasive species, and nutrient runoff from land has led to coastal eutrophication and ocean dead zones. In California, 60 percent of the fish species for which landings are reported appear to have declined since the early 1970s. California's Ocean Action Plan recognized the evolution in understanding that the marine environment has been overexploited to the point that its biological integrity and the viability of economies that depend on it are threatened. Reflecting recent national and State reports and Acts, this ocean protection strategy and the establishment of the California Ocean Protection Council is further recognition of the acute need to develop policies that restore the marine environments of the State, and "increase the abundance and diversity of aquatic life in California's ocean, bays, estuaries, and coastal wetlands."

California's coastal power plants are partly responsible for ocean degradation. Recent studies required by the California Energy Commission and other State agencies have shown that coastal power plants that use seawater for once-through cooling are contributing to declining fisheries and the degradation of estuaries, bay and coastal waters. These power plants indiscriminately 'fish' the water in these habitats by killing the eggs, larvae, and adults when water drawn from the natural environment flows through the plant (entrainment impacts) and by killing large adult fish and invertebrates that are trapped on intake screens (impingement impacts). These facilities also affect the coastal environment by discharging heated water back into natural environments. Most impacts are to early life stages of fish and shellfish. It is difficult to understand the magnitude of the impact of once-through

cooling systems because of a lack of adequate and standardized studies of entrainment. It also is difficult to put an economic value on these ecological losses.

The 21 California coastal power plants (generating capacity 23,910 megawatts (MW)) that use once-through seawater for cooling occur along the entire length of the State from Humboldt Bay to San Diego Bay, with the majority (13) south of Point Conception in Southern California. Together they are permitted by Regional Water Quality Control Boards, and some also by the Energy Commission, to use nearly 17 billion gallons per day (BGD) of coastal and estuarine water for cooling. Except the Potrero Unit 7 project, which was withdrawn, all of the coastal power plants that have come before the Energy Commission to date have been re-licensed to use their once-through cooling system. The seawater that is used in the once-through cooling systems of these power plants is not just water. It is habitat and contains an entire ecosystem of phytoplankton, fishes, and invertebrates.

Withdrawal of cooling water removes billions of aquatic organisms, including fishes, fish larvae and eggs, crustaceans, shellfish and many other forms of aquatic life from California water each year. Most impacts are to early life stages of fish and shellfish. A lack of adequate and standardized impact studies of entrainment makes it difficult to understand the magnitude of the impact of once-through cooling systems. Appendix 1 contains an analysis of the studies used to detect impacts to the marine environment by California's coastal power plants that use once-through cooling. Only seven of the 21 coastal power plants have recent studies of entrainment impacts that meet current scientific standards; all of these recent studies have found adverse impacts of entrainment. Entrainment losses quantified in these studies are equivalent to the loss of productivity of thousands of acres of coastal habitat. Impingement impacts add to the entrainment losses because often the same species that lose early life stages to entrainment lose adults and larger juveniles to impingement. Thermal impacts tend to be site specific and may be significant for some power plants and insignificant for others.

The cumulative ecological effects of coastal power plant entrainment and impingement relative to all impacts to coastal waters, while likely to be of concern, are difficult to quantitatively estimate given the number of different impacts, the large spatial scales over which they occur, difficulties in attributing changes in populations to any particular impact, and lack of knowledge about impact interactions.

The legal and regulatory framework regarding once-through cooling systems for power plants in California consists of a multi-layered assortment of federal, state, regional and local laws that are neither fully integrated nor consistently applied throughout the state. Various laws and policies related to once-through cooling are administered by different agencies that have not always worked together in a consistent manner to address the impacts of once-through cooling on California's coastal ecosystems. Recently, in September 2004 the U.S. Environmental Protection Agency released a new federal rule under Section 316(b) of the Clean

Water Act to reduce impingement and entrainment from existing power plants that use once-through cooling.

Use of alternative cooling technology, such as recirculating cooling (cooling towers) or air cooled condensers (dry cooling) have the potential to either greatly reduce the impacts of once-through cooling or eliminate the impacts entirely. In fact, 95 percent of the power plants licensed in California since 1996 have used alternative cooling technology rather than once-through cooling. Flow reduction options are operational approaches to reduce the volume of cooling water used on a seasonal or daily basis. Other approaches to reducing entrainment and impingement can be grouped into location and design. Location options refer to actually moving the location of the intake to reduce entrainment or impingement while design options include reconfiguration of the intake structure through the addition or modification of intake screens and fish handling/return systems.

Methods to reduce impingement and entrainment that do not involve alternative cooling or flow reduction have not been found to be feasible and/or effective at most California coastal power plants. Because changing to an alternative cooling method or retrofitting an existing intake may be costly or technically challenging, mitigation for the impacts of once-through cooling systems often takes the form of habitat restoration.

Placing an economic value on ecological losses would be useful to make appropriate decisions regarding requirements to retrofit intakes or employ other technologies to reduce once-through cooling impacts; however, doing so is difficult. While placing dollar values on changes in the natural environment can be controversial, economic analyses, when carefully developed and clearly presented, can provide important information for the public, corporate decision-makers, public policymakers, and regulators (for example, helping the public understand the relative magnitude of economic benefits relative to the costs of facility modifications required to achieve such benefits). Different methods have been used to estimate the value of ecological losses to once-through cooling systems in recent power plant studies, and in most cases the ecological losses were estimated to be millions of dollars although market losses of commercially and recreationally important species generally were much less.

Goals of the Staff Report

Given the health of California's estuarine and coastal water and the impacts of once-through cooling, do the environmental costs exceed their economic benefits? Energy Commission staff developed six specific goals for this staff report to address this question.

- Place once-through cooling impacts within larger scientific and public concerns about ocean resources.
- Quantify and interpret, to the extent allowable by available data, the water uses and ecological effects of once-through cooling. Lack of sufficient

scientific information is a major issue in understanding the role and impacts of once-through cooling systems in California. Data and knowledge from the five recent coastal re-powering cases before the Energy Commission helped inform this section of the paper, as did recent consultant reports on optimal study designs, existing monitoring data, and supporting studies for each of the 21 coastal power plants. This section also discusses impact assessment and potential mitigation strategies based on results from the Energy Commission's Public Interest Energy Research program.

- Review impact assessment protocols being developed by state and federal regulatory agencies as a result of new scientific knowledge and significant changes to federal Clean Water Act Section 316(b) permit regulations.
- Discuss the manner in which State of California agencies with permit and California Environmental Quality Act compliance authority interpret and implement the new regulations and the growing body of scientific evidence about once-through cooling effects will also be discussed.
- Examine costs and feasibility issues associated with alternative cooling technologies and water sources that can eliminate once-through cooling impacts at California coastal power plants.
- Present possible policy options for consideration by the Energy Commission.

Recommendations and Policy Options

Staff suggests that the Energy Commission consider doing the following:

California Ocean Protection Council

The Energy Commission has an opportunity through the new California Ocean Protection Council (Council) to coordinate with other agencies, environmental organizations and the concerned public to address once-through cooling issues. Ocean protection and restoration is a major policy initiative for the Schwarzenegger administration. The Council is charged with implementing the California Ocean Protection Act of 2004 (SB 1319) and it would provide an appropriate forum for agencies and concerned environmental groups to develop state-wide policies to address the impacts of once-through cooling. The Energy Commission may want to consider working through the Ocean Protection Council in developing methods to educate responsible agencies, industry, and the public regarding the impacts of once-through cooling and to develop and support statewide policies to address the impacts of once-through cooling.

Develop A New Policy For Siting Cases

The Commission could develop a policy similar to the one adopted in 2003 for conservation of freshwater sources. The new Commission policy could state "The Energy Commission may approve once-through cooling by power plants it licenses, or for licenses it amends related to cooling system modifications, only where alternative water supply sources or alternative cooling technologies are shown to be both environmentally undesirable and economically unsound." The Commission interprets "environmentally undesirable" to mean the same as having a significant adverse environmental impact," and "economically unsound" to mean "economically or otherwise infeasible."

Create Incentives to Promote the Use of Alternative Cooling

Costs have kept project owners from readily utilizing alternatives to once-through cooling. The impetus created by requiring power plants to implement Phase II cooling water intake structure improvements by January 8, 2008, in accordance with Section 316(b) of the Clean Water Act, may not be adequate financial incentive by itself to encourage replacement of once-through cooling with alternative cooling technologies. The Energy Commission could explore methods to create financial incentives that would encourage project owners to adopt alternatives to once-through cooling. Otherwise, older power plants will likely continue using once-through cooling and thus continue coastal species and ecosystem impacts indefinitely.

Update the Energy Commission Data Adequacy Regulations

The Energy Commission is in the process of updating the Biological Resources 12-month Data Adequacy Regulations to provide a much broader explanation of the types of studies and data that needs to be provided as part of a complete application to the Energy Commission for a power plant project proposing to use or currently using once-through cooling. Updating these regulations would be consistent with the language found in the 2005 MOA between the Energy Commission and the Coastal Commission regarding the need for applicants to provide a discussion of the project's compliance with California Coastal Act section 31413(d) and the need for a current and site-specific analysis of entrainment impacts.

Require Current Impact Studies For Licensing Analyses

The Energy Commission may want to adopt a policy that requires filing of a current impacts study with an application for any power plant that proposes the use of once-through cooling. The Energy Commission may also want to consider developing a standardized impact analysis protocol for power plant siting cases. Staff has begun to develop a standardized impact analyses protocol as described in Appendix 3 of this paper. Without a valid assessment based on sound science, the Energy Commission cannot meet its obligations and address those impacts, determine their significance and what, if any, mitigation is necessary.

Obtain Current Impact Analyses For All California Coastal Power Plants

Current impact analyses are lacking for approximately two-thirds of California's coastal power plants. None of the nine power plants in the Santa Monica Bay region have current impact studies. The Energy Commission could work with other concerned agencies through the Ocean Protection Council to develop site specific and cumulative impact studies for all Santa Monica Bay power plants. As part of this study, the Energy Commission could help investigate and identify local alternative cooling water sources such as recycled water supplies from wastewater treatment facilities. The Energy Commission Public Interest Energy Research program could coordinate the impact studies under the current contract with Moss Landing Marine Laboratories to help generate sufficient information to complete a sound cumulative impacts analysis.

With Interested Stakeholders, Create Standardized Approaches To Regulations and Policies

With the other responsible agencies, the Energy Commission could update the current Memoranda-of-Understanding/Agreement with the State Water Quality Control Board, Regional Water Quality Control Boards, and the California Coastal Commission to develop a consistent regulatory approach to once-through cooling power plants and Best Available Retrofit Technology to help minimize impacts. This would create a clear, standardized approach to administering the regulations and policies that relate to once-through cooling. Other state and federal agencies may want to participate in the Memoranda-of-Understanding.

CHAPTER 1:INTRODUCTION

"Your report is a wake-up call that the oceans are in trouble and in need of help." Governor Arnold Schwarzenegger (in response to U. S. Commission on Ocean Policy 2004 Report).

The State of the Ocean

It was once assumed that the marine environment was so vast that its habitats and life within them were essentially limitless and its biological integrity immune to abuse. The use of the environment as a resource would, therefore, have little impact. Policies and regulations were crafted accordingly. We now know the assumption was naive and the impacts of humankind are significant. The 1969 Stratton Report (USCMSER 1969), the first comprehensive review and recommendations concerning U.S. ocean policy, was written at a time when ocean fisheries were booming, concern centered on competition for ocean resources with foreign fleets, and emerging technology could enable the U.S. to more completely exploit this "last frontier." While the report recognized potential environmental problems from overexploitation, particularly in the coastal zone, the emphasis was on increased use. In a similar review 25 years later, the U.S. Commission on Ocean Policy (USCOP 2004) came to a very different conclusion: "Unfortunately, our use and enjoyment of the ocean and its resources have come with costs, and we are only now discovering the full extent of the consequences of our actions." This was also the conclusion of the recent review sponsored by The Pew Charitable Trusts (POC 2003): up to 30 percent of fish stocks are overexploited, the size and water quality of estuaries have been greatly reduced, toxins and plastic wastes have become ubiquitous constituents of the world's oceans, harmful algal blooms appear to be more frequent, increased shipping has lead to increases in invasive species, and nutrient runoff from land has led to coastal eutrophication and ocean dead zones. The frontier is gone. The recommended federal policy is now sustainability, stewardship, ecosystem based management, and preservation of biodiversity, implemented by coordinated regulation and adaptive management based on the best available science and information (USCOP 2004).

The Status of California's Coastal Waters

A similar policy evolution has occurred in California. The 1971 California Department of Fish and Game review, "California's Living Marine Resources and Their Utilization," recommended greater utilization of fisheries resources and encouraged the development of more effective fishing gear, markets and harvesting methods for "underutilized marine resources" (Frey 1971). While potential problems with oil, pesticide and sewage pollution were recognized, the outlook was for continued, productive fisheries. A similar report in 1992 (Leet et al. 1992) noted that by this time landings from California fisheries had declined from over 900 million pounds in 1976 to less than 400 million pounds. This was attributed primarily to changes in the tuna fishing industry. Few policy changes were recommended. The report highlighted new fisheries.

California's Coastal Waters Are Ailing

The evidence for declining fisheries and better understanding of ecological relationships between fisheries and the condition of the ecosystems that support them continued to increase. These factors finally led to the California's Marine Life Management Act in 1998, Marine Life Protection Act in 1999, and Ocean Protection Act in 2004. These Acts define new marine resource management policies for California similar to those recommended for the nation in 2004 by the U.S. Commission on Ocean Policy. The Ocean Protection Act established the California Ocean Protection Council to make these policies more effective, efficient, and coherent. In the California Department of Fish and Game's 2001 review of California's living marine resources, the word "utilization" was absent from the title (Leet et al. 2001). With its primary purpose still that of providing baseline information on the status of California fisheries, the report noted concerns about sustainability of nearshore fisheries and habitat degradation. The data in the report indicate that of the species for which trends in landings were reported, 60 percent appear to have declined since the early 1970s. These data are based on commercial fish catches and can reflect changes in fishing practices and markets, not just changes in fish populations. Independent data on the abundance of fished species, including data from species killed on power plant intakes screens in Southern California (Herbinson et al. 2001) indicate these are real population declines. There is no doubt that fish populations may vary in abundance related to natural changes in oceanographic conditions including short term El Niños and longer term variation such as decadal oscillations. Anthropogenic (human-caused) impacts, however, can magnify natural declines. As Parrish and Tegner (2001) concluded in their review of the effects of fisheries and oceanographic change on California's fish populations, "It is clear that over the next decade a major research effort will have to be made to better understand the climatic connection and that fishery management will have to consider policies to reduce exploitation rates when species are impacted by adverse climatic factors."

This evolution in understanding that the marine environment has been overexploited to the point that its biological integrity and the viability of economies that depend on it are threatened is most recently recognized in California's Action Strategy (CRA/USEPA 2004). Reflecting recent national and state reports and acts, this ocean protection strategy and the establishment of the California Ocean Protection Council is further recognition of the need to develop policies that restore the marine environments of the state, and "increase the abundance and diversity of aquatic life in California's ocean, bays, estuaries, and coastal wetlands." The actions listed include focusing on ecosystems rather than species-by-species management, facilitation of projects and programs that restore and protect coastal and nearshore resources, habitats, and water quality and increasing the efficiency and effectiveness of efforts to achieve these goals by reducing fragmentation of planning and regulation among responsible agencies.

Real and Potential Impacts of California's Coastal Power Plants

Once-Through Cooling Systems Contribute to the Degradation of California's Coastal Waters

California's coastal power plants are partly responsible for this ocean degradation. Recent studies required by the California Energy Commission and other state agencies, performed by environmental consulting firms, and assisted by technical working groups that include outside experts in marine biology, ecology, and impact assessment, have shown that coastal power plants that use once-through seawater for cooling are contributing to declining fisheries and the degradation of estuaries, bays and coastal waters. These power plants indiscriminately "fish" the water in these habitats by killing the eggs, larvae, and adults when water drawn from the natural environment flows through the plant (entrainment impacts), by killing large adult fish and invertebrates that are trapped on intake screens (impingement impacts), and by discharging heated water back into natural environments (thermal impacts). The U.S. Environmental Protection Agency (USEPA), based in part on recent studies at some California power plants, now concurs that this may be a significant problem (USEPA 2004). There are currently 21 coastal power plants in California totaling 23,910 megawatts of generation capacity. USEPA regulations, administered by California Regional Water Quality Control Boards, permit the use of nearly 17 billion gallons of estuarine, bay and coastal water each day for cooling. Most of these power plants were constructed prior to 1980 when, as discussed above, and there was little knowledge of once-through cooling impacts on the marine environment. Thus, as with fishing, it was reasonable to assume that power plant impacts would be negligible.

CHAPTER 2:OVERVIEW OF ONCE-THROUGH COOLING SYSTEMS AND THEIR IMPACTS

Findings:

- Once-through cooling with seawater is an effective and relatively inexpensive cooling method for coastal power plants.
- Withdrawal of sea water for once-through cooling systems kills marine organisms by drawing them with the sea water through the power plant (entrainment) and by pinning them against the intake screens (impingement).
- The sea water entrained by power plants is habitat with high biodiversity. Millions of eggs and larvae of marine fishes and invertebrates are removed with sea water used for cooling.
- Impingement results in the death of large fishes and invertebrates and its impacts are similar to those of a fishery.
- The thermal impacts of particular plants have been large when discharges occur in bays and estuaries with reduced mixing or into the open coast where heated water quickly contacts rocky habitat.
- Each once-through cooling system may interact with other impacts to stress coastal ecosystems in ways that are not well understood.

Cooling System

Once-Through Cooling Is Affordable and Effective, But It Kills Marine Life

Once-through cooling with seawater is used in power generation because seawater is free, abundant, and cold. Ignoring environmental damage, it is an effective and relatively inexpensive method for re-condensing super-heated steam after it has been used to generate power. There is a positive linear relationship between electricity generated and volume of ocean water needed for cooling for most California coastal power plants that use fossil fuels (Figure 1). Comparatively, the nuclear power plants at San Onofre and Diablo Canyon use much more water per amount of electricity generated, while the fossil fuel power plant at Moss Landing uses less due to the recent addition of combined-cycle generators. Combined, California coastal power plants are permitted by State Regional Water Quality Control Boards to use nearly 17 billion gallons (~ 64 Mm^3 or 52,000 acre-feet) of seawater every day. For perspective, if San Francisco Bay had no water flowing into it and this volume of water was removed from it, the Bay would be drained dry in ~100 days.

Seawater used for cooling is drawn through intakes by pumps, and passes through traveling screens [generally 3/8” (0.95 cm) mesh] to remove large organisms and debris before entering the plant. Organisms and debris pinned against the screens (impinged) are removed and discarded (Figure 2). The water (and all organisms smaller than 3/8") are then drawn into the power plant (entrained) to absorb waste heat to condense steam. The organisms are also subjected to mechanical stress, pressure changes, and residual anti-fouling chemicals during entrainment. Some of the entrained organisms may be consumed by animals that live attached to the habitable parts of the cooling system. The temperature of the cooling water is increased by ~ 20^0 F (11^0 C). The heated water is finally discharged back into the environment in a location that minimizes re-entrainment of the heated water.

Entrainment

Impingement and entrainment are commonly called 316(b) impacts because they are regulated by the USEPA under Section 316(b) of the Clean Water Act.

Sea Water Is Habitat, Not Just Water

What is killed during entrainment? The shallow, well mixed, well lit, and nutrient rich estuarine and coastal marine waters are highly productive and diverse ocean habitats. They contain a variety of small, photosynthetic plants (phytoplankton) and numerous small animals (zooplankton; e.g., copepods) that reside entirely in the water, and other zooplankton that are the young stages (eggs and larvae) of larger, adult animals that live in the water or on the bottom – fishes, abalone, crabs, lobsters, and clams, among many others (Figure 3). The larvae commonly depend on phytoplankton and other zooplankton in the water for food as they grow. Coastal waters are also habitat for gametes, spores and seeds of many types of seaweed, sea grasses, and marsh plants, the adults of which live attached to intertidal and shallow subtidal bottoms.

The great diversity and abundance of plants and animals that live in the water entrained in coastal power plants in California is clear from Figure 3, but may be underestimated. Phytoplankton data for California were not available in a suitable format so the values given are from a similar region. California is noted for its high phytoplankton diversity and primary productivity related to periodic upwelling of cold, nutrient rich water along the coast. The phytoplankton data do not include reproductive stages of seaweeds and marine plants because these are difficult to sample. Their abundance can be very high; data for giant kelp alone indicate around 10^{10} giant kelp spores/1,000 m^3 can be found in the water near kelp forests (M. Graham, pers. comm.). Data for "related animals" were also unavailable because quantitative sampling and sorting is difficult. The data for fish and crab larvae are more accurate as they come from thorough sampling associated with recent entrainment studies in California (Table 1).

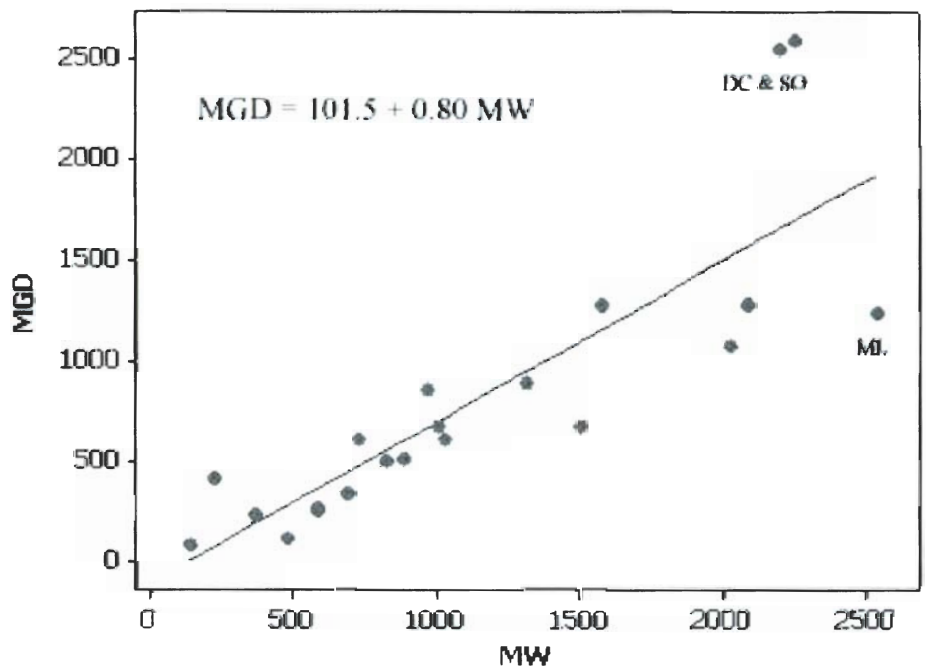


Figure 1. Relationship between generation capacity (MW; megawatts) and volume of seawater (MGD; million gallons/day) used for cooling. Power plants indicated are Diablo Canyon (DC), San Onofre (SO), and Moss Landing (ML). Data from Table 1.

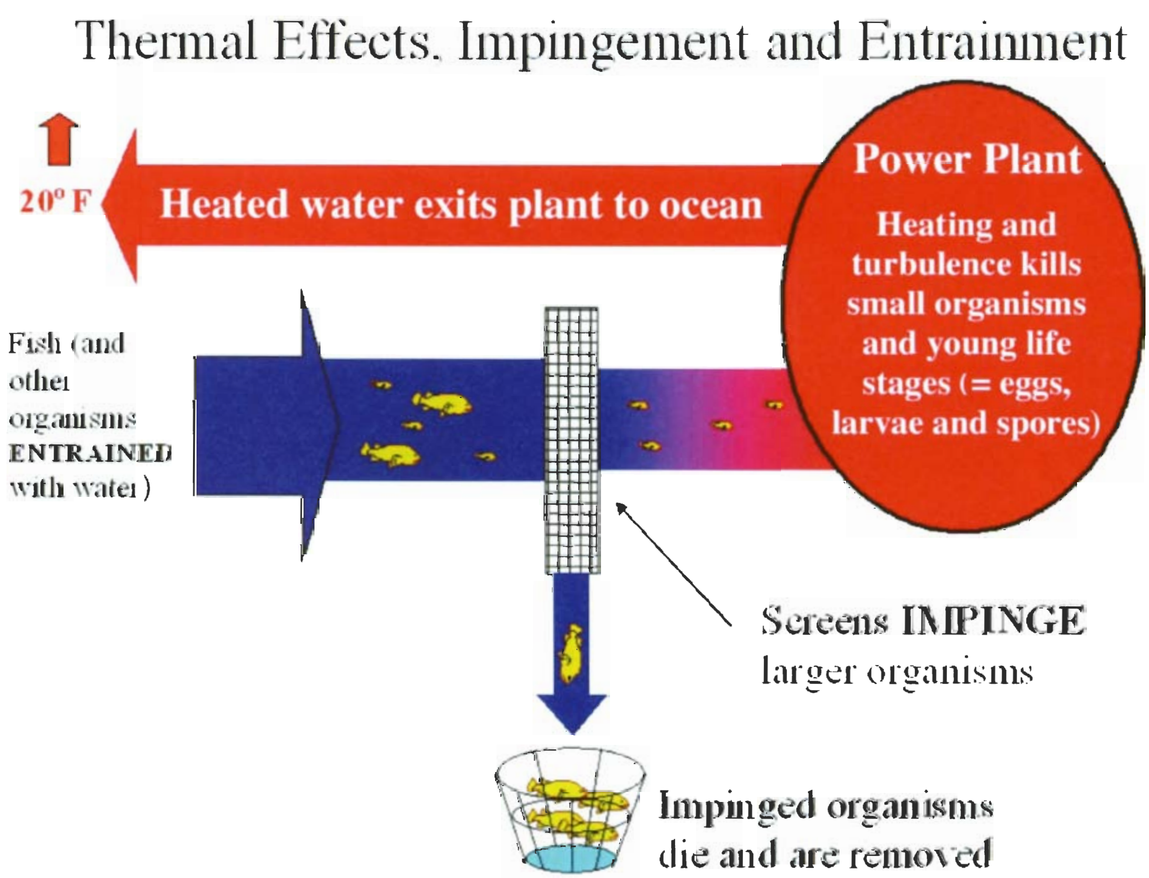
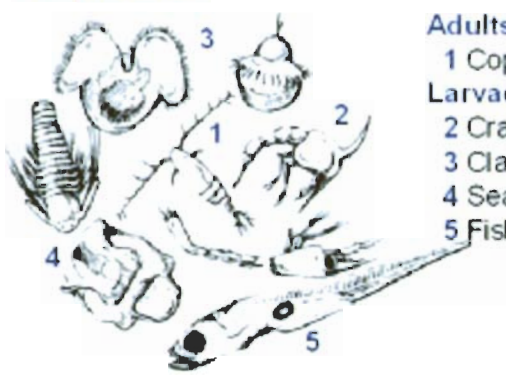


Figure 2. Once-through cooling system (courtesy of P. Raimondi)

PLANKTON DIVERSITY (SPP, # species) & ABUNDANCE (#, #1000 m3) IN CALIFORNIA COASTAL WATERS

Phytoplankton 10^2 SPP 10^9 #

Zooplankton



	SPP	#
Adults		
1 Copepods and related animals	10^2	10^6
Larvae		
2 Crabs	8	3×10^3
3 Clams & mussels	> 5	1.8×10^6
4 Sea urchins	2	6×10^2
5 Fish	44-200	400 – 600

Data from: phtoplankton. Petipa et al 1970; copepods. Hopcroft et al 2002: all other, Table 1.

Figure 3. The diversity and abundance of some of the plankton entrained by coastal power plants in California.

Table 1 Entrainment Impacts of California Power Plants
Data from AEG (2002) and Foster (2005) unless otherwise noted
ND = no data or no accurate data available * = fished species

Power Plant	*Intake Environment*	*Generation Capacity (MW)*	*Intake Volumes MGD*	*Density Larvae (/1000m^3) & # taxa entrained*	*Most Abundant Entrained Species*	*Mitigation for Entrainment Impacts*[+]
1. Alamitos	South Coast - South Palos Verdes Region; shore in bay/harbor	2083	1275 (4.817)	ND	ND	ND
2. Contra Costa	San Francisco Bay-Delta	680	341 (1.291)	ND	ND	ND
3. Diablo Canyon[A] (nuclear)	Central Coast; shore in open coast rocky cove	2200	2540 (9.615)	Fish density: 465 #taxa: 218 Crabs density: 10,960 #taxa: 9 Urchins density: 593 #taxa: 2	*Rockfishes, Clinid Kelpfishes, Blackeye Goby, Monkeyface Eel, Smoothead Sculpin, Snubnose Sculpin, *White Croaker, *Cancer Crabs, *Yellow Rock Crab, Purple Sea Urchin	120 - 240 hectares (296-593 acres) of rock reef
4. El Segundo	South Coast -Santa Monica Bay; subtidal open coast sand bottom	1020	605 (2.29)	ND	ND	ND
5. Encina	South Coast; shore in bay/estuary	965	857 (3.244)	ND	ND	ND
6. Haynes	South Coast - South Palos Verdes Region; shore in bay/harbor	1570	1271 (4.811)	ND	ND	ND
7. Humboldt Bay	North Coast; shore in estuary	135	78 (0.2953)	ND	ND	ND
8. Hunters Point	South San Francisco Bay; shore of estuary	215	412 (1.560)	ND	ND	ND

Table 1 (continued) Entrainment Impacts of California Power Plants . Data from AEG (2002) and Foster (2005) unless otherwise noted. ND = no data or no accurate data available. * = fished species

Power Plant	*Intake Environment*	*Generation Capacity (MW)*	*Intake Volume (MGD)*	*Density Larvae (/1000m^3) & # taxa entrained*	*Most Abundant Entrained Species*	*Mitigation for Entrainment Impacts*[+]
9. Huntington Beach[B]	South Coast - South Palos Verdes Region; subtidal open coast sand bottom	880	507 (1.919)	Fish density: 407 #taxa: 53 Crabs density: 667 #taxa: 8	Gobies, *Anchovies *Spotfin Croaker, *White Croaker, *Queenfish, *"Croakers," Blennies, *Mole Crabs, *Cancer Crags	2.3 - 56.4 km of sandy coastline to 5 km offshore = 1,150 - 28,240 hectares (2,840 - 69,752 acres)
10. Long Beach	South Coast- South Palos Verdes Region; shore in harbor	577	261 (0.988)	ND	ND	ND
11. Los Angeles Harbor	South Coast - South Palos Verdes Region; shore in harbor	472	110 (0.4164)	ND	ND	ND
12. Mandalay	South Coast- Ventura Region; in harbor	577	255 (0.9653)	ND	ND	ND
13. Morro Bay[C]	Central Coast; shore in estuary/harbor	1002	668 (2.529)	Fish density: 590 #taxa: 92 Crabs density: 24 #taxa: 8 Clams & Mussels density: 1.8 x 10^6 #taxa: >5	Gobies, Staghorn Sculpin, Blennies, Shadow Gobies, Jacksmelt, Blackeye Goby, Northern Lampfish, *Cancer Crabs, *Clams, *Mussels	93-307 hectares (230-759 acres) estuarine habitat

Table 1 (continued) Entrainment Impacts of California Power Plants
Data from AEG (2002) and Foster (2005) unless otherwise noted.
ND = no data or no accurate data available. * = fished species

Power Plant	*Intake Environment*	*Generation Capacity (MW)*	*Intake Volume (MGD)*	*Density Larvae (/1000m^3) & # taxa entrained*	*Most Abundant Entrained Species*	*Mitigation for Entrainment Impacts*[+]
14. Moss Landing[D]	Central Coast; shore in estuary/harbor	2538	1224 (4.633)	Fish density: 638 #taxa: 67 Crabs density: 3.9 #taxa: 8	Gobies, Bay Goby, Blackeye Goby, Pacific Staghorn Sculpin, Blennies, *White Croaker, *Pacific Herring	460 hectares (1135 acres) of estuarine wetlands
15. Ormond Beach	South Coast - Ventura Region: subtidal open coast sandy bottom	1500	688 (2.605)	ND	ND	ND
16. Pittsburg	San Francisco Bay-Delta	2029	1070 (4.050)	ND	ND	ND
17. Potrero[E]	South San Francisco Bay; shore in estuary	362	226 (0.8555)	Data incomplete	Gobies, Yellowfin Goby, Bay Goby, *Pacific Herring, *Northern Anchovy, *White Croaker, *Cancer Crabs, European Green Crab	357 hectares (882 acres) of estuarine habitat
18. Redondo Beach	South Coast - Santa Monica Bay; harbor	1310	881 (3.335)	ND	ND	ND
19. San Onofre[F] (nuclear)	South Coast; subtidal open coast sand bottom	2254	2580 (9.766)	Fish density:1590	*Northern Anchovy, *White Croaker, *Queenfish, Gobies, Blennies, *Grunions & Smelts	60.7 hectares (150 acres) of estuarine wetlands

Table 1 (continued) Entrainment Impacts of California Power Plants. Data from AEG (2002) and Foster (2005) unless otherwise noted. ND = no data or no accurate data available. * = fished species

Power Plant	*Intake Environment*	*Generation Capacity (MW)*	*Intake Volume (MGD)*	*Density Larvae (/1000m^3) & # taxa entrained*	*Most Abundant Entrained Species*	*Mitigation for Entrainment Impacts*[+]
20. Scattergood	South Coast-Santa Monica Bay; subtidal open coast sand bottom	818	495 (1.874)	ND	ND	ND
21. South Bay[G]	South Coast-Southern San Diego Bay; shore in estuary	723	601 (2.275)	Fish density: 2,744 #taxa:44	Gobies, *Bay Anchovies, Blennies, Mudsuckers, Pipefish, Yellowfin Gobies	406 hectares (1003 acres) of estuarine habitat
TOTAL		23,910	16,925 (64.13)			

+. Except for plant 19., based on Habitat Production Foregone (HPF), the area of habitat needed to replace larvae killed by entrainment. These areas vary in part because of the use of different PM values (e.g., PM average versus PM max.). The most appropriate value to use needs to be better resolved (see Recommendations, Appendix 2.)

A. Entrainment data from Tenera (2000a) and mitigation from CCRWQCB (2005) using average PM max.

B. Generation capacity, intake vol. and entrainment data from MBC/Tenera (2005) and preliminary mitigation estimate from using range of average PM max. to average PM max. 95 percent CI (Raimondi pers. comm.).

C. Generation capacity, intake vol. and fish and crab entrainment data from Tenera (2001a), clam densities from Geller (pers. comm.), mitigation from CCRWQCB (2004) using average PM and average PM max.

D. Entrainment data from Tenera (2000b), mitigation from Anderson & Foster (2000) using average PM.

E. Entrainment data from Tenera (2001b; Jan.-June 2001 data only). Mitigation calculated from data in Tenera (2001b) using average PM max = 0.0059 and area of source water habitat = 39,700 hectares.

F. Entrainment data from MRC (P. Raimondi, pers. comm.), mitigation data from CCC (1997)

G. Entrainment data from Duke (2004b), mitigation calculated from data in Duke (2004b) using average PM max(?) = 0.134 and area of source water habitat = 3,033 hectares.

Conversion factors: 1 m^3 = 264.173 US gallons; 1 liter = 0.001 m^3; 1 hectare = 1 x 10^4 m^2 = 2.471 acres; 1 acre-foot = 325,851 US gallons; 1 megawatt = 10^6 watts

It is important to note that because of the present difficulty and cost of sampling and identifying plankton less than ~ 0.3 mm, even the most well designed entrainment sampling programs are constrained to estimating direct impacts on only fishes and crabs. The eggs and/or larvae of these organisms are generally larger than 0.3 mm and relatively easy to identify. Impacts, particularly on species of invertebrates, are potentially large but currently not assessed. The abundance of sea urchin larvae was similar to that of fish as determined by the entrainment study at Diablo Canyon Nuclear Power Plant (Table 1). A pilot study using molecular genetic markers to identify clam and mussel larvae in water entrained at the Morro Bay Power Plant found larval abundances on the order of a million/1000 m^3 (J. Geller, pers. comm.). Such data suggest these unassessed impacts may be large. They may be critical to organisms such as abalone, a commercially and recreationally important group of marine animals whose larvae occur in coastal waters and whose adult populations are in severe decline with some species possibly headed for local and perhaps complete extinction (Haaker et al. 2001).

The seawater entrained by power plants is habitat with very high biodiversity. Moreover, it is now recognized that considering only impacts to commercially fished species does not consider the degradation of the ecosystems that support them. Thus, it is clear that an ecosystem/habitat approach to understanding the impacts of entrainment by coastal power plants is the necessary foundation upon which to build effective regulation and impact mitigation.

Impingement

Impingement results in the death of large fish and invertebrates in the cooling water, and its impacts are similar to those of a fishery. The species and biomass entrained varies greatly depending on the volume of water used for cooling, the local environment, and the behavior of organisms relative to the intake structure. How these factors interact to affect impingement is poorly known. The impact is commonly assessed relative to local fisheries landings, with impacts to non-fished species considered negligible.

Thermal and Other Impacts of the Discharge

The environmental impacts or thermal discharges, commonly referred to as 316(a) impacts because they are regulated by the USEPA under Section 316(a) of the Clean Water Act, were long considered to be potentially the most severe impacts of once-through cooling systems. It was thought that the elevated temperature of the discharged water would cause fish kills and greatly change marine communities, especially in more tropical waters where organisms live near their natural upper temperature limits (Langford 1990). The thermal impacts of particular plants, including some in California (discussed below), have been large when discharge occurs in bays and estuaries with reduced mixing, or into the open coast where heated water quickly contacts rocky habitats (Duke 2004a, Schiel et al. 2004, Foster 2005). However, heated water discharged offshore on the open coast where cooling due to mixing is rapid and occurs prior to contact with the bottom appears to have little impact (e.g., Huntington Beach Generating Station; Davis et al. 2001). If the water around the intake structure is more turbid than that around the discharge structure, the environment receiving discharged water can also be altered by reduced water clarity. It can also be altered by the increased dead organic matter in the discharge, as well as by scour if discharge occurs on shore.

Cumulative Impacts

Each Once-Through Cooling System May Interact With Other Impacts To Stress Coastal Ecosystems In Ways That Are Not Well Understood

The above impacts for a particular once-through cooling system occur in the context of other anthropogenic impacts affecting the same environment, including other power plants. Cumulative impacts are impacts that are greater when considered together than they are if taken separately and then added together ("the whole is greater than the sum of the parts"). Cumulative impact analyses determine the particular power plant's contribution to these overall impacts. These may be important because natural population dynamics are rarely linear. Thus, while the reduction in abundance of a species from once-through cooling may be small, it can reduce a species below a threshold, resulting in disproportionately large reductions in populations. A similar argument can be made for the effects of habitat losses on populations. Three suites of cumulative impacts can be identified: (i) cumulative impacts due to multiple effects of a given power plant on the local environment, e.g., do thermal impacts and entrainment impacts affect the same marine populations? (ii) cumulative impacts due to closely sited power plants, e.g., do two nearby intakes have a greater effect than they would if they were sited further apart? (iii) cumulative impacts due to effects of multiple activities in the coastal zone, e.g., for a specific population, is the loss of reproductive output due to the combination of entrainment and fishing pressure sustainable?

CHAPTER 3 - ASSESSING IMPACTS

Findings:

- Studies of once-through cooling impacts prior to 1980 were not done in a consistent manner and were not subject to independent scientific review.
- Recent studies use more standardized methods and are reviewed by independent scientists, agency representatives, and representatives of environmental groups.

Standardize Impact Assessments Based on Sound Science

Determining impacts is fundamentally a science issue, and should be independent of the regulations it serves, and their interpretations, except as the regulation specifies the impacts to be determined. Whether the assessment is to comply with regulations of the U.S. Clean Water Act or the California Environmental Quality Act (CEQA), the assessment study designs and analyses should be similar, if not the same. They have not, however, been similar. While these Acts require studies to determine impacts, they generally do not specify what metrics (e.g., number of individuals of species X/1,000m^3) should be used, how the studies should be done, or how the results should be interpreted. In California, the first impact studies at most power plants were done in the 1970s. These early studies were typically proposed by consultants hired by the power plant owner, and approved by the State Regional Water Quality Control Board responsible for a particular power plant. Study designs and metrics approved by State Regional Water Quality Control Boards were rarely reviewed by independent experts. This began to change in the 1980s when the California Coastal Commission required thermal, entrainment and impingement impact studies for the San Onofre Nuclear Generating Station to be designed and supervised by the Marine Review Committee composed of academic scientists, representatives from environmental groups, and the plant owner (MRC 1989). The Marine Review Committee used study designs and approaches that have been applied, with modification based on more recent analytical approaches and the operational and environmental setting of a particular plant, in all subsequent impact assessments at other power plants, including those required by the Energy Commission. These recent assessments have commonly relied on a technical working group composed of independent scientists plus representatives from relevant agencies, the consulting firms doing the study, the power plant owner/operator and, in some cases, environmental groups, to oversee study design, implementation, and data and impact analyses. The essential elements currently and generally agreed upon for studies at a power plant that is already operating are summarized in Appendix 3.

CHAPTER 4 - ENVIRONMENTAL IMPACTS OF ONCE-THROUGH COOLING IN CALIFORNIA

Findings:

- The 21 California coastal power plants that use once-through cooling are permitted to withdraw nearly 17 billion gallons per day of coastal and estuarine water for cooling.
- Only seven of these 21 coastal power plants have recent studies of entrainment impacts that meet current scientific standards.
- All of these recent studies have found adverse impacts due to entrainment.
- Thermal impacts are likely to be significant for shoreline discharges and discharges in enclosed water bodies.
- Impingement and entrainment impacts are equivalent to the loss of biological productivity of thousands of acres of habitat.
- The cumulative impacts of entrainment and impingement when added to the other impacts to coastal resources are unknown.

Coastal Power Plants Withdraw Billions of Gallons of Seawater Per Day

The 21 California coastal power plants that use once through seawater cooling occur the entire length of the State from Humboldt Bay to San Diego Bay (Figure 4), with the majority (13) south of Point Conception in Southern California. Under federal EPA regulations administered by Regional Water Quality Control Boards, they are permitted to use nearly 17 billion gallons per day (BGD) of coastal and estuarine water for cooling (Table 1). Categorized according to the habitat from which water is withdrawn (from Table 1):

- Open Coast Sand and Rock (2 plants) ---- 5.12 BGD
- Open Coast Sand/Harbor (6 plants) ------- 3.43 BGD
- Bay/Estuary (13 plants) --------------------- 8.39 BGD

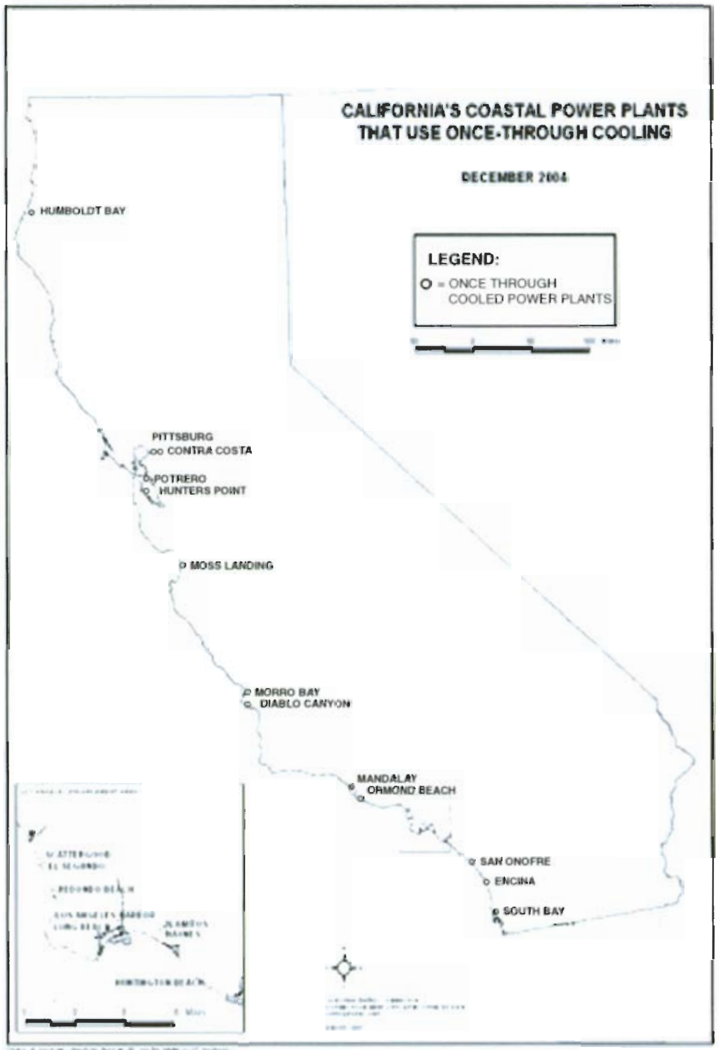


Figure 4. California's coastal power plants that use once-through cooling.

Only Adequate Studies Will Assess Ecological Effects of Seawater Use For Cooling

It is impossible to know what the impacts of these plants are without adequate assessments. Foster (2005) reviewed existing impact assessments for these power plants relative to the methods and analyses described in Appendix 3. Michael Foster's (2005) draft consultant's report is included as Appendix 1. Appendix 2 contains the author's responses to the reviewer's comments on the draft report. Prior to the mid-1980s State Regional Water Quality Control Boards had primary responsibility for regulating power plant discharges according to the U.S. Clean Water Act Sections 316(a) and (b). Assessment information was obtained from 316(a) and (b) reports submitted to the Regional Boards by the power plant owners as part of the discharge permit process. These early studies usually concluded that the cooling system had no or minimal adverse impact on the environment, and Water Boards generally accepted these conclusions. Foster (2005) concluded, however, that while the impingement studies generally provided accurate impact estimates, many of the thermal impacts and nearly all of the entrainment impacts in these early studies were poorly assessed, most often due to problems with study designs and sampling methods. Conclusions of "no adverse impacts" were generally unjustified. The USEPA (2004) arrived at a similar conclusion based on review of impingement and entrainment studies done nationwide in the 1970s and 80s. It found "a substantial number of serious study design limitations" and that the evaluations done were often "inconsistent and incomplete, making quantification of impacts difficult in some cases."

The assessment of once-through cooling system impacts in California began to improve when the Coastal Commission required impact studies of proposed new generating units at San Onofre Nuclear Power Plant, and formed the Marine Review Committee to oversee study designs and analyses (MRC 1989). Further improvement occurred during the process of impact assessment of the Diablo Canyon Nuclear Power Plant. This assessment was required by the Central Coast Regional Water Quality Control Board and guided by a technical working group (Tenera 1997, 2000a). With slight modification, assessment approaches at Diablo Canyon have been used in subsequent studies done at the Moss Landing, Morro Bay, Potrero, South Bay, and Huntington Beach power plants (Foster 2005; Steinbeck et al. in prep.), and the soon-to-be completed study at Encina Power Plant (J. Steinbeck, pers. com.). Studies at Morro Bay, Moss Landing, Potrero, and Huntington Beach were required by the Energy Commission in conjunction with re-powering projects. Assessments at Moss Landing and Morro Bay power plants benefited from coordination and support of the Central Coast Regional Water Quality Control Board, and all were guided by a technical working group. Assessments for the South Bay and Encina Power Plants were required by the San Diego Regional Water Quality Control Board. There are, therefore, more accurate assessments for seven of the 21 power plants (power plants with larval data in Table 1). All of these recent studies have found adverse impacts.

Thermal Impacts Are Site Specific

Thermal impacts are site specific. The Diablo Canyon Nuclear Power Plant discharges directly into a natural rocky cove and discharge has greatly altered rocky intertidal and shallow subtidal communities over 1.4 miles of shoreline. Discharge at the San Onofre Nuclear Generating Station occurs very near a kelp forest. Thermal effects are small, but turbidity caused by the discharge is estimated to result in the loss of 179 acres of kelp forest. The South Bay Power Plant discharges into the southern end of southern San Diego Bay where circulation is very weak. Recent studies indicate thermal impacts include the loss of an estimated 100 acres of eelgrass, and large alterations in benthic invertebrate assemblages. The Morro Bay Power Plant discharges onto the shore next to Morro Rock. The discharge alters approximately 600 feet of rocky intertidal and shallow subtidal habitat. Both the Moss Landing and Huntington Beach power plants discharge into the shallow subtidal zone on sandy beaches where impacts appear to be minimal.

Five power plants that have not been adequately assessed have the potential for large impacts (summarized in Table 2, below). Alamitos and Haynes power plants discharge a combined ~2.5 BGD of heated water into the lower part of the San Gabriel River and coastal ocean. The impacts may be large but studies have not been adequately done to determine their full extent, and the impacts may be difficult to separate from other impacts to this highly industrialized area. Encina Power Plant discharges onto a sandy beach and the thermal plume may impact the beach as well as a local kelp forest. Effects, however, are essentially unknown because of inadequate studies.

Contra Costa and Pittsburg power plants discharge into the San Francisco Bay-Delta within a few miles of each other. The San Francisco-Bay Delta estuary is an extremely valuable and stressed estuarine environment that is under constant scrutiny and heavily managed. It is also the largest estuary in the western United States. These thermal discharges may be affecting organisms in the water and on the bottom, but available studies are inadequate to accurately determine impacts. The zone of where freshwater meets ocean water moves up and down in front of these two power plants, and, as discussed later, six special status fish species occur in the vicinity of the Contra Costa and Pittsburg power plants.

Thermal impacts from the remaining coastal power plants are poorly known, but because of the discharge location (e.g., offshore along the open coast where dilution is rapid) and/or small volume of the discharge, the effects are likely small compared to shoreline discharges or discharges in enclosed water bodies.

Impingement and Entrainment Impacts Equal the Loss of Biological Productivity of Thousands of Acres of Habitat

Power Plants That Withdraw Water from Open Coast Sand and Rock Habitats

Diablo Canyon and San Onofre are the only power plants that have intakes in open coast habitats composed of rock and sand, and the impacts of both have been recently assessed. A draft Habitat Production Foregone analysis (analysis described in Appendix 3) based on modern entrainment sampling and analyses for Diablo Canyon suggests that 296 - 593 acres of rock reef are needed to replace the larvae lost as a result of entrainment by this power plant. The impingement and entrainment study at San Onofre did not estimate Habitat Production Foregone. Instead, it was decided that entrainment losses could be compensated for by producing 150 acres of coastal wetlands.

Table 2 Discharge environments, impacts, and mitigation for thermal discharges from California coastal power plants with once-through cooling. (Impacts and mitigation from Foster (2005) unless otherwise noted)

Power Plant	***Cooling Water Discharge Environment***	***Discharge Impacts***	***Mitigation***
1. Alamitos	South Coast; tidally influenced mouth of San Gabriel River	Incompletely assessed but possibly large in river and coast; discharge cumulative with Haynes	None
2. Contra Costa	San Francisco Bay-Delta	Incompletely assessed – special status species	None
3. Diablo Canyon[A] (nuclear)	Central Coast; rocky shore in cove	Large changes in intertidal and shallow subtidal communities along 2.2 km of coastline	*Being Considered*: artificial reef, marine reserve, protection of 9.2 km of shore, docents to reduce shore impacts in local parks
4. El Segundo	South Coast; subtidal open coast sand bottom	Localized and small.	None
5. Encina	South Coast; intertidal sandy beach	Incompletely assessed; may affect sandy beach, rocky shore and kelp forest	None
6. Haynes	South Coast; tidally influenced mouth of San Gabriel River	Incompletely assessed but possibly large in river and coast; cumulative with Alamitos	None
7. Humboldt Bay	North Coast; shore within estuary	Incompletely assessed.	None
8. Hunters Point	South San Francisco Bay shore	Incompletely assessed.	None.
9. Huntington Beach	South Coast; subtidal open coast sand bottom	Localized and small.	None
10. Long Beach	South Coast; Long Beach Harbor	Incompletely assessed.	None

Table 2 (continued) Discharge environments, impacts and mitigation for thermal discharges from California coastal power plants with once-through cooling. (Impacts and mitigation from Foster (2005) unless otherwise noted)

Power Plant	***Cooling Water Discharge Environment***	***Discharge Impacts***	***Mitigation***
11. Harbor	South Coast; Los Angeles Harbor	Incompletely assessed but likely localized.	None
12. Mandalay	South Coast; intertidal open coast sandy beach	Incompletely assessed.	None
13. Morro Bay[B]	Central Coast; open coast intertidal in sandy and rocky habitats	Alters rocky intertidal and shallow subtidal communities over ~ 180 m of shore; little detectable impact to sand communities	None
14. Moss Landing	Central Coast; subtidal open coast sand bottom and rock jetties	Effects probably highly localized, but detection confounded by dredge spoil disposal	None
15. Ormond Beach	South Coast; subtidal open coast sand bottom	Likely very localized.	None
16. Pittsburg	San Francisco Bay-Delta	Incompletely assessed – special status species present	None
17. Potrero[C]	South San Francisco Bay shore	Incompletely assessed but likely localized; effects confounded by other impacts and shoreline modification	None
18. Redondo Beach	South Coast; subtidal open coast sand habitat with rock jetties	Incompletely assessed; potential for impacts to sand and rock habitat over large area.	None

Table 2 (continued) Discharge environments, impacts and mitigation for thermal discharges from California coastal power plants with once-through cooling. (Impacts and mitigation from Foster (2005) unless otherwise noted)

Power Plant	*Cooling Water Discharge Environment*	*Discharge Impacts*	*Mitigation*
19. San Onofre[D] (nuclear)	South Coast; subtidal open coast sand bottom and kelp forest	72.4 hectares (179 acres) of kelp forest lost due to increased turbidity	60.7 hectare (150 acres) artificial reef to support medium-high kelp density; partial funding for fish hatchery
20. Scattergood	South Coast; subtidal open cost sand bottom	Incompletely assessed but likely localized.	None
21. South Bay[E]	South Cost; southern San Diego Bay	Impacts over the southern Bay, including loss of 40 hectares (100 acres) of eelgrass beds	None yet determined

A. Impacts from Tenera (1997), potential mitigation from CCRWQCB (2005)
B. Impacts from Tenera (2001c)
C. Survey in Tenera (2001d)
D. CCC (1997)
E. Duke (2004a)

Power Plants That Withdraw Water from Open Coast Sand and Harbor Habitats

Six California coast power plants withdraw water and the organisms in it from open coast sand and harbor habitats: El Segundo, Huntington Beach, Mandalay, Ormond Beach, Redondo, and Scattergood. Only Huntington Beach has a recently completed entrainment study, and preliminary estimates of Habitat Production Foregone for this plant range between 2,840 - 69,752 acres (average = 36,292 acres; Table 1). This acreage range is large due to large variance in the proportional mortality rates of the species impacted by the project. Relative to the Huntington Beach intake volume and using the average Habitat Production Foregone, this is ~72 acres/MGD (million gallons/day) of water used for cooling. Assuming this habitat loss rate is similar among all such plants and scaling based on MGD (3,431 MGD), cooling water use by these plants may effectively be eliminating all the organisms produced by ~ 247,000 acres of coastal and estuarine habitat. Estuarine habitat is included because the data from the Huntington Beach impact analyses (MBC/Tenera 2005) indicate such power plants entrain species from nearby estuaries and bays.

Power Plants That Withdraw Water from Bays and Estuaries

Four bay/estuarine power plants have recently been assessed: Morro Bay, Moss Landing, Potrero and South Bay, and Habitat Production Foregone was determined for each (Table 1). The sum of the habitat production loss for these plants (using the average for Morro Bay) is 3,515 acres. This acreage, divided by the sum of their intake volumes (2.719 BGD) yields an estimate of 1.29 acres of habitat lost/MGD of water used for cooling. There are nine other power plants in California that intake water from bays/estuaries, Alamitos, Contra Costa, Haynes, Humboldt Bay, Hunters Point, Long Beach, Los Angeles Harbor, Pittsburg and Encina. They have a combined intake volume of 5.675 BGD. Impacts from these plants have not been adequately assessed (Foster 2005). Projecting habitat production losses for them based on the four power plants that have been recently assessed suggests that these nine plants potentially eliminate habitat production equivalent to ~7,300 acres, for an estimated combined habitat loss from all 13 power plants of ~10,800 acres. This is nearly twice the combined area of Elkhorn Slough and Morro Bay, two estuaries in central California (Anderson and Foster 2000, CCRWQCB 2004). Moreover, it is widely recognized that these ecologically important habitats, many of which have been designated for special protection (e.g., Elkhorn Slough is a U.S. National Oceanic and Atmospheric Administration National Estuarine Research Reserve; Morro Bay is part of the USEPA’s National Estuarine Program) have been drastically altered by the nearby power plants. The San Francisco Bay-Delta area, home to four coastal power plants, is the largest estuary in the western United States. Only ~5 percent of California’s coastal wetlands remain intact (Sheehan and Tasto 2001).

The Assessment of the Cumulative Impacts of Entrainment from California Coastal Power Plants Is in Its Infancy

A preliminary estimate for 12 coastal power plants in southern California was required by the Energy Commission as part of the Huntington Beach impingement and entrainment study (MBC/Tenera 2005). The study considered that, based on available information, the fish larvae that are likely to be entrained by these plants occur in coastal waters 245 feet deep or less. It estimated that the 12 coastal power plants along the 340 miles of coast between Point Conception and 17.5 miles south of the USA/Mexico border (roughly what is called the “Southern California Bight”) cause an overall entrainment mortality of 1.4 percent, or a “Length of Production Foregone” (shoreline length out to 245 feet deep) of ~5 miles. The volume of water (shore to 245 feet depth) is ~27 trillion gallons, so a “Volume of Production Foregone” would be ~377 million gallons of coastal marine habitat.

There are likely smaller regions with much larger cumulative effects. For example, the surface water in Santa Monica Bay can circulate in a large eddy which increases the time a given parcel of water spends in the Bay (residence time) relative to unidirectional flow. Three power plants (Scattergood, El Segundo, and Redondo) withdraw cooling water from the Bay. Based on ocean circulation and volumetric relationships determined by IRC (1981), these three plants may consume nearly 13 percent of the nearshore water in the Bay every six weeks. Cumulative impacts increase with longer residence times because the water and the organisms in it are subject to entrainment for longer times. Potrero and Hunters Point may have significant cumulative effects on South San Francisco Bay, as may the Contra Costa and Pittsburg power plants as they are close to each other and both draw water from the San Francisco Bay-Delta. More research is needed to determine these cumulative impacts, and a recent Energy Commission PIER workshop concluded such research is a high priority (Appendix 4).

Cumulative Impacts from Impingement at Southern California Coastal Power Plants May Be 8 to 30 Percent of the Fish Caught in the Southern California Recreational Fishery

The Huntington Beach impact assessment (MBC/Tenera 2005) also summarized the 2003 impingement data for 11 coastal power plants in Southern California. Encina was excluded because of lack of recent data, and the South Bay Power Plant because it is in the lower part of an estuary. The estimated total impingement for the 11 power plants was ~3,600,000 fish weighing ~58,000 lbs. San Onofre Nuclear Generating Station contributed 97 percent of the individuals and 83 percent of the biomass. The cumulative impact of this impingement on fish populations was not estimated. However, considering only recreationally fished species, impingement amounted to 8-30 percent (depending on the fishery database used) of the number of fish caught in the Southern California recreational fishery. Recent impingement estimates are only available for a very few of the eight power plants south of Point Conception so cumulative impacts cannot, as yet, be estimated.

The Cumulative Impacts of Entrainment, Impingement and Other Factors is Unknown

The cumulative effects of coastal power plant entrainment and impingement relative to all impacts to coastal waters may be ecologically important but have not been assessed. While such effects are likely, they are very difficult to quantitatively estimate given the number of different impacts, the large spatial scales over which they occur, difficulties in attributing changes in populations to any particular impact, and lack of knowledge about impact interactions. As discussed in the Introduction, individual and cumulative effects were, in the 1970s, assumed to be negligible. It is now known these are potentially large, but the effects of even the individual impacts are difficult to accurately determine. Nevertheless, population and habitat trends generally show declines. Such circumstances have indicated it is prudent to follow the Precautionary Principle:

where the possibility of serious harm exists, lack of scientific certainty should not preclude cautious action (e.g., Ludwig et al. 1993). Understanding cumulative effects would be greatly facilitated by efficient communication and cooperation among the State agencies responsible for understanding and regulating the individual effects. Such an integrated approach could be fostered by the recently formed California Ocean Protection Council.

Once-Through Cooling Systems Affect Special Status Species

Once-through cooling systems can directly impact special status species if their adults and larvae are subject to impingement or entrainment. Examples of such species whose adult populations are in severe decline along the coast of California are some rockfishes and all abalone (Leet et al. 2001). Six fish species of “special status” occur in the vicinity of the Contra Costa and Pittsburg power plants in the San Francisco Bay-Delta (Tenera 2000c). Three of these species (Delta and longfin smelt, and Sacramento splittail) were impinged or entrained during impact assessments at the Contra Costa Power Plant in 1978-79 (Tenera 2000c). Also, the Bay-Delta is the migratory pathway for all salmonid species with habitat in the Sacramento and San Joaquin River basins, including winter and spring run salmon. A Habitat Conservation Plan has been developed under Section 10 of the federal Endangered Species Act for these Delta power plants.

These and other power plants in estuaries and bays may indirectly impact special status species by reducing food availability. New impact assessments are clearly needed at all inadequately assessed power plants (Appendix 1), assessments that include impacts on invertebrates whose larvae are likely to be entrained and whose adult populations are declining.

CHAPTER 5:THE REGULATORY ENVIRONMENT IN CALIFORNIA

Findings:

- A variety of regulations administered by different agencies address the environmental impacts of once-through cooling.
- Each responsible agency has tended to focus on its particular responsibilities. Consequently, responsible agencies have not always worked together in a consistent manner to address the larger issue of protecting the marine environment from once-through cooling.

A series of legal and regulatory requirements apply to the re-licensing of power plants that have a capacity of 50 MW or greater and will use once-through cooling. This section summarizes the most significant laws, policies, and regulatory requirements applicable to such projects and identifies how they are implemented in the Energy Commission's licensing process. This list, however, is not exhaustive; a review of Energy Commission decisions for the Moss Landing Power Plant Project, Morro Bay Modernization and Replacement Power Plant Project, and the El Segundo Power Plant Project will provide a more comprehensive discussion of applicable requirements.

Laws Applicable to Once-Through Cooling Systems

Warren-Alquist Act

Under California law, the authority of the Energy Commission to license thermal power plants with a capacity of 50 MW or greater is exclusive. Public Resources Code section 25500 states:

> [T]he commission shall have the exclusive power to certify all sites and related facilities in the state….The issuance of a certificate by the commission shall be in lieu of any permit, certificate, or similar document required by any state, local or regional agency, or federal agency to the extent permitted by federal law….and shall supercede any applicable statute, ordinance, or regulation of any state, local, or regional agency, or federal agency to the extent permitted by federal law.

However, the Energy Commission is also required to make findings regarding the conformity of the project with applicable local, regional, state, and federal standards, ordinances, and laws, must take certain steps in the event it finds noncompliance with an applicable standard, ordinance, or law, and is prohibited from certifying a facility it finds does not conform unless specific findings are made. (Public Resources Code, §§ 25523(d)(1)), 25525.) In addition, there are specific requirements imposed when the proposed project is located in the coastal zone. (Public Resources Code, § 25523(b).) Finally, the Energy Commission is the Lead Agency under the California Environmental Quality Act (CEQA). (Public Resources Code, § 21000 et seq.) Thus, when the Energy Commission re-licenses a power plant utilizing once-through cooling, its decision must take into account several different sets of statutory requirements, and it must coordinate closely with a number of different regulatory agencies.

California Environmental Quality Act

The California Environmental Quality Act is designed to ensure that governmental decision-makers and the public have access to information about the environmental consequences of proposed governmental actions. The agency approving the project -- referred to as the Lead Agency -- is required to conduct a public review of the project's potential environmental impacts, to consider those impacts prior to making a decision on the project, and to impose feasible mitigation or alternatives needed to ensure that the project does not cause any significant unmitigated impacts. If the project will cause significant impacts, and mitigation and alternatives are infeasible, the Lead Agency may license the project if it finds, in writing, that benefits of the project outweigh the unavoidable adverse environmental effects.

Of particular interest in the re-licensing of projects using once-through cooling is CEQA's focus on evaluating the *change* in the environment. Under CEQA, determining whether project impacts are significant requires comparing those impacts to a "baseline", which normally consists of the physical conditions in existence at the time the project application is filed. (Cal. Code Regs., tit. 20, § 15125(a).) Thus, if the project is already using once-through cooling, there may be no change or a reduction in water use (e.g., water use for once-through cooling may be projected to continue at the same or lower levels as before re-licensing), or changes in water use may be extremely difficult to evaluate (e.g., water use for once-through cooling may be projected to increase over some short-term periods, but decrease over others). As can be seen in the discussion below, the "baseline" concept is not reflected in other laws applicable to a project's use of once-through cooling.

Porter-Cologne Water Quality Control Act

The Porter Cologne Water Quality Control Act (Water Code, § 13000 et seq.) establishes certain state water quality policies. The Act specifically addresses power plants using once-through cooling. Section 13142.5(b) of the California Water Code states that:

> For each new or expanded coastal power plant or other industrial installation using seawater for cooling, heating, or industrial processing, the best available site, design, technology, and mitigation measures feasible shall be used to minimize the intake and mortality of all forms of marine life.

(Water Code, § 13142.5, subd. (b).). This statutory policy is one of several adopted by the Legislature or the State Water Quality Control Board providing principles, guidelines, and objectives for water quality control throughout the state. The statutory policy in section 13142.5(b) appears to establish a higher level of environmental protection in coastal areas than CEQA, as it directs "minimization" of mortality, regardless of the levels of existing water use. However, both this section and CEQA direct agencies to consider feasibility in establishing the mitigation requirements applicable to facilities using once-through cooling.

Federal Clean Water Act

The federal Clean Water Act (33 U.S.C.A, § 1251 et seq.) addresses a broad range of water quality issues and imposes a series of permitting requirements applicable to power plants. In addition to point and non-point source discharge requirements, section 316(b) of the Act (33 U.S.C.A § 1326) requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. In California, this permit program (called the National Pollution Discharge Elimination System, or "NPDES", program) is administered by the State Water Resources Control Board and the nine Regional Boards, via a Memorandum-of-Agreement, entered into between the federal Environmental Protection Agency (USEPA) and the State Water Board in 1989. Thus, although the NPDES permits are state permits, under the MOA, it is the State Water Board and the Regional Boards-- not the Energy Commission -- that are responsible for ensuring compliance with the NPDES program. As such, the NPDES permits are an exception to the exclusive permitting authority granted to the Energy Commission in Public Resources Code section 25500. NPDES permits have a term of five years and must therefore be renewed on a regular basis.

Although the Regional Boards issue NPDES permits for power plants in California using once-through cooling, the USEPA is responsible for establishing the standards that are implemented through these permits. USEPA originally published guidance for section 316(b) determinations in 1976; these were challenged, by Riverkeeper and other environmental groups, and subsequently remanded to USEPA by the U.S. Court of Appeals for the 4th Circuit. USEPA withdrew the remanded rule and permitting agencies determined compliance with section 316(b) on a case-by-case basis. In August 2002, the USEPA published Phase I of the new regulations for new intakes. On February 16, 2004, as a result of a consent decree, USEPA published rules (Phase II) applicable to cooling water intake structures at existing power plants. These are the rules that now apply to re-licensing existing power plants using once-through cooling.

The new rules establish a performance standard consisting of an 80 – 95 percent reduction in impingement and a 60 – 90 percent reduction in entrainment relative to a facility with minimal controls. (Since most power plants using once-through cooling in California are not utilizing significant levels of control, this standard would result in a reduction in entrainment and impingement relative to existing levels.) USEPA identified four major compliance options: 1) installing technology that reduces water use to that achieved with a closed-cycle cooling system, 2) using operational technologies or controls or restoration measures that achieve the performance standard, 3) using a submerged cylindrical wedge-wire screen, or 4) making a site-specific determination that the costs of compliance with the new standard are significantly greater than the environmental benefit associated with the performance standard. The rule also establishes a detailed set of requirements for data submission at the expiration of current permits and provides extensive guidance on measurement issues and the role of restoration in determining compliance with the new standards. In July 2004, a coalition of environmental groups challenged the rule in the U.S Court of Appeals for the 2nd Circuit. No decision has been issued.

There is uncertainty about how the Regional Water Quality Control Boards will implement the new section 316(b) standards in California. Power plant owners have until January 2008 to comply with the new regulations. It is unclear how the Regional Boards will define the baseline to which each facility will be compared to meet the required impingement and entrainment reductions. Furthermore, it is unknown how lenient the Regional Boards will be in permitting power plant operators to determine that the cost of reducing impingement and entrainment are much greater than the anticipated environmental benefits.

One pending permit for a power plant using once-through cooling -- that for the Morro Bay facility -- has been undergoing regulatory review at the Central Coast Regional Board since Fall of 2004, with no hearing date currently scheduled. Given the controversy surrounding the new standards, and the ongoing litigation, it is likely to be several years before there is a clear understanding of how the new rules will affect re-licensing of power plants using once-through cooling.

California Coastal Act

Notwithstanding the Energy Commission's exclusive licensing authority, the Warren-Alquist Act calls out a special role for the California Coastal Commission. Specifically, under provisions of the California Coastal Act, the Coastal Commission is directed to participate in the Energy Commission's licensing proceedings for projects located in coastal areas and to prepare a written report on the suitability of the project. (Public Resources Code section 30413(d)). The statutory provisions state that the report shall contain "a consideration of, and findings regarding" seven specific issues, including "the conformance of the proposed site and related facilities with certified local coastal programs ..." If the report identifies that specific provisions are necessary to meet the objectives of the Coastal Act, the Energy Commission must include those provisions in any decision approving the project, unless the Energy Commission finds that they would result in greater adverse impact on the environment or are not feasible. (Public Resources Code section 25523(b))

Therefore, where the Coastal Commission has identified provisions necessary to achieve conformity with Coastal Act policies, the Energy Commission can *only* remedy that non-conformity by including the provisions identified in the suitability report in its final decision on the project, or by making the findings identified in Public Resources Code section 25523(b). The Energy Commission cannot otherwise determine that the project without the provisions identified by the Coastal Commission is nonetheless consistent with the policies of the Coastal Act.

Several Coastal Act policies are typically addressed during the re-licensing of power plants using once-through cooling. Specifically, Public Resources Code section 30230 states that marine resources shall be maintained, enhanced, and where feasible, restored. Similarly, Public Resources Code, section 30231 identifies a policy of minimizing the adverse effects of entrainment. There are other policies involving visual resources, biological resources, and other environmental issues that the Coastal Commission may address as well, but the Coastal Commission has cited these two sections as support for its findings on the compliance of power plants using once-through cooling with Coastal Commission policies protecting marine resources. Explicit inclusion of restoration of marine resources in the state policy appears to provide a higher level of protection than available under either CEQA (which requires avoidance of significant adverse impacts), section 316(b) (which requires a percentage reduction in impingement and entrainment mortality), and the Porter Cologne Water Quality Control Act (which requires minimization of intake mortality).

McAteer-Petris Act

The McAteer-Petris Act has long served as the key legal provision under California state law to preserve San Francisco Bay. The role of San Francisco Bay Conservation and Development Commission in the Energy Commission process is parallel to that of the California Coastal Commission, although Bay Conservation and Development Commission jurisdiction is limited to the San Francisco Bay. Similar to the California Coastal Commission, the Bay Conservation and Development Commission is required to participate in the Energy Commission siting process, make findings of the project's conformity with the San Francisco Bay Plan, and provide a report to the Energy Commission listing the "specific provisions" (i.e., mitigation) necessary to meet the requirements of Bay Conservation and Development Commission's statute. The Bay Conservation and Development Commission recommendations included in its report must be adopted by the Energy Commission "unless the [Energy] Commission specifically finds that the adoption of the provisions specified in the report would result in greater adverse effect on the environment or the provisions proposed in the report would not be feasible." (Public Resources Code, § 25523(c).) Currently, three once-through cooled coastal power plants (Potrero, Hunters Point, and Pittsburg) fall under Bay Conservation and Development Commission jurisdiction.

Federal and State Endangered Species Acts

Both the Federal and State Endangered Species Acts provide protection for various species that have been formally listed as threatened or endangered. If listed species or habitats have the potential to be harmed by the use of once-through cooling, consultation with the appropriate resource agencies is required. The California Endangered Species Act is administered by the California Department of Fish and Game. The Federal Endangered Species Act is administered by the U.S. Fish and Wildlife Service and (for marine species) the National Marine Fisheries Service (NMFS).

Magnuson-Stevens Fishery Management and Conservation Act

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 *et seq*.) was passed to take immediate action to conserve and manage the fishery resources found off the coast of the United States. Section 395 (b)(4)(A) of this act specifies that if NMFS determines that any action undertaken by any state or federal agency would affect any essential fish habitat, it recommends measures that can be taken by such agency to conserve such habitat. Once-through cooling systems in marine and estuarine waters affect Essential Fish Habitat. Congress defined Essential Fish Habitat as "those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. 1802(10)).

California's Existing Legal Framework Is Complex and Poorly Integrated

As described above, the legal and regulatory framework regarding once-through cooling systems for power plants in California consists of a multi-layered assortment of federal, state, regional and local laws (e.g., the federal and state Clean Water Acts, Endangered Species Acts, Coastal Acts, CEQA, etc.). In addition to this complex regulatory environment, there are several other factors that complicate efforts to analyze the effects associated with the use of once-through cooling in California power plants. These factors include the following.

First, as mentioned elsewhere in this report, currently there are 21 separate power plant sites utilizing 30 individual once-through cooling intakes in California. These facilities are deployed at different locations along the California coastline, ranging from Humboldt Bay in the north, through San Francisco Bay, the Central Coast region, the Los Angeles region, and Orange and San Diego Counties in the south. Because of this wide ranging deployment, regulatory agencies with jurisdiction over these facilities normally differ depending on the specific location of the facility in question. Thus, for example, there are seven separate California Regional Water Quality Control Boards (North Coast, San Francisco, Central Valley, Central Coast, Los Angeles, Santa Ana, and San Diego) with water quality permitting jurisdiction over these power plants depending on the specific location of the facility under review. These differing regulatory agencies do not always apply the existing regulations in a consistent manner. And, there is some uncertainty as to the role of the State Water Resources Control Board in applying the new federal regulations.

Second, no single regulatory agency has jurisdictional authority over all 21 once-through cooling facilities in California. For example, under the Warren-Alquist Act the California Energy Commission only has jurisdiction over "new" or "modified" thermal facilities with expansions exceeding 50 MW or more. (*See*, Public Resources Code section 25123 regarding "modification of an existing facility.") Thus, many once-through cooling facilities built prior to 1975 are not subject to the Energy Commission's jurisdiction at this time, nor are new or modified facilities which add less than 50 MW of net capacity to their site. Similarly, while the California Coastal Commission has jurisdictional responsibilities for many of these once-through cooling facilities, at least four facilities are *not* subject to Coastal Commission jurisdiction (Hunters Point, Potrero, Contra Costa and Pittsburg). Thus, there is no single regulatory agency with the legal authority to regulate all 21 plants in a comprehensive and consistent manner.

Third, the ecology and topography where these 21 power plants are located is diverse and, consequently, differing environmental regulations may need to be applied to facilities in differing locations. For example, the Humboldt Power Plant is located on a bay where salmon, steelhead, and other threatened or endangered salmonid fish species live. However, these particular species do not live in San Diego Bay, where the South Bay Power Plant is located. Accordingly, the applicability of federal and/or state "Endangered Species" regulations will differ depending on the particular location in question.

In short, California's existing regulatory framework for power plants using once-through cooling technology is complex, and multi-layered. Furthermore, in some specific cases, agencies administering the regulations for which they are responsible have been in conflict about applicable requirements. For example, for the recent El Segundo Generating Station Power Redevelopment Project, Los Angeles Regional Water Quality Control Board staff took the position that impingement and entrainment issues should be addressed by the Regional Water Board under the NPDES permit and the new section 316(b) regulations rather than through the Energy Commission's siting process. However, the Coastal Commission recommended that the Energy Commission impose specific provisions regarding once-through cooling in order for the project to be consistent with the California Coastal Act.

CHAPTER 6:MITIGATING, REDUCING AND ELIMINATING IMPACTS OF ONCE-THROUGH COOLING

Findings:

- Alternative cooling methods can greatly reduce or completely eliminate the impacts of once-through cooling.
- Flow reduction is an effective way to reduce impingement and entrainment impacts.
- Other entrainment and impingement reduction methods such as changes in intake location or physical or behavioral barriers have not proved to be feasible and/or effective for most power plants.
- Because retrofitting existing intakes or switching to an alternative cooling system may be costly or technically challenging, mitigation for once-through cooling impacts often takes the form of habitat restoration.
- Methods to reduce the effects of thermal discharges include relocation, design modifications and operation options. While some of these methods may be expensive, they are usually effective.

Power plant owners can attempt to compensate for impacts by mitigation (producing, restoring or protecting habitat equivalent to what is lost, or by replacing the organisms killed), by reducing the impacts through modifications of the cooling system and/or how it operates, or eliminating them by using alternative cooling systems. Alternatively, agencies may not require changes to reduce impacts and plant owners may choose to do nothing without being required. The latter may occur at the South Bay Power Plant (Foster 2005). Prior to the California Coastal Commission's action at the San Onofre Nuclear Generating Station, state agencies apparently required little or no modification or mitigation to reduce impacts of normal cooling system operation. Numerous power plants in Southern California voluntarily modified their cooling system intakes in the 1970s to reduce impingement (installation of velocity caps). Since then, the Energy Commission has required mitigation via habitat restoration and preservation at Moss Landing, and the Central Coast Regional Water Quality Control Board is requiring mitigation at the Diablo Canyon and Morro Bay power plants. The owner of the Moss Landing Power Plant voluntary modified the cooling system intake (reduced intake tunnel), which reduced impingement.

Once-through cooled power plants also impact the local environment when they discharge the heated cooling water, so the last portion of this section discusses thermal discharge impact minimization measures.

Alternative Cooling Systems That Can Eliminate Most If Not All Once-Through Cooling Impacts

Dry Cooling Can Eliminate or Greatly Reduce Cooling Water Demand

Air cooled condensers (ACC) or direct dry cooling can eliminate the use of seawater entirely. Instead of transferring the heat to cooling water as in once-through cooling, an ACC radiates the heat from the stream in the condenser directly to the atmosphere. An ACC consist of flanged tube bundles arranged in an "A" frame configuration. To ensure adequate air movement through the ACC, numerous large fans are used.

In California, there are eight operating power plants using ACCs, with an addition one currently under construction. The majority of these plants, are small, most with capacities significantly less than 25 MWs. The two largest air cooled power plants within the state are the 540 MW Sutter Power Plant in Sutter County and the 240 MW Crockett Power Plant in Contra Costa County. Currently under construction is the 510 MW Otey Mesa Generating Project in San Diego County.

While significant amounts of water can be saved by the use of dry cooling, the savings come at a price in the form of a higher plant capital cost, reduced power production, increased fuel consumption as a result of lower plant efficiency, higher plant operating power requirements and hence higher operating costs, all resulting in a reduction in potential revenue from the power generation operation. Quantifying costs is difficult because any power plant can be designed to deal with a higher design ambient temperature and thus use a larger ACC. This would improve capacity on a hot day, reduce the fall-off between design and hot day performance, but incur higher capital and parasitic load costs.

The estimated capital cost for the 540 MW Potrero Unit 7 power plant project ACC is approximately $35 million as opposed to the $25 million for the new intake and outfalls needed for the use of once-through cooling technology.

Higher operating costs include providing the parasitic load for the fans needed for an ACC. This load may be as high as 8 MW for a 500 MW plant. There is also a loss of capacity for a plant using an ACC as compared to use of once-through ocean cooling. This capacity loss occurs when ambient temperatures exceed the ACC design point sufficiently enough that load needs to be dropped to avoid tripping the turbines off. This potential loss occurs during the hottest hours of a year and may range from zero to 25 MW. The cost of this loss is difficult to quantify because it is tied to the design (size) of the ACC. There is also an efficiency loss due to a higher heat rate for a power plant with an ACC in comparison to a facility using once-through cooling. This heat rate means more natural gas will be burned to generate a specific amount of electricity in comparison to a once-through cooling power plant. The higher heat rate will also increase with higher temperatures. Depending on the design of the ACC, this efficiency loss may vary from zero to 25 MW for a 500 MW plant, that is from about zero to 5 percent. A 5 percent loss could amount to $7.5 million per year. Other major disadvantages of an ACC compared to once-through ocean cooling are likely to be noise and visual impacts.

Cooling Towers Can Substantially Reduce or Eliminate the Need for Seawater

Conversion from once-through cooling to re-circulating cooling can reduce cooling water demand by up to 95 percent. This cooling process recycles the water as it passes the condenser several times with the heat dissipated to the atmosphere in the cooling towers. This large reduction in cooling water demand results in a similar reduction in entrainment and impingement impacts as well as thermal discharge levels. However, re-circulating cooling does reduce plant efficiency, a significant portion of the water used is evaporated, and blow down from the cooling water system requires disposal. The discharge of cooling tower blow down is concentrated so that essentially all the incoming chemical salts are discharged back to the ocean, while only the water is evaporated in the stream.

The capital cost of this system has been estimated to be approximately $10 to $12 million over the cost of once-through cooling. Salt water cooling towers must use corrosion resistant materials and low drift design to minimize dispersal of corrosive droplets. They can be designed to operate at lower condenser pressure than ACC but higher than once-through cooling. Maximum capacity loss would be 7MW compared to once-through cooling. Operation costs other than capacity and efficiency should be minimal; not more than $2 million per year. Disadvantages of an ocean water cooling tower include continued, although reduced, use of sea water, noise, visibility of the vapor plume, and visibility of the cooling tower. At present, all inland base load power plants, except for the Sutter Power Plant and the Crockett Power Plant, use cooling towers. Although cooling towers may be more expensive than once-through cooling, clearly this cooling technology is feasible since the vast majority of inland power plants use this form of cooling.

Using Wastewater for Cooling Can Eliminate Impingement and Entrainment Impacts

The substantially reduced flow levels of a cooling tower system make alternative sources of cooling water, such as wastewater effluent, feasible. Wastewater rather than seawater may be treated appropriately (in accordance with California Title 22) and used for feedwater to a cooling tower. Treated wastewater is less corrosive than ocean water so cooling tower construction materials may be less costly than is the case with salt water. Wastewater treatment requirements must be determined at each specific site since the requirement may vary depending on locale with respect to public proximity. Given ideal conditions, treatment may be minimal (chlorination only), but under more difficult conditions may include tertiary treatment, which can increase the cost substantially. There is substantial experience using this concept, for instance at the Magnolia Plant of the City of Burbank. Practicality depends on the distance to a sewage treatment facility of adequate size for the application.

Advantages and disadvantages of this system are very much dependent on local conditions including the location of the sewage treatment plant, the geography between the power plant and the treatment plant, and the amount of land available at the power plant. But, in the situation where the sewage plant is close and piping costs are reasonable, the capital cost may be lower than for an ocean water cooling tower. This advantage will be partially offset by the increased condenser pressure compared to an ocean water cooling tower.

The major advantages of this option are the reduction of sewage flow to the ultimate disposal location and the elimination of ocean water for power plant cooling. All solids and dissolved chemicals that are input to the cooling tower will still be discharged, but in a concentrated form.

The disadvantages of a cooling tower system using a cooling water source other than sea water are the higher cost than once-through cooling, the potential vapor plume (although plume abatement is practical with this water source), noise, and performance penalties similar to the ocean water cooling tower.

Treated wastewater also may be used for direct cooling a power plant rather than a cooling tower system. A repowering project was proposed and approved by the Energy Commission for the El Segundo generating plant site in Los Angeles County. This power plant is located within 1.25 miles of the Hyperion Wastewater Treatment Facility of the City of Los Angeles. The Hyperion waste treatment facility has a capacity of 450 million gallon per day (mgd), whereas the El Segundo repowering facility proposes to use 207 mgd ocean water for cooling. Due to concerns about entrainment impacts of once-through cooling, Energy Commission staff proposed that the project owner use the Hyperion wastewater for cooling and return the water to the waste treatment facility after use. Capital costs to do so were estimated to be $12 million. Operation cost was expected to be slightly greater due to efficiency loss since the wastewater is slightly warmer than ocean water; a cost of the order of $1 - 2 million dollars per year. It was expected that some cost would be incurred to obtain the wastewater, but this was not negotiated with the City of Los Angeles which did not indicate a willingness to sell the treatment plant wastewater to the project.

Flow Reduction is a Reliable Way to Reduce Impingement and Entrainment Impacts

As discussed above, alternative cooling technologies and/or alternative cooling water sources are the most effective way to reduce the flow of seawater and associated impingement and entrainment impacts. Other flow reduction options are operational approaches to reduce the volume of cooling water used on a seasonal or daily basis. There are a variety of options to reduce intake flows including repowering to combined-cycle combustion technology, seasonal outages and variable speed pumps.

Conversion to combined-cycle combustion technology through repowering a power plant can significantly reduce water demand. Combined-cycle generation generally consists of two gas-fired turbines coupled with a heat recovery steam generator which utilizes the waste heat from the gas turbines to create steam to run a steam turbine. Therefore, two-thirds of the electricity comes from the gas-fired turbines, which require no cooling water, and only one-third from the steam turbine that does require cooling water to condense the steam, resulting in an approximately 67 percent reduction in cooling water withdrawals and a similar reduction in fish kills (Super 2005). For example, Moss Landing Power Plant Units 6 & 7 with a capacity of 1,478 MW require 600,000 gallons per minute of cooling water while the two new combined-cycle units (Units 1 & 2) with a capacity of 1,060 MW only require 250,000 gallons per minute of cooling water.

Many power plants use one or more single speed pumps to withdraw cooling water. When operating at less than full capacity, power plants with single speed pumps cannot adjust the volume of water withdrawn without shutting pumps off. Many of the coastal power plants run at lower capacity factors, so they entrain an disproportionate amount of water and organisms when they are producing reduced amounts of electricity. Variable speed pumps allow plants to scale down their water withdrawals to match decreased generation output thereby reducing entrainment and impingement levels. The speed of the variable speed pumps increase or decrease depending on load levels. The amount of cooling water withdrawn increases or decreases accordingly. The amount of reduction depends upon many variables, including a plant’s capacity factor, the number of pumps operating, the volume each pump can withdraw, and thermal discharge limits (Super 2005). For example, the variable speed pumps to be installed in the Pittsburg Power Plant would, when load levels are at minimal levels, withdraw only 70 percent of the design cooling water intake flow. PG&E (Central Coast Regional Water Quality Control Board 2003) estimated that the cost of installing variable speed pumps would be $6.7 million.

Seasonal reductions in cooling water intake during periods when sensitive species are present are another option for reducing entrainment and impingement of special status species. In California, the only area where such seasonal patterns are apparent is within the San Francisco Bay and Delta. To reduce entrainment of larval stage striped bass from approximately May 1 to mid-July, the Pittsburg and Contra Costa power plants operate under a program known as the “delta dispatch.” This program requires the operator to dispatch power production from Pittsburg Unit 7 to meet system demand, in place of and before dispatching the other units at the Pittsburg or Contra Costa power plants. The operator of both power plants will use the variable-speed circulating water-pump drives whenever the units operate at reduced loads and shut off circulating water pumps for uncommitted units as soon as feasible (NPDES permit). Pittsburg Power Plant Unit 7 uses re-circulating cooling (cooling towers) and therefore does not have the large water demand of the other units at Pittsburg and Contra Costa require.

Other Methods of Reducing Entrainment and Impingement

The following discussion identifies potential measures that power plant owners could propose as “best technology available” to reduce entrainment and impingement at existing power plants using once-through cooling technology. It should be noted that the suitability, efficiency, and cost of any one approach are dictated by site specific conditions. These conditions include: the nature of the existing cooling water intake structure; cooling water demand; water intake velocity; characteristics of the species affected; near shore bathymetry; and water levels and currents.

USEPA (2004) provides capital and operating and maintenance costs for many of these approaches to reducing entrainment and impingement based upon data from existing installations and from vendor estimates. In addition, there are other sources of estimates on potential costs to add or modify intake systems to minimize entrainment and impingement. Where relevant, this information is provided. Taft and Cook (2005) provide capital and operating and maintenance costs, based upon existing installations, for over 35 power plants of various sizes and locations. This cost information is summarized in Table 3 (below), however these cost values are for reference only. Actual costs are dictated by site specific concerns and cost factors such as lost generation are not reflected. It should also be noted that the cost of measures to address impacts from once-through cooling can not be wholly disproportionate to the benefits to be gained. Since most approaches to reduce impacts have significant costs, this points out the need to develop standardized methods for assigning a dollar figure. Methods to address the economic values of ecological losses from once-through cooling are described in the last section of this paper, and in more detail, in Appendix 5.

Table 3 - Annualized Average Cost Ranges in 2002 Dollars for Fish Protection Technologies Based Upon Historic Data

Technology	Capital Costs	Operation & Maintenance Costs
Aquatic Filter Barrier	$30,974,000	$2,263.000
Behavioral Barrier	$2,633,000	$180,000
Coarse Mesh Ristroph Screen	$6,830,000	$546,000
Fine Mesh Ristroph Screen	$10,867,000	$609,000
Fixed Panel Screen	$3,818,000	$251,000
Narrow Slot Wedge-Wire Screen	$25,240,000	$640,000
Wide Slot Wedge-Wire Screen	$2,595,000	$163,000
Velocity Cap	$8,608,000	$42,000

Source: Taft and Cook (2005)

Location Options

Location options refer to actually moving the location of the intake to reduce entrainment or impingement. The location of the cooling water intake structure may have a great influence on the level of entrainment and/or impingement that is occurring. Relocating the intake structure to an area of lower sensitivity or biological productivity, may provide an opportunity to significantly reduce entrainment or impingement levels. In California, normally the best option is to move the intake to deeper, less biologically productive water. For example, since the shoreline cooling water intake at Diablo Canyon entrains species that spawn in the near shore area, moving the intake to an offshore, less biologically productive location was considered by the Central Coast Regional Water Quality Control Board as part of the 316(b) evaluation. The estimated capital cost for extending the intake ($105 million) was not considered commensurate with the impacts and therefore was not implemented. Instead, habitat restoration was selected to mitigate impacts. USEPA (2004) identifies an average cost of $134,000 for relocating an existing intake to a submerged offshore location with a passive fine-mesh screen inlet. For the South Bay Power Plant, extending the intakes 4,500 feet beneath San Diego Bay, the Silver Strand Beach and out into the Pacific Ocean with an estimated cost of approximately $100 million was one alternative considered by the San Diego Regional Water Quality Control Board (Tenera 2004). For the South Bay Power Plant, the Regional Board has directed the power plant operator to reduce entrainment impacts, but did not specify how this was to be accomplished. Although these two examples reflect relocating the intakes a significant distance, it is likely that extension or relocation of intakes for any of the California plants would involve a significant distance with associated cost, much greater than that identified by USEPA.

Design Options

Design options to help reduce entrainment and impingement include: the use of barriers which physically preclude aquatic organisms from moving into the intake; fish handling systems which collect and safely return fish to the water; diversion systems, which divert fish to bypasses for return to a safe release location; and behavioral barriers, which rely on sensory stimuli, such as light or sound, to elicit behaviors that result in a fish avoiding or swimming away from the intake or to a fish handling system. The following discussion describes those technologies that show the greatest potential for application in California and is not an exhaustive review. More complete reviews of these technologies can be found in USEPA (2001, 2004, 2005), Taft and Cook (2005) and EPRI (1986, 1994b, 1999). Trash racks and traveling screens with 3/8” mesh or smaller to exclude debris are standard on California power plants. This equipment provides absolutely no entrainment protection for smaller organisms, but it may reduce impingement of juvenile and adult fish.

Traveling Screens and Fish Return Systems

Almost all cooling water intake structures in California use traveling screens. These screens consist of screen faces on a rotating belt arranged perpendicular to the flow. Screen mesh sizes range from one inch or less. Most facilities use 3/8” mesh or smaller. A high pressure spray is used to dislodge debris from the screen. Factors influencing impingement mortality with traveling screens include operating parameters, through-screen intake velocity, screen mesh size, spray pressure, and fish handling systems. Many screens are operated only intermittently.

Operational and design modifications to traveling screens can significantly improve impingement mortality. Since impingement mortality increases when the screens are not operating, continuous operation can reduce mortality, if not overall impingement (USEPA 2004; EPRI 1999).

Higher through-screen flow velocities also increase impingement. USEPA (2004) has set a maximum through-screen velocity of 0.5 feet per second; and a facility meeting this flow velocity is considered by USEPA to have met the impingement mortality performance standard. Finer screen mesh will reduce the amount of entrainment as well as allow easier escape for impinged fish.

Traveling screens fitted with a fish collection system, known as Ristroph screens, are modified with troughs or buckets to carry water which safely contains collected fish. Once the bucket is carried over the top of the screen, the fish are spilled or washed into a sluiceway and returned to the source water body (USEPA 2004; EPRI 1999). Fish return systems reduce impingement mortality, not entrainment, although the use of sufficiently small enough screen mesh, approximately 1.0” or less, may also reduce entrainment by impinging species. Survival of early life stages impinged on fine mesh screens is highly dependent on the species and the life stage (EPRI 2003). Taft and Cook (2005) contend that impingement mortality on fine mesh screens can exceed entrainment mortality.

USEPA (2004) has identified three facilities within the state as using modified traveling screens with a fish handling system. Factors affecting the cost of such systems include the number of screens required, the total screen area, through-screen flow velocity and whether the intake structure needs to be modified (Taft and Cook 2005). Nationwide cost estimates for such systems range from $20 million to $130 million. For the Huntington Beach Generating Station, equipped with conventional traveling screens with 3/8” wire mesh, retrofitting the screens with fine mesh (<0.5 mm) panel overlays was estimated to cost $ 2.4 million with operating and maintenance costs of about $255,000 (AES HBGS 2005). Additional water pumps and a fish return flume would add more than $500,000 to capital costs; other costs, such as excavation beneath Highway 1 were not addressed.

Wedge-wire Screens
Another technology with the potential to reduce both entrainment and impingement is the use of a wedge-wire screen. Cylindrical wedge-wire screens consist of a wedge-shaped wire welded to a large frame to form a slotted screen element (EPRI 2003). For these screens to be effective, the screen slot size must be small enough to block passage of the eggs and larva of the species being protected, there must be low through slot flow velocities, from 0.5 to 1.0 feet per second to avoid creating a flow which will entrain additional organisms, and ambient cross currents must be present to clean the screen face (EPRI 2003; USEPA 2004).

Large-scale applications of wedge-wire screens to cooling water intakes have been limited to two plants in the eastern United States where relatively large slot openings (6.4 and 10.0 mm) have been used (Taft and Cook 2005; Amaral 2005). Since the only two large scale applications use such large slot openings, the potential for clogging and fouling with slot sizes small enough to prevent entrainment is unknown. Wedge-wire screens have been applied at power plants with lower cooling water intake flows. Results from an evaluation at Chalk Point Generating Station in Maryland show that entrainment was reduced by 80 percent, with no information available on impingement (USEPA 2001).

Laboratory evaluation of wedge-wire screens with eggs and/or larvae of nine fish species using 1, 2 and 3 mm slot sizes indicates that impingement decreased with increases in slot size while entrainment increased with increases in slot size and both entrainment and impingement increased with greater through slot flow velocities (EPRI 2003). A follow-up study is being conducted by EPRI to test a pilot scale wedge-wire screen under a variety of operating conditions (Taft and Cook 2005).

Due to the need for cross currents to keep the cylindrical wedge-wire screens clean, this technology is most applicable for those facilities with offshore intakes. For those facilities with on-shore intakes, use of a passive T screen configuration with fine mesh and a fish handling system would be more practical.

Site-specific factors influencing cost estimates for wedge-wire screens include slot size, flow, water depth, fouling potential and current site configuration (Taft and Cook 2003). USEPA (2004) estimates the construction cost of adding a cylindrical wedge-wire screen with a mesh width of 1.75 mm to average about $4.6 million. Operation and maintenance costs would add on average another $80,000 per year.

Aquatic Filter Barriers
Another recent technology, designed to address both impingement and entrainment, is the aquatic filter barrier (AFB). The AFB is a semi-permeable mat of polyester fibers (EPRI 2004) that will allow water through the filter while

excluding aquatic organisms. The AFB is floated and anchored in front of the intake to provide protection through the water column. The AFB is commercially available as the Marine Life Exclusion System from Gunderboom. An air burst system is attached to the AFB to displace collected sediment and organisms. Perforation sizes vary and can be as small as 0.02mm. Large perforation sizes allow a higher through-barrier water flow and facilitate cleaning. Deployment requires a large enough area to be incorporated within the barrier to ensure sufficient water is available to meet intake flows. Since through-barrier flows are limited to 10gpm/ft^2 (0.02 feet per second), a large area is required for facilities using once-through cooling technology. Therefore, for facilities where navigation is a concern, such as at Moss Landing where the cooling water intake is within the harbor, this technology is probably not practical.

There has only been limited applications of this technology, none approaching conditions similar to what is present in California. The greatest amount of work with the AFB has occurred at the Lovett Generating Station on the Hudson River in New York. Tests in 2000 between an AFB protected and an unprotected intake showed the barrier provides an 80 percent reduction in entrainment (Rafenberg 2005). Laboratory studies associated with this effort indicated that contact with the fabric did not cause mortality.

Other laboratory studies on retention and survival of the early life stages of fish exposed to aquatic filter barrier fabric were conducted for EPRI (2004). The test evaluated the survival of fish eggs and larvae for several species at different perforation sizes and flow rates. Results indicate that for the barrier material with 0.5 and 1.0 mm perforation sizes provided a high level of entrainment protection for the species tested. The material with the 1.5 mm perforations was less effective in preventing entrainment (EPRI 2002). A major concern with the AFB is long term resistance to bio-fouling.

Bio-fouling can reduce the permeability of the fabric to water and damage the material (Henderson 2005). Testing of the AFB material in a pond showed that the fabric can be quickly fouled, with permeability reduced close to 97 percent on the panel tested and that use of the airburst system actually enhanced bio-fouling (Henderson 2005).

A demonstration of the AFB was required for the Contra Costa Power Plant to comply with a Habitat Conservation Plan, however it has not been implemented and is unlikely to be installed since it has been determined that it is infeasible. Although the AFB has been deemed best technology available by the New York Department of Environmental Conservation and required for several power plant projects, the ability of the AFB to successfully reduce entrainment under bio-fouling, tides, high wind and water current conditions and being deployed year-round remains to be seen.

Estimated costs for deploying a 3,000 foot long AFB (66,000 ft^2 total filter area) is $7.85 million for the Arthur Kill Station in New York. This cost does not include the cost of dredging and spoil disposal which will also be required. Operation and maintenance costs may be as much as $500,000 per year (Henderson 2005).

Behavioral Barrier Technologies

Behavioral barrier technologies employ sensory stimuli such as light or sound to induce fish to avoid a cooling water intake and reduce overall impingement. Mechanisms that fish use to respond to auditory and visual stimuli are not well understood and many responses appear to be species-specific. Therefore, responses can be highly variable, depending on species present and environmental conditions.

Sound is directional, rapidly transmitted through water, is unaffected by turbidity and light changes, and is used by fish for general environmental cues. There is uncertainty in the frequencies fish use and different species may respond to only narrow ranges of sound, and there may be day/night differences in responses as well (Ross et al. 1993, 1996). Low frequency sounds have not proved effective in field testing while higher range frequencies (>100 Hz) show promise with some species (EPRI 1999). The most commonly used acoustic barrier is the “popper” which is used to elicit a startle response in fish. Tests at the Pickering Power Plant in Ontario showed reductions in alewife impingement by 73 percent in 1985 (USEPA 2004). The use of the “popper”, however, did not reduce impingement for smelt and shad species.

Light is also directional, transmitted rapidly through water and is not masked by noise, but may be affected by turbidity (Anderson et al. 1988). Species may be attracted or repelled by light and responses of species may vary with fish size, development, and physiology and other factors. Mercury and strobe lights have been tested on different species in the laboratory and field with strobe lights showing the greater promise. Once again, effectiveness is generally species specific.

For the San Onofre Nuclear Generating Station, mercury lights were used for one year with no discernable effect (California Coast Commission 2000). Efforts to use strobe lights indicated the lights repelled some species but attracted the Pacific sardine. Use of sound devices, electric barriers and air bubble curtains were considered infeasible and were not implemented.

Use of behavioral devices may offer lower capital and operating cost options and may partially reduce fish entrainment, but do not provide sufficient protection except, perhaps for efforts focusing on a specific species. Use of behavioral barriers in conjunction with other entrainment and impingement controls may be a more effective approach.

Technologies to Help Minimize Thermal Discharge Impacts

Thermal discharges from one-through cooling plants must meet the Section 316(a) of the Clean Water Act requirement of "…protection and propagation of a balanced, indigenous population of shellfish, fish….", as well as the numerical and narrative standards set forth by the State Water Resources Control Board (1975) in the Thermal Plan. The aim of these standards is to protect beneficial uses of the receiving water. Although specific numerical standards in the Thermal Plan apply under certain conditions, variances allowing exceedances of applicable standards are available. Thermal discharge is regulated in California by the Regional Water Quality Control Boards through the NPDES permit.

Many California power plants discharge the once-through cooling water at shoreline outfalls. For the Alamitos facility, three channel bank outfalls discharge directly into the San Gabriel River. Other facilities use channels to convey the discharge water from the power plant to the receiving water body. For example, the Morro Bay Power Plant outfall is a 100-foot channel. For the South Bay Power Plant, a discharge channel is used to convey cooling water to San Diego Bay. Other facilities utilize offshore outfalls. For San Onofre, multi-port diffusers run from slightly more than one mile to one mile and a half offshore.

Similar to those available to reduce entrainment and impingement, a variety of opportunities are available to reduce the effects of thermal discharges, including relocation, design, and operation options.

Relocating the discharge outfall to deeper water can enhance mixing of the thermal plume, reducing the area affected by the higher elevated temperatures or removing the thermal plume from proximity to sensitive biological resources, such as sea grass beds. One example considered by the Central Coast Regional Water Quality Control Board to bring Moss Landing Power Plant Units 6 & 7 into compliance with the thermal plan was to move the outfalls into deeper water 700 feet out into Monterey Bay. This would avoid having the thermal plume affect the shoreline and was estimated to cost approximately $20 million. This option was not pursued because combining the discharge from the new combined cycle units with the existing units reduced the temperature of the discharge and resolved the violation of the Thermal Plan standards. To address thermal impacts from the Diablo Canyon power plant, the Central Coast Regional Water Quality Control Board evaluated relocating (extending) the cooling water outfall to deeper water approximately 1,125 feet offshore. Tetra Tech (2002) estimated that the capital costs for extending the outfall would be $154 million, a cost the Regional Board found wholly disproportionate to the resulting benefits. Offsite restoration was selected to mitigate the thermal effects from the power plant.

Design options for reducing thermal effects from power plants are mainly limited to changing the type of discharge outfall used to enhance mixing or use of a cooling pond or helper tower to reduce the temperature of the discharge water. Many of the plants within the state using once-through cooling use offshore outfall pipeline terminating in a riser reaching shallow water depths. This approach is used because the atmosphere serves to dissipate heat quicker than water so that the sooner the thermal plume reaches the surface the quicker the heat dissipation. Use of multiport diffusers provides an even better way to dissipate the heat from thermal discharge. By diffusing the heated water through multiple ports along a length of pipe, near distance mixing is enhanced. Mirant proposed three multiport diffusers for once-through cooling discharge for Units 3 (existing) and 7 (proposed, in suspension) at the Potrero Power Plant.

Cooling ponds are used through much of the United States to allow heat to dissipate to the atmosphere before being discharged back to the receiving water body. Concerns about using cooling ponds mainly relates to high land requirements and the need for additional water due to solar heating of the pond water. Benefits include the relatively low costs, provision of a backup water supply and buffering from varying cooling water source conditions. Maulbetsch (2004) estimates capitol costs for cooling ponds accommodating a discharge flow of 144,000 gpm would range from $1.45 to $3.6 million based upon local meteorological conditions.

Another design approach to reduce the heat of the cooling water being discharged is the use of “helper” cooling towers. By routing the discharge through a cooling tower, the heat of the water can be dissipated to the atmosphere through evaporation and radiation before discharge to a receiving water body. Concerns with this approach are that for power plants with large flows, a significant number of “helper’ towers would be required. It is not necessary to route all the discharge water through the towers, if blending the cooled water with the remainder lowers the overall water temperature sufficiently.

Other options for reducing the effects of thermal plumes are similar to some of the flow reduction approaches discussed under entrainment and impingement above. Since combined cycle technology requires less water for cooling and loads less heat per unit of water, repowering is one way to significantly reduce thermal effects as was done at Moss Landing.

Also as discussed above, conversion to re-circulating cooling (cooling towers) significantly reduces flow but also, because heat is efficiently dissipated to the atmosphere in the cooling tower, significantly reduces the discharge water temperature. Use of an air-cooled condenser, of course, removes water needs for power plant cooling.

CHAPTER 7:ECONOMIC COSTS OF ONCE-THROUGH COOLING IMPACTS

Findings:

- Placing an economic value on ecological losses to once-through cooling systems can help decision makers evaluate the benefits of switching to alternative cooling methods or retrofitting the once-through cooling system.
- No consistent method exists to determine the economic value of losses of marine and estuarine organisms to once-through cooling. Different approaches have been used for different facilities.
- Approaches that estimate the value of losses based on recreational and commercial fisheries underestimate the total ecological value of losses.
- No satisfactory approach has been developed to put a value on total ecosystem losses.

Placing a Value on Ecological Losses to Once-Through Cooling

As discussed in previous sections, the use of ocean water for cooling by electric generating facilities can lead to ecological impacts. The purpose of this section is to discuss available methods for assigning economic values to these impacts, as well as some issues that arise in the application of these methods. While placing dollar values on changes in the natural environment can be controversial, economic analyses, when carefully developed and clearly presented, can provide important information for the public, corporate decision-makers, public policymakers, and regulators (e.g., to help the public understand the relative magnitude of economic benefits relative to the costs of facility modifications required to achieve such benefits).

Appendix 5 discusses economic theory and approaches to valuation of ecological losses in more detail. The key points of that discussion include:

- To-date, attempts to measure the public's willingness to pay to reduce the environmental impacts associated with once-through cooling have been limited. Past studies have generally considered the most easily quantified and monetized impact categories, such as reductions in commercial and recreational fish harvest associated with impingement and entrainment. In addition, the standards of economics have not been consistently and universally applied in these analyses. As a result, little information is available on the public's true views regarding the value for actions or policies that reduce these impacts.

- It is often suggested that equivalency-based approaches can provide a measure of the public's willingness to pay for reducing the environmental impacts associated with once-though cooling. Equivalency based approaches involve the scaling and costing out of "compensatory restoration" projects (e.g., wetland development or enhancement, artificial reef construction). These projects are intended to off-set the ecological and human-use impacts associated with once-through cooling, and thus "make the public whole" for these impacts. Estimates of environmental impacts are typically described as "debits" and the benefits of compensatory restoration projects as "credits." These methods, however, generally can only provide measures of the *cost* of off-setting these impacts. While regulators and the regulated community have successfully used equivalency-based approaches to reach agreements on the scale of actions to offset the impacts of once-through cooling, these agreements in and of themselves do not provide measures of the public's willingness to pay to avoid the effects of once-through cooling. As more is learned about the biological impacts of once-through cooling, the scale of the required off-sets could increase, raising further questions regarding whether the cost of these efforts exceeds the public's willingness to pay (i.e., the costs of reducing the impacts of once-through cooling could exceed the benefits).

- Many of the analyses conducted to-date have not explicitly addressed the baseline conditions of impacted resources (e.g., the condition of affected resources in the absence of the impact of once-through cooling). Variations in baseline conditions is an especially important consideration in the context of transferring economic values for reductions in once-through cooling from one site to another, and could introduce significant error to these analyses.

- Most of the past assessments of the environmental impact of once-through cooling have provided too little information on the sensitivity of the results to reasonable variations in the underlying assumptions. In many cases, the range of uncertainty is quite large. These include uncertainties associated with the underlying bio-physical science, as well as in the economic and cost analyses. Without sufficient presentation of uncertainties, stakeholders have no means to judge the confidence that should be placed on these results.

- More consideration should be given to break-even analysis for assessments conducted for specific plants (especially if detailed case specific economic analyses cannot be developed). Threshold or "break-even" analysis answers the question, 'How small could the value of the non-quantified benefits be (or how large would the value of the non-quantified costs need to be) before the rule would yield zero net benefits?' In addition, in some cases consideration should be given to the regional economic costs and benefits that could result from changes in cooling technology.

Because several studies have been completed, it is reasonable to ask "*what is the economic value of the environmental impacts of once-through cooling in California?*" Several possible approaches to estimate such a value are available.[i] First, it might be feasible to review all of the studies done to-date at facilities throughout the U.S., in order to generate a unit value estimate (i.e., "dollar impact per million gallons per day intake"). This unit value could then be transferred to the population of California facilities to develop an overall measure of economic impacts. However, this approach is unlikely to yield valid impact measures, since there are too few existing studies to generate a robust value estimate. That is, given between-facility and between-location variations in baseline conditions and impacts, combining results from the small sample of studies that are available would be unlikely to yield a benefit estimate that can be transferred to other sites.

An alternative approach would be to apply the models developed by USEPA for the Section 316(b) rule, as discussed below, to value the environmental impacts associated with California facilities. However, in its final rule USEPA presented quantitative economic impact measures only for expected changes in recreational and commercial fish harvests. Thus, if we were to follow USEPA's lead and only consider those two categories of economic impact, the results would likely substantially understate the overall economic impacts of once-through cooling. While it might be feasible to apply the models developed by USEPA for other benefit categories (e.g., non-use), significant concerns with these approaches have been raised.

Finally, an analysis of the total cost of providing environmental enhancement projects that off-set the impacts of once-through cooling (e.g., installation of reefs, construction of coastal wetlands) could be developed. However, such a cost estimate would not reflect the public's willingness to pay to avoid the environmental impacts of once-through cooling, but simply the cost of completing these projects.

Two specific research efforts could be undertaken to better incorporate economics into assessments of the environmental impact of once-through cooling and to better understand the total economic cost associated with such impacts. First, a carefully developed survey of the public intended to ascertain the public's willingness to pay to avoid the environmental impacts of once-through cooling should be developed. Such a "stated preference" survey is the only available means to assess the non-use values the public holds for these impacts. Note that such surveys do not represent an alternative to development of an accurate and detailed understanding of the biological impacts of once-through cooling. Such understanding is required to allow for development of a valid survey instrument. Second, efforts should be undertaken to establish more detailed standards for the conduct of equivalency based approaches in the context of establishing the scale of actions to off-set the impacts of once-through cooling. This would include detailed guidance that establishes the minimum data requirements for such assessments.

Recent Studies Have Used Different Approaches to Estimate the Economic Value of Resources Lost to Once-Through Cooling

Table 4 summarizes some recent assessments of the economic value (or cost of off-setting) of environmental impacts of once-through cooling in California. These studies include assessments conducted for specific plants, as well as the regional analysis developed by USEPA to assess the economic benefits of additional requirements under Section 316(b).

Note that the results obtained by these studies are not comparable, since (1) the economic valuation and cost methods used varies across the studies; (2) the categories of lost environmental services varies; (3) the size and characteristics of the facilities (including existing technology to control impingement and entrainment impacts) as well as the magnitude of the assumed change in plant operations differ; and (4) the attributes of the environment in which these plants are located differ. Specific examples of attempts to apply economic analysis to ecological losses to once-through cooling systems are described in the following section.

Examples of Economic Analysis of Once-Through Cooling Impacts

In this section we review several economic analyses of environmental impacts resulting from once-through cooling technology, as well as an application of an equivalency based model to establish the cost of off-setting the environmental impacts of once-through cooling. The purpose of this section is not to provide a comprehensive review of existing assessments, but a means to demonstrate the concepts and issues raised in the previous sections. Consistent with that goal, we only describe underlying biological models used to the extent that they are required to assess the economic approaches followed. [ii](found at end of Appendix 5)

The first analysis considered below was developed to support the USEPA's Section 316(b) Phase II Final Rule. This is not an economic assessment of the impacts of cooling water use at a particular location, but instead a general analysis of the economic benefits that could result from additional requirements on facilities that have a design cooling water intake of 50 million gallons per day or more. The other two analyses described are all for specific generating facilities.

USEPA's Analysis of the Economic Benefits of the Final Section 316(b) Phase II Existing Facilities Rule

The purpose of this USEPA report was to provide an analysis of the economic benefits that could result from additional requirements to reduce impingement and entrainment at facilities that have a design cooling water intake of 50 million gallons per day or more. It is important to note that this analysis was intended to support regulatory development at the national level, not a plant-by-plant assessment of the impacts of once-through cooling. However, the analyses performed to support this rulemaking do provide benefit estimates for the 21 plants in California that would be impacted by this rulemaking.

Table 4 - Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California

Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
California Studies Completed				
Diablo Canyon Power Plant[1]	Estimate of the natural resource benefits associated with implementation of a closed cycle cooling system at the Diablo Canyon Power Plant (DCPP).	• Market benefits (commercial fishing) • Non-market benefits (recreational fishing) • Indirect use benefits (indirect impacts on commercial and recreational fishing) • Non-use benefits	Net Present Value (2001): $15,786 to $1,905,757 ($1,755 to $110,647 per year)	A review commissioned by the California Central Coast Regional Water Quality Control Board concluded that, while ASA appropriately applied an existing USEPA approach, the report may significantly underestimate true entrainment losses (Stratus 2003). Dr. Pete Raimondi, an independent scientist representing the California Regional Water Quality Control Board, indicated that larval losses could be valued around $10 million. This estimate is based on HPF, an equivalency based approach.

Table 4 - (continued) Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California

Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
Morro Bay Power Plant[2]	Estimate the economic impact of once-through cooling, as measured by the cost of off-sets.	• Considers the cost of implementing representative (or equivalent) projects to off-set impacts associated with once-through cooling at $9.7 million, plus an amount to provide an additional margin of safety for program performance at $2.8 million.	Final HEP package: $12.5 million for preservation and enhancement of Morro Bay habitat	CEC staff testimony suggested that proper funding for a HEP would be $37.4 million. However, the CEC's final decision did not find these cost figures well-supported. The Regional Board staff explored several approaches to estimate restoration costs. Estimates include: (1) $12 to $23 million based on converting larval loss to equivalent acres; and (2) $12 to $16 million using the same methodology as 1 but based on USEPA values for restoration projects.
	Duke Energy conducted a Habitat Equivalency Analysis in order to demonstrate that the proposed HEP funding level of $12.5 million provided adequate compensation.	Habitat Equivalency Analysis: • Wetted surface areas of Morro Bay is approximately 2,300 acres • Equivalent acreage: 17 percent - 33 percent of 2,300 acres = 391 – 759 acres • Assuming $30,000 per acre on average to acquire larger parcels and/or restoration of habitat.	$11.7 to $22.8 million	

Table 4 - (continued) Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California

Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
Moss Landing[3]	Duke Energy North America proposed the construction of Moss Landing Power Plant (MLPPP) on the site of the existing Moss Landing generating facility. This analysis estimates the cost of a mitigation package to compensate for expected biological losses associated with this facility.	Habitat Restoration Cost: • Average loss: 13 percent • 13 percent of 3,000 surface acres in Elkhorn Slough = 390 wetland replacement acres • Wetland restoration cost range from $12,000 to $25,000 per acre • Total restoration costs range from $4.68 million to $9.75 million with an average of $7.215 million.	Final mitigation package: $7 million to enhance biological productivity in the Elkhorn Slough	
San Onofre[4]	In connection with issuing a coastal development permit to Southern California Edison for the operation of San Onofre Nuclear Generating Station (SONGS) Units 2 and 3, the CCC required a study of the operation of the plant on the marine environment offshore from San Onofre and mitigation of estimated adverse impacts.	Habitat Restoration Cost: • Based on construction of 150 acres of kelp forests.	Estimated project cost: $51.42 million	As a result of these studies, the CCC required SCE and its partners to create or substantially restore at least 150 acres of southern California wetlands.

Table 4 - (continued) Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California

Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
EPA 316(b) Final Rule[5]				
National Perspective[5]	The new rule will require all large existing power plants to meet performance standards to reduce the number of organisms killed by 80 to 95 percent. Depending on location, the amount of water withdrawn, and energy generation, certain facilities will also have to meet performance standards to reduce the number of aquatic organisms drawn into the cooling system by 60 to 90 percent.	• Market benefits (commercial fishing) • Non-market benefits (recreational fishing) • Indirect use benefits (forage species that support commercial and recreational fisheries)	Affected Community: 550 facilities Estimated Benefits: $80 million annually.	
California Perspective	Average expected reductions of: • 30.9 percent for impingement • 21.0 percent for entrainment		Affected Community: 21 facilities Estimated Benefits: $3 million annually for the 21 facilities considered in the analysis. Total impacts at these facilities of $9 million.	

Table 4 (continued) Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California

Sources:

[1] ASA Analysis and Communications, Inc. and Ivar Strand. 2003. Estimation of Potential Economic Benefits of Cooling Tower Installation at the Diablo Canyon Power Plant. Prepared for Pacific Gas & Electric Company. April 2003; Strange, L., B. Raucher. D. Cacela, D. Mills, and T. Ottem. 2003. Review of PGE's Benefits Analysis for the Diablo Canyon Power Plant. Prepared for Michael Thomas, Central California Coast Regional Water Quality Control Board. Stratus Consulting, Inc. January 22, 2003; Raimondi, P., G. Cailliet, and M. Foster. 2005. DRAFT DCPP Mitigation Recommendation. Diablo Canyon Power Plant Independent Scientist's Recommendations to the Regional Board Regarding Mitigation for Cooling Water Impacts, January 20, 2005.

[2] California Energy Commission. 2004. 3rd Revised Presiding Member's Proposed Decision on the Morro Bay Power Plant Project (00-AFC-12). Document Number: P800-04-013. Sacramento, CA. June 2004; Duke Energy Morro Bay LLC. 2002. Morro Bay Power Plant Modernization Project: Habitat Enhancement Program. August 30, 2002.

[3] Commission Order Adoption in the Matter of Application of Certification for the Moss Landing Power Plant Project. Docket No. 99-AFC-4. Order No. 00-1025-24; Testimony of Richard Anderson and Mike Foster. Biological Resources Errata for Moss Landing. June 19, 2000.

[4] California Coastal Commission 1997. San Onofre Nuclear Generating Station Permit #6-81-330-A (formerly 183-73).

[5] USEPA. 2004. Economics and Benefits Analysis for the Final Section 316(b) Phase II Existing Facilities Rule. Document Number: USEPA-821-R-04-005. February 2004; USEPA. 2004. Regional Analysis Document for the Final Section 316(b) Phase II Existing Facilities Rule. Document Number: USEPA-821-R-02-003. February 12, 2004.

While USEPA considered a broad range of benefit categories, their final analysis focused on assigning monetary values to three categories of benefit, each based on a different economic methodology. Specifically,

- Estimated increases in commercial catch were valued based on a market price methodology. The analysis considered the gain in commercial harvest that could be associated with reductions in impingement and entrainment. This additional harvest was then valued based on market data to yield estimates of gross revenues. These gross revenues estimates were adjusted to reflect the fact that only a portion of gross revenue represents social willingness to pay.
- Estimated changes in recreational harvests were valued based on a revealed preference model of recreational angler behavior (a random utility model).[iii]
- USEPA recognized that indirect impacts (i.e., food web impacts) on commercial and recreational use values can result from impingement and entrainment of forage species. USEPA estimated changes in commercial and recreational harvests of several species of fish, and valued these changes using the same models as described above.
- USEPA considered several methods for estimating the non-use benefits resulting from reduced environmental impacts of impingement and entrainment (benefits transfer using a meta analysis, societal revealed preference (restoration costs), and equivalency based approaches), but decided to describe these impacts qualitatively in the final rule.[iv] (found at end of Appendix 5)
- USEPA considered a wide-range of other values (e.g., endangered species protection) that might be enhanced by reductions in impingement and entrainment, generally describing these impacts qualitatively.

USEPA's assessment assumed a reduction in the biological impacts of approximately 31 percent for impingement and 21 percent for entrainment for plants in California under this rule. Based on this change in impingement and entrainment, this analysis found annual benefits of $0.5 million for commercial fishing and $2.5 million for recreational fishing. The analysis also estimates that the total value of all lost recreational fishing opportunities due to impingement and entrainment to currently be approximately $7 million per year, and commercial fishing losses to be about $2 million per year (present value). This analysis, by focusing on commercial and recreationally valued species, does not address the values of reducing losses to other species (of the 248 species reported as impinged or entrained, 20 are harvested). With 21 coastal power plants in California, the commercial and recreational losses associated with any one plant will be relatively modest when compared to the cost of alternative cooling technologies.

Overall, this analysis provides the most exhaustive assessment of the value of environmental impacts associated with once-thorough cooling. However, several factors likely lead this analysis to understate the benefits associated with reductions in the impacts of once-through cooling. First, it considers only a subset of the species that are impacted by these facilities. Second, in presenting the final costs and benefits of the rule, USEPA chose only to present a limited subset of these values – the direct and indirect impacts associated with commercial and recreational fishing. While USEPA considered several methods to estimate non-use values (as well as other categories of benefit), in the end they decided that uncertainties in the methods and results were too significant to allow for presentation of national benefit measures. As a result, the results may understate the total benefits of reductions in the environmental impacts of once-through cooling probably to a significant degree.

Estimation of Potential Economic Benefits of Cooling Tower Installation at the Diablo Canyon Power Plant[v]

The Pacific Gas and Electric Company commissioned a study of the economic benefits of reductions in entrainment losses that could arise from installation of cooling towers at the Diablo Canyon Nuclear Power Plant. These benefit estimates were intended for comparison to the estimated costs for cooling tower installation. The benefit categories considered and the methods used were partly drawn from recent work by USEPA to assess the benefits of actions to reduce impingement and entrainment impacts.

The biological model used in this report considers the magnitude of reductions in entrainment that would result from cooling tower installation. The assessment then considers four categories of economic benefit: market benefits (for commercial fishing), non-market benefits (for recreational fishing), indirect use benefits, and non-use benefits.

The analysis estimates the change in commercial catch that would be expected to result from closed-cycle cooling, as well as the economic value of that catch. The analysis does not assume that all lost fish would be caught, but assumes a range of exploitation of 10 to 50 percent. Since a portion of these fish would be harvested by recreationalists, the analysis apportions fish to the commercial and recreational sectors on a species by species basis. Lost harvest to the commercial sector was then multiplied by market prices in the commercial fishery to estimate the change in revenue experienced by commercial fishermen. In keeping with economic conventions, the analysis assumed that a large portion of this revenue stream represented the cost of harvest, with the remainder reflecting the public's willingness to pay for the enhanced commercial harvest (that is, the cost of harvest is not included since it is not incurred in the absence of fish). For expected changes in recreational harvests, the analysis relied on a transfer of values for caught fish from an existing analysis in a similar geographic region, ranging from $5 to $25 per fish for popular recreationally targeted species. For less popular (non-targeted) species, a commercial value was used.

This analysis recognized that enhanced populations of forage species provide an indirect benefit to the public, and thus applied a model to estimate the contribution of forage fish species to the abundance of targeted species. Specifically, the analysis assumes that impacted forage species would be consumed by California halibut, a commercially and recreationally popular species. The study authors explicitly consider and reject application of a replacement cost estimate for these indirect use benefits, since “the cost of production is a function of the difficulty of rearing and has nothing to do with the economic value of these species.”

Finally, the authors assume that non-use values are equal to 50 percent of recreational use values. This assumption is drawn from a draft analysis by the USEPA of the economic benefits of the Section 316(b) rule. A number of studies have considered both the non-use and use values associated with changes in water quality, and thus provide a means to calculate a ratio of use to non-use values. However, these ratios vary substantially between studies and resources, and thus there is little empirical (or theoretical) basis for the assumption that non-use values will be a function of use values. In short, few economists would support application of this “rule of thumb.”

The analysis concludes that implementation of a closed cycle cooling system at Diablo Canyon would result in a net present value benefit of $16,000 to $1.9 million. Two subsequent reviews of this report were developed by consultants to the Regional Board. The first (Strange 2003), concluded that the approach used and assumptions made would likely lead to an underestimate of benefits, because most of the entrained taxa were not incorporated in the analysis. In a separate review, Dr. Raimondi concluded that larval losses could be valued in the $10 million range, depending on the assumptions made. This estimate was preliminary based on an equivalency approach (e.g., the cost of undertaking restoration to offset the biological impacts of impingement and entrainment, M. Foster, pers. comm.).

Overall, this analysis considers a relatively wide-range of economic services and conducts several sensitivity tests of important assumptions. It also provides a transparent present value analysis, discounting the expected flow of future benefits to allow comparison of the expected costs of alternative cooling technologies to the benefits of such technologies.[vi]

Duke Energy Morro Bay LLC, Morro Bay Power Plant Modernization Project Habitat Enhancement Program (HEP), 2002[vii]

Duke Energy conducted a habitat equivalency analysis of impacts resulting from the use of ocean water as cooling water for the Morro Bay Power Plant. To estimate the ecological impact associated with cooling water use, Duke considered the total biomass of fish and crab larvae entrained as a measure of the ecological service loss. They note that not all organisms entrained were included in the biomass estimate, but it was assumed that those measured are good indicators of all entrained species. The analysis also notes that the fish and crabs measured are important to recreational and commercial activities in the bay (and thus, presumably, are the species to focus on in the analysis). The analysis assumes that 100 percent of all entrained organisms suffer mortality, and that all of these organisms would have remained in Morro Bay. The analysis then considers possible habitat restoration projects that would provide larval fish and shellfish biomass, including coastal salt marsh and eelgrass beds. Specifically, the analysis uses estimates of the primary productivity of these two habitat types to determine the number of acres of habitat required to offset losses due to entrainment. The analysis concludes that 57.2 acres of eelgrass or coastal salt marsh creation would be required to offset entrainment losses.

While the Duke report discusses various factors that may lead the analysis to overstate impacts, no attempt is made to quantitatively track these uncertainties formally. Given uncertainties on both the “debit” and “credit” side of the analysis, a more formal assessment would provide greater confidence that the overall results of the analysis are in fact conservative.

The report also raises an important point: the habitats provided as an off-set for once-through cooling impacts likely provide other benefits. However, no attempt was made to assess the scale of this credit.

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APPENDICES

Appendix 1
An Assessment of the Studies Used to Detect Impacts to Marine Environments by California's Coastal Power Plants Using Once-Through Cooling (Draft Consultant Report by Dr. Michael Foster)

Appendix 1 Addendum: Author Responses to Reviewer's Comments on Appendix 1

Appendix 2: Summary of Assumptions, Methods, and Analyses Used In Recent Studies To Assess The Impacts of Power Plants That Use Seawater For Once-Through Cooling, and Conceptual and Research Approaches To Improve Assessment of Entrainment and Cumulative Impacts

Appendix 3: Research Recommendations From The Energy Commission Pier Wiser Workshop

Appendix 4: Economic Costs of Once-Through Cooling Impacts

EndNotes

[i] In order to place a value on the environmental impacts of once-through cooling in California, we would also need to characterize the bio-physical impacts generated by these facilities. This discussion focuses solely on the availability of economic methods.

[ii] In addition, no attempt has been made to replicate the results presented in these existing analyses.

[iii] For one region of the country USEPA used a benefits transfer approach to recreational fishery valuation.

[iv] As noted previously, a recent peer review panel considered the non-use portion of USEPA's analysis and is expected to raise several fundamental concerns, including the linkage of the studies considered from the literature to the changes expected to result from this rulemaking, as well as the overall quality of the analysis.

[v] ASA, 2003.

[6] A critique of this report was developed by the California Central Coast Regional Water Quality Control Board (see Strange et al. 2002).

[vii] This report was developed as a component of Duke Energy's efforts to modernize the Morro Bay Power Plant. Duke Energy's stated intention in presenting a habitat equivalency analysis was to "demonstrate the conservative nature of the Regional Board's approach and validate scientifically the magnitude of the safety margin that is incorporated into the HEP (habitat enhancement program)." (page 47)