316(b)
Once Through Cooling
Deadline: 9/25/06

Pacific Gas and Electric Company™

Kathleen B. Jones

Mailing Address
P.O. Box 7442
San Francisco, CA 94120

Street/Courier Address
Law Department
77 Beale Street
San Francisco, CA 94105

(415) 973-4297
Fax: (415) 973-0516
Internet: KAB7@pge.com

RECEIVED
SEP 2006
SWRCB
Executive Ofc.

September 15, 2006

VIA MESSENGER

Ms. Song Her
Clerk to the Board
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

Re: PG&E Comments - Proposed Statewide Policy for Once-Through Cooling (CWA Section 316(b) Regulations)

Dear Ms. Her:

Attached please find Pacific Gas and Electric Company's comments on the State Water Resources Control Board's proposed policy for the implementation of Clean Water Act Section 316(b). PG&E appreciates the opportunity to comment on the proposal and looks forward to working with the State Board staff to develop a policy for regulating cooling water intake structures that is both effective and sustainable by promoting a healthy marine environment and maintaining a stable electric supply and delivery system.

If you have any questions, please call me at 415-973-4297 or Lorraine Paskett at 916-386-5709.

Sincerely,

Kathleen Jones

Kathleen B. Jones
KBJ/kp

Attachments

cc: James Becker (PG&E)
John Busterud (PG&E)
Lorraine Paskett (PG&E)

PACIFIC GAS & ELECTRIC COMPANY'S COMMENTS REGARDING PROPOSED STATEWIDE POLICY ON CLEAN WATER ACT § 316(B) REGULATIONS SEPTEMBER 15, 2006

This document provides Pacific Gas and Electric Company's (PG&E) comments on the State Water Resources Control Board Staff's Proposed Statewide Policy on Clean Water Act § 316(b) Regulations (June 13, 2006) (Staff Proposal or Proposal). We look forward to working with the State Water Resources Control Board (SWRCB) to help formulate a policy for cooling water intake structures (CWIS) at California's power plants that is effective and sustainable, and that will protect and promote a healthy marine environment without destabilizing the State's electric supply and delivery system. Because the subjects addressed by the Proposal are so factually and scientifically complex, and because the Proposal would impact so many significant social, economic and environmental issues, we hope there will be future opportunities for additional information exchanges and dialogue (i.e., SWRCB Workshops). Such opportunities would help assure that the Section 316(b) policy ultimately selected reflects the best balance of competing interests, and maximizes the welfare of all Californians who could be materially impacted by the Proposal's far-reaching implications for the availability, reliability and cost of electricity in our State.

I

OVERVIEW AND SUMMARY

PG&E strongly supports the protection of California's marine resources through the application of Section 316(b) to coastal power plants. We support constructing new power plants without once through cooling (OTC); we support repowering existing facilities without OTC when feasible;[1] and we support the application of site-specific assessments of environmental impacts and alternative technologies at other existing power plants that employ OTC.

At the same time, PG&E is also responsible for helping to assure the availability and reliability of California's electric system. The July 2006 heat storm and the Independent System Operator's (ISO) declaration of a statewide Stage 2 Emergency[2] are blunt reminders that California needs to reduce peak customer demand and to *add* additional electric generating capacity, not reduce it. The existing OTC plants subject to the Staff Proposal constitute 40% of California's generating capacity, and presently are indispensable baseload, intermediate, peaking and reserve capacity for reliably meeting peak consumer demand and preventing blackouts. We

---

1 PG&E is in the process of repowering its 135 MW Humbodlt Bay plant without OTC.

2 Emergency notices are issued by the ISO when system reliability is in danger of instability. A Stage 2 Emergency is declared when the operating reserves are five percent (5%) or less.

are seriously concerned by the very real prospect that the Proposal's inflexible standards would force the premature closure of many *existing* OTC plants that support critical customer load.[3]

Without the Staff Proposal, existing OTC facilities would be governed by USEPA's 316(b) Phase II Rule, which can require substantial modifications to existing OTC power plants. The Phase II Rule rationally does so by providing for: (1) ranges of required impingement and entrainment (I&E) reductions depending upon site-specific conditions; (2) compliance options; and (3) variable performance standards for those facilities where compliance costs would significantly exceed the benefits. After a multi-year, peer-reviewed rulemaking, USEPA intentionally promulgated more flexible standards for existing facilities than for new ones because existing plants face "technological challenges and high costs associated with retrofitting" that new facilities can avoid.[4] California's 316(b) policy, like USEPA's Phase II Rule, must be structured in a manner that provides for a smooth transition away from the use of OTC while effectively balancing all impacts – social, economic and environmental – during the transition period.

On the other hand, a policy which effectively eliminates 40% of the State's electric generation resources without regard to human health and safety, electric market stability, costs to customers and other unintended adverse environmental impacts by replacement facilities would be irresponsible and unacceptable. In this decade, California has already experienced the worst energy crisis in the State's history. Indeed, the situation became so severe in 2001 that the State itself was forced to step in and purchase electricity in order to stabilize the markets and prevent further outages. Californians are still recovering financially from that energy crisis, and the Executive Branch has been working steadily to continue to stabilize the market. By eliminating up to 40% of the State's generating capacity, the Staff Proposal would undo the progress that has been made and virtually guarantee another energy crisis.[5]

---

3 PG&E recognizes that there are times when it is important for California to go beyond what is required or regulated by the USEPA or Congress. Such was the case with Assembly Bill 32 (Nunez), the California Global Warming Solutions Act of 2006, which recently passed the California state legislature and is waiting for action by Governor Schwarzenegger. PG&E was the only investor-owned utility to support this legislation, and did so because AB 32 put California in an environmental leadership position by offering important solutions to a significant problem in a measured and reasonable fashion.

4 69 Fed. Reg. at 41,628 (July 2004); H.R. Rep. No. 92-911 at 110. Congress specifically instructed EPA in the Clean Water Act to consider a broad range of factors in establishing performance standards for existing facilities, and a much narrower range of factors when establishing standards for new facilities. Compare CWA § 306 (new facilities) and CWA § 301 (existing facilities).

5 The California Energy Commission's Executive Director, for example, stated in an April 11, 2006 letter to the State Lands Commission (SLC), which was then considering a resolution to require the termination of leases for OTC facilities on SLC-managed lands, that "it must be recognized that a State Lands Commission resolution, if passed, could

The problems with the Staff Proposal are that it: (1) prohibits site-specific determinations, even though I&E impacts are known to vary dramatically from site to site; (2) imposes maximum I&E reductions in all cases, even where I&E effects are insubstantial; (3) greatly restricts compliance options, even though the efficacy and need for technologies vary considerably from plant to plant; and (3) rejects site-specific performance standards based on cost-benefit analysis, even if compliance costs greatly outweigh the benefits.[6] In short, the Staff Proposal would adopt a "one-size fits all" approach to California's existing OTC power plants that imposes new facility standards on existing plants where those standards may well be technologically and legally infeasible.[7]

Moreover, many of the existing OTC fossil plants are quite old and expected to retire in the next five to fifteen years. They will be replaced by non-OTC plants. Because emergency retrofits of these aging but important facilities would be extremely costly, the Staff Proposal would likely result in their premature retirement for economic reasons alone. The unanticipated, early retirement of these plants would cause severe electric system reliability impacts.

Facility location is yet another important consideration in evaluating the Staff Proposal. Many of the existing OTC plants are located in geographically desirable positions for transmission system reliability and efficiency. There are no guarantees that replacement facilities can be located in the same geographic region, and this could put further strain on an already stressed transmission grid. Forcing early retirement would therefore also hamper strategic transmission planning and undermine electric grid stability.

Since forced closures or significant generating limitations on California's existing OTC plants could destabilize the State's electric system and cause significant adverse social, economic and environmental consequences,[8] the Staff Proposal must be fully and fairly evaluated before the SWRCB considers its adoption, including thorough assessments of the true technical, legal and economic feasibility of meeting the proposed standards at existing plants, and of the true

---

eventually result in the loss of a significant amount of California's generating capacity with adverse impacts to system reliability." Exhibit 1 p. 8.

6 Under the Clean Water Act, states may obtain EPA approval to implement state programs that are compatible with the federal program, or implement measures that are more stringent than EPA's requirements. To our knowledge, no other state has imposed or even considered this extraordinary combination of stringent and inflexible measures for existing power plants.

7 As discussed in Section IV.A below, a requirement to install cooling towers at coastal facilities (which the Staff Proposal in essence mandates) would require approvals from the California Coastal Commission (or a Local Coastal Authority) and Air Pollution Control Districts, which are likely deny the necessary authorizations.

8 For example, the Staff Proposal could significantly increase greenhouse gas emissions while producing only marginal benefits to marine habitat and fish and shellfish populations, as explained below. This issue is discussed in detail in Section below IV.D.

costs and benefits of the Proposal's requirements. The California Environmental Quality Act (CIA) and the Porter Cologne Water Quality Control Act require no less.

For the reasons explained above and below, PG&E strongly recommends that:

1. The Staff Proposal's functional equivalency document should objectively evaluate:
   - the Proposal's technical, legal and economic feasibility at *existing* facilities;
   - the Proposal's impact on electric system availability and reliability;
   - the Proposal's impact on electricity rates;
   - the adverse environmental impacts that could arise from closing or requiring new technologies at existing OTC plants, including significant increases in greenhouse gas emissions;
   - the true costs and benefits of the Proposal's regulatory requirements; and,
   - the Proposal's impacts on the economy of the Western United States.

2. The State's final 316(b) policy should provide for:
   - site-specific compliance determinations, including a compliance alternative based on cost-benefit analysis;
   - expert panel oversight of I&E characterization studies;
   - the ability to rely on past I&E characterization studies in permit renewal proceedings when on-going monitoring data confirm the continued validity of a past study;
   - no requirement to use the habitat production foregone methodology in permit proceedings;[9]
   - an alternative resolution if other regulatory agencies (e.g., the California Coastal Commission and Air Pollution Control Districts) fail to adopt or implement regulations that are consistent with the policy requirements adopted by the State Board.

II

LEGAL STANDARDS

Clean Water Act Section 316(b) requires that CWIS's reflect the "best technology available for minimizing adverse environmental impact." This requirement is implemented through the federal National Pollution Discharge and Elimination System (NPDES) permit program. States with delegated NPDES permitting authority may implement their programs in lieu of USEPA's, and Section 510 of the Clean Water Act authorizes states to impose more stringent standards. California has received delegated authority from USEPA to implement the NPDES program, which is incorporated into State law by Water Code Section 13377. The

9 The habitat production foregone methodology is a means of sizing mitigation projects, as discussed in Section V.C below.

SWRCB Staff are now proposing to impose more stringent standards than USEPA's Phase II Rule for existing power plants, which are the focus of these comments.[10]

The California Environmental Quality Act (CEQA), Public Resources Code (PRC) Section 21000 *et seq.*, applies to the promulgation of statewide policies by the SWRCB, and requires that a policy not be adopted unless it is "feasible," meaning "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social and technological factors." PRC Section 21061.2. In this regard, "an agency may consider specific economic, environmental, legal, social and technological factors," and "has an obligation to balance a variety of public objectives, including economic, environmental and social factors. . ." 14 CCR Section 15021 (b) and (d).

CEQA's broad objective of balanced social, economic and environmental decision-making is also reflected in the Legislature's specific mandates to the SWRCB regarding State water policy. California Water Code Section 100 provides that: "because of the conditions prevailing in this State, the general welfare requires that the water resources of the State be put to beneficial use[[11]] to the fullest extent of which they are capable." Water Code Section 13000 further provides that:

> activities and factors which may affect the quality of the waters of the state shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible.

In the present context, the beneficial industrial use of ocean water for cooling existing electric power plants - which in turn provide an essential service (electricity) for human health, welfare and the economy - must be reasonably balanced against other competing human and ecological beneficial uses of marine waters, such as commercial and recreational fishing, fish spawning and migration, and maintenance of marine habitat and Areas of Special Biological Significance. The best balance of competing uses does not necessarily mean a perfect balance, and Water Code Section 13241 expressly provides that "it may be possible for the quality of water to be changed to some degree without *unreasonably* affecting beneficial uses." (Emphasis added.)

---

10 In addition to incorporating the federal 316(b) program into State law, the Porter Cologne Water Quality Control Act requires that each "new or expanded powerplant or other industrial installation using seawater for cooling, heating, or industrial processing [use] the best available site, design, technology, and mitigation measures feasible . . . to minimize the intake and mortality of all forms of marine life." Water Code Section 13142.5(b). By its terms, this section does not apply to *existing* power plants.

11 The beneficial uses of marine waters include "industrial supply water; water contact and non-contact recreation, including aesthetic enjoyment; navigation; commercial and sport fishing; mariculture; preservation and enhancement of Areas of Special Biological Significance (ASBS); rare and endangered species; marine habitat; fish migration; fish spawning and shellfish harvesting." California Ocean Plan (2005), Section I.A.

Thus, the fundamental legal question posed by the Staff Proposal is whether it – based on evaluation of *all* relevant social, legal, economic and environmental factors – would unreasonably interfere with the continued use of ocean water for the purpose of generating electricity at existing power plants. Regulation of California's existing OTC power plants pursuant to USEPA's Phase II Rule would already prevent the use of ocean water for cooling purposes from unreasonably interfering with marine habitat, fish spawning and migration, etc. As discussed below, however, the adoption of the Staff Proposal would unreasonably interfere with the use of ocean water at existing OTC plants since the resulting adverse social, economic and environmental harms would greatly exceed any benefits derived from its implementation.

III

BACKGROUND

In April 2006, the California Energy Commission's (CEC) Executive Director provided the following summary of the State's twenty-one (21) existing large coastal power plants that (then) utilized OTC:

Technology	Number of Facilities	Annual Capacity Factor (percent)	Generation as Percent of State Total (2004)
Steam Boilers	15	19.4	9.0
Combined Cycles	4	34.9	2.05
Nuclear	2	79.1	11.08
Totals	21	NA	22.13

Source: CEC 2006 [modified to include a "Totals" line]

Based on 2004 data, the CEC Executive Director concluded that existing coastal plants produce 22% of the electricity used in the State and constitute 40% of the State's generating capacity. Although many of the older steam boilers have relatively low annual capacity factors (i.e., under 15%), many of them are located in local reliability areas and have been designated by the CA ISO as necessary to maintain system reliability. Specifically, in 2006, almost one-third (4,800 of 14,700 MW) of the older steam boiler units within the CA ISO control area have been designated as reliability must-run units. In addition to meeting local reliability needs, these plants run nearly full time during peak summer demand periods, and their capacity is thus critical to system reliability. During this summer's 2006 CA ISO peak demand of 50,270 MW, for example, the ISO was required to issue a Stage-2 Emergency when operating reserves were forecast to drop below 5%. In addition, the CA ISO called for voluntary load reductions, with Stage 3 Emergency and rotating outages imminent if consumers did not step-up conservation efforts. Collectively, the older steam units contributed 25-35% of the peak demand during this period. These older steam boilers were thus crucial in meeting this year's peak demand, and will remain so until new capacity can be brought on line. It is hardly surprising then that the CEC Executive Director observed that:

SF\578146.3

> the above table does not adequately reflect the importance of the coastal plants to the state's electricity system, since their generation as a percent of state total is significantly higher during periods of peak demand when system reliability becomes a critical issue. Most of these coastal facilities have been operating at their full capacity during the highest peak demand periods of the summer.

Exhibit 1 p.3.

The existing OTC plants are also important because they supplement the State's hydroelectric system, which in normal years generates a significant portion of the State's power during the peak demand summer months. The output of the hydroelectric system, however, is dependent on weather conditions. Low winter snow fall or rapid melting of a large snow pack, for example, can dramatically reduce the volume of water available for hydropower, which in turn increases the need for production from more reliable means of generation, such as the existing fossil and nuclear OTC plants. The OTC plants are also important in providing ancillary services, such as load following to meet daily swings in load or sudden changes on the system. In short, the existing OTC plants are essential to the supply and reliability of electricity in California, and especially so during peak demand periods when system reliability is critical.

Two of the reported 21 OTC facilities (Hunters Point and Long Beach) have closed since the Executive Director's letter, and another two (Humboldt and South San Diego Bay) are repowering without OTC. Thus, there soon will be only seventeen (17) remaining coastal OTC plants, the majority of which are the older, less efficient steam boilers that will continue to be phased out over the next five to fifteen years. On the other hand, the State's two nuclear plants, "which are critical to maintaining system reliability from both a generation and transmission system perspective," Exhibit 1 p. 7, and the four newer combined cycle OTC plants all have substantial remaining useful lives, and will be critical to the State's electric system for years to come. Therefore, the Staff Proposal will have a significant effect on important existing plants for the foreseeable future, even though its overall impact will lessen as the older steam boilers continue to be replaced or repowered with different technologies.

IV

COMMENTS REGARDING THE NEED FOR ADDITIONAL ANALYSIS OF THE STAFF PROPOSAL

This section identifies those areas which PG&E believes require additional analysis in the Staff Proposal's functional equivalency document in order to determine whether its adoption would be consistent with CEQA, the Porter Cologne Water Quality Control Act, and the State's best overall interest. Many of our observations and comments arise from our recent and on-going experiences with the Section 316(b) permitting process for PG&E's Diablo Canyon Power Plant (DCPP), a 2300 MW baseload facility on California's central coast. In light of the information developed there, we are convinced that the Staff Proposal is in all probability technically, legally and economically infeasible, that it would result in existing plant closures that would destabilize the electric system and increase rates, and that it would create greater environmental problems than it would solve. We urge that these issues be thoroughly investigated and analyzed before the Proposal is considered by the SWRCB.

A. The Technological, Legal and Economic Feasibility of the Proposal at Existing Plants Must Be Thoroughly Analyzed

Given their location on California's coast, bays and estuaries, the existing OTC plants must comply with the Staff Proposal's standards for both impingement mortality and entrainment reduction. 40 CFR Section 125.94(b). By imposing maximum levels of reduction in both categories and precluding the use of restoration as a compliance option (with one limited exception), the Staff Proposal effectively eliminates all compliance options other than cooling towers for most if not all existing OTC plants that operate at a capacity utilization greater than 15%.[12] Although the Proposal appears to grant some flexibility for the entrainment standard by allowing the use of restoration to offset up to 30% of the required 90% reduction (provided that achieving 90% reduction through technology or operational measures is shown to be infeasible), PG&E's experience suggests that there is no feasible way to achieve even a 60% entrainment reduction through any technology or operational measures other than cooling towers.[13] Since the existing OTC facilities must meet both the I&E standards, and because cooling towers are the only technology under the Staff Proposal that meets both standards, there are, in reality, few if any other conceptually available options for existing facilities to comply with the Staff Proposal.

As explained below, however, it is likely that many existing OTC's will be unable to achieve 90% entrainment reduction standards. There are technical, legal and economic reasons why this is the case.

1. Technical Infeasibility: The DCPP has been extensively studied in recent years, including numerous assessments of alternative CWIS technologies by the Central Coast RWQCB staff and PG&E. The following sections summarize the major alternatives considered, their costs, and the RWQCB staff's findings:

a. Dry Cooling: According to the RWQCB's consultant, Tetra Tech, a conceptual dry cooling system for DCPP would require eight (8) units, each occupying an area of

---

12 According to the Phase II Rule and the Staff Proposal, plants operating at less than 15% capacity utilization are exempt from entrainment reduction requirements, but not impingement mortality reduction requirements.

13 Restricting intake flow by 60% to 90% as a means of meeting the entrainment reduction standard (or to 95% to meet the impingement standard) would not be done since that effectively takes the plant out of service or would otherwise make operations uneconomical. Reducing design intake velocity to 0.5 feet per second to achieve compliance with the impingement standard would not be done since that would be extremely expensive and would not address entrainment. Instead, an existing OTC would most likely have to use cooling towers to achieve compliance with both the I&E standards, assuming that were feasible.

316 feet long x 197 feet wide x 119 feet high, and each containing forty (40) 150 horse power fans. Tetra Tech concluded that dry cooling is not even remotely feasible at DCPP because, among other things, ducts can be no longer than 200 feet, and this is physically impossible at the site. Exhibit 3 pp. 11 – 12.

b. Natural Draft Cooling Towers: According to the RWQCB's consultant, a conceptual natural draft cooling system for DCPP would consist of ten (10) 450 foot high, 208 foot diameter concrete cooling towers whose capital costs alone were estimated at $1.58 billion (i.e., does not include future O&M, revenue losses during construction tie-in of the system, etc.). Exhibit 3 p. 19. Furthermore, natural draft cooling towers are not efficient in cool, damp climates such as those along California's central coast, the complex would have significant adverse visual impacts, and probably could not be constructed because of space constraints and seismic concerns.

c. Mechanical Saltwater Cooling Towers: According to the RWQCB's consultant, a conceptual mechanical draft saltwater cooling system would consist of 132 cells, each of which would be 60' x 60' x 65' high with a 250 horse power fan. The minimum estimated cost for this system would be $1.3 billion, assuming the DCPP would only need to be closed for six months to accomplish condenser replacements for the two units and cooling tower complex tie-in. Exhibit 3 pp. 13 – 17. PG&E's consultant concluded that mechanical draft cooling towers would be infeasible because:

- The DCPP would have to be shut down for at least a year;
- The system would cost at least $1.9 billion;
- The system would require 50 MW to run the pump station and fans, i.e., enough electricity to power a town of 50,000 people;
- Frequent ground level vapor plumes caused by the cooling towers would create significant safety and security hazards during much of the year;
- Drift from the towers would deposit 7 tons of salt a year in the vicinity of the plant;
- There is insufficient space at the DCPP to construct the project;
- The cooling towers would have a high saline content discharge of 69 million gallons per day;
- The project would be of unprecedented scale, whether as a retrofit or new construction, and would constitute the largest cooling tower complex in the United States.

Exhibit 2 pp. 4-7.

d. Fine Mesh Screens: The RWQCB's consultant concluded that fine mesh traveling screens might reduce entrainment by 80% (which would not meet the Staff Proposal's 90% entrainment reduction standard), and that such a system would cost $ 650 million. Pilot studies would be required to determine if the system were feasible. Exhibit 3 pp. 7 – 10. EPA's consultant, Science Application International Corporation, had previously concluded that "the use of fine-mesh mounted on traveling screens has not been demonstrated as an effective technology for reducing mortality of entrainment losses." Exhibit 4 p. 3-4. PG&E's consultant concluded that fine mesh screens were unproven and likely would not work in an open ocean environment because of biofouling, that the costs of such a system at DCPP would likely be $ 770 million, and that the net environmental benefit of screens was doubtful because they would reduce entrainment by increasing impingement. Exhibit 5 p. 1. Thus, fine mesh screens are not feasible, and in any event would not comply with either the Proposal's entrainment or impingement standards.

e. The RWQCB Staff Determined that there Is No Feasible Alternative CWIS for Diablo Canyon: The RWQCB staff made explicit findings with respect to each of the foregoing technologies and a number of others in July 2003, which are fully presented in Exhibit 6. As discussed in Section V.A below, the RWQCB staff found that the rate of *impingement* at the DCPP was already so low that further reductions were unnecessary. The staff summarized their overall findings regarding *entrainment* reduction alternatives as follows:

> The technologies that may reduce entrainment at DCPP are either experimental (screens and filters) or only conceptually available at this site (saltwater cooling towers). Therefore the Board cannot conclude that these systems are available at DCPP under the meaning of Section 316(b) of the Clean Water Act . . . There are no demonstrated applications of these technologies at facilities similar to DCPP, and there are many significant problems associated with their potential use at DCPP.

Exhibit 6 pp. 2 – 3. The staff also found that the costs of cooling towers and fine mesh screens were wholly disproportionate to the benefits, which staff then estimated to be in the $10 million range. Exhibit 6 p. 3.

2. Legal Infeasibility: As a practical matter, retrofitting with cooling towers is the only technology that could theoretically satisfy the Proposal's entrainment (and impingement) standards for existing facilities. In addition to the technical problems described above, there are several reasons why these structures may be legally infeasible:

a. Air Permits: A requirement to establish cooling towers at coastal power plants is likely to require air permits because of particulate emissions (salt), among other things. The conceptual saltwater cooling tower design for DCPP, for example, would emit 7 tons of salt a year, and would be difficult if not impossible to permit for that reason. The San Luis Obispo County Air Pollution Control District recently concluded that saltwater cooling towers probably could not be permitted at the Morro Bay Power Plant because of particulate emissions. Exhibit 7.

b. Coastal Development Permits: Since most existing OTC power plants are located in the California Coastal Zone, permits would also have to be approved by the Coastal Commission, a Local Coastal Authority or the Bay Conservation and Development Commission. Given the significant adverse impacts associated with large scale cooling tower complexes – such as those listed above regarding the conceptual cooling tower design for the DCPP - it is highly doubtful that such projects would pass environmental review by these agencies, thus presenting yet another potentially insurmountable legal hurdle that could prevent an existing facility's compliance with the Staff Proposal.

3. <u>Economic Impracticability:</u> Congress expressly recognized that there was "a significantly lower expense of attaining ... effluent control in a new facility as compared to the future cost of retrofitting." H.R. No. 92-911 at 110 (1972). The Legislative History of Section 316(b) explains that the "best technology available" should be interpreted to mean the "best technology commercially available at an economically practicable cost," and USEPA intentionally structured the Phase II Rule to provide for flexible compliance standards, flexible compliance options, and a cost-benefit exception, in order to assure that the Rule would be economically practicable. 69 Fed. Reg. 41,628 (July 9, 2004). There is a substantial possibility that the Staff Proposal's rigid standards will prove economically impracticable at many existing facilities, and therefore force their closure.

As noted in the CEC Executive Director's letter, fifteen (15) of the existing OTC plants are merchant generators. Merchant generators "currently need long-term contracts in order to secure the financing necessary to pay for major facility repowers or retrofits." Exhibit 1 p. 8. As the CEC Executive Director explained:

> Coastal generators would face regulatory and financial market uncertainty that could jeopardize the repowering of coastal plants and state goals for meeting resource adequacy in generation/transmission-constrained areas. Merchant generator ability to secure financing and long-term contracts for repowering is already uncertain. Incremental cost differences for plants with tower cooling or dry cooling could make coastal plants less competitive than other plants.

Exhibit 1 p. 9. Thus, retrofit financing may not be available. Moreover, even if it were, retrofitting a plant could make it non-competitive with other plants, and result in its closure for that reason alone. Perhaps most significantly, many of the existing OTC units are more than forty years old and approaching the end of their useful lives. Exhibit 8. The imposition of high retrofit costs on this aging fleet would be yet another significant incentive for early closure.

B. <u>The Consequences of Destabilizing the Electric System Must Be Carefully Analyzed</u>

1. <u>Impact of Existing Plant Closures:</u> California's demand for electricity is increasing because of the State's expanding population and economy. The system is already resource-constrained, and there is a current need to maintain the existing portfolio, implement aggressive customer demand response programs, and to add new dispatchable and peak generating capacity. The July 2006 heat storm and statewide Stage 2 Emergency are clear reminders of the system's vulnerability.

The existing OTC plants constitute 40% of California's existing generating capacity. It is inconceivable that the electric system would operate reliably without these or replacement plants. For the reasons identified in Section IV.A above, however, it is likely that the Staff Proposal would result in the closure of some or all of these facilities. At a minimum, the economic, social and environmental impacts of multiple plant closures must be fully assessed and considered before the SWRCB makes a final determination to adopt the Proposal in its present form.

The older steam boiler plants will continue to be phased out over the next five to fifteen years, and this timing would provide the opportunity for an orderly transition to replacement power. Providing for an orderly transition - as opposed to sudden and premature closures because of the Staff Proposal's inflexible standards – would also allow an increased opportunity for development of cost-effective generating capacity with lower environmental impacts. The need to build replacement plants on an emergency basis because of the unanticipated closure of the existing OTC facilities would severely limit the opportunity to develop well-planned alternatives. Moreover, a need to rapidly develop new replacement generating capacity could also result in increased development of generating plants in different geographic regions than the existing OTC facilities occupy. This could exacerbate the situation by greatly increasing transmission problems in an already constrained transmission grid.

Given the foregoing consequences, we strongly recommend that the California Public Utilities Commission, the California Energy Commission and the California Independent System Operator be directly involved in the Proposal's environmental assessment. These agencies have direct responsibilities regarding the availability and reliability of the State's electric system and customer rate considerations, and the insights they have on the consequences of closing existing OTC plants should be solicited and seriously considered.

2. The 15% Capacity Utilization Exemption: At the July 31, 2006 scoping hearing on the Proposal, Staff suggested that many existing facilities might be exempt from the Proposal pursuant to its 15% capacity utilization exemption. If true, this could impact the degree to which the Proposal would degrade the electric system. PG&E suspects, however, that this may not be the case. First, the 15% capacity utilization exemption is only from the Proposal's entrainment requirements, not the impingement requirements. Second, the Proposal's environmental review should carefully examine the extent to which this exception is likely to apply to existing facilities in light of reliability must-run contracts with the CA ISO, load service entity responsibilities, long-term power contracts between merchant generators and utilities, and the cumulative effect that other plant closures may have on the rate at which remaining plants must be dispatched. These factors would determine how feasible it is for the OTC facilities to run at less than 15% capacity utilization, and therefore the degree to which this exemption might work to maintain electric system supply and reliability. For example, in 2005, 2500 MW of CA ISO reliability must-run units had capacity factors that ranged from 17-60%, with a collective average capacity of 31%.

C. The Staff Proposal's Impact on Electricity Rates Should Be Analyzed

Assuming the Staff Proposal is technologically and legally feasible, the high compliance costs imposed on existing facilities will have to be borne by customers. In California, the wholesale commodity cost for electricity is passed directly to the customer of an investor owned utility. In other words, there is no difference between the wholesale and retail price for the customer. When the power generating facility is owned by an investor-owned utility, the commodity is provided to the customer at a cost-based price.

In California today, however, there are a number of factors which are placing upward pressure on the electricity rate, including increased costs for premium contracts given to qualifying facilities, a public goods charge that supports renewable energy development, and long-term contracts that were entered into by the California Department of Water Resources during the energy crisis which are still in place. In short, the Staff Proposal will force a choice between two high cost alternatives: (1) eliminating a low-cost, base load utility-owned energy supply and forcing replacement with a higher cost alternative; or (2) mandating conversion costs of between $1.3 - $1.9 billion at the Diablo Canyon Power Plant alone.

The SWRCB must consider the impacts of the Staff Proposal on California's citizens and electricity customers. Since the energy crisis, the California Public Utilities Commission, the California Energy Commission, the California Independent System Operator, the Department of Water Resources and the Governor have been working toward a more stable energy market and a more reliable and affordable energy delivery system. The Staff Proposal would significantly undermine these objectives.

D. The Proposal's Potential to Increase Greenhouse Gas Emissions and Cause Other Adverse Impacts Must Be Analyzed

It should be clearly recognized that closure of the State's two nuclear plants would have a tremendous impact on greenhouse gas emissions. The nuclear plants have extremely low air emissions, and they likely would have to be replaced by fossil plants if closed. PG&E estimates that replacement of DCPP's 2300 MW capacity by fossil fuel plants would increase CO2 emissions by 8 – 10 million tons/year.

Converting fossil OTC power plants to cooling towers would also reduce power plant efficiency significantly, and this too would increase greenhouse gas emissions. More fuel would have to be burned to maintain current levels of electric output. The California Council for Economic and Environmental Balance (CCEEB) has estimated that conversion of existing plants to wet cooling systems would increase statewide annual CO2 emissions by 311,491 metric tons, and that conversions to dry cooling systems would increase annual CO2 emissions by nearly 2 million metric tons. Exhibit 9 p. 869.

If Governor Schwarzenegger signs Assembly Bill 32 (Nunez), the electric generating community will embark on a large scale effort to begin greenhouse gas emission reductions. By effectively removing thousands of existing megawatts from service and forcing replacements with fossil fueled facilities, the Staff Proposal directly undermines the emission reduction goals of Assembly Bill 32 (Nunez), passed by both houses of the legislature and supported by the Governor.

As noted in Section IV.A above, the construction of new saltwater cooling towers along the California coast would also have a number of other significant adverse environmental impacts – including visual/aesthetic impacts, high saline discharge impacts, major construction impacts, and huge increases in energy requirements. If potable water cooling towers were constructed, CCEEB estimates an annual demand of over 20 billion gallons of fresh water.

Exhibit 9 at 869. The Proposal's environmental review must carefully evaluate all of the foregoing since there is a substantial possibility that the Proposal's total adverse environmental impacts would far outweigh its benefits.

E. <u>The Staff Proposal Should Not Be Adopted Unless Justified by a New Statewide Cost-Benefit Analysis</u>

At the outset, it should be noted that the economic principles associated with the valuation of natural resources are complex, and generally not part of common knowledge. In the interest of efficiency, we have not repeated those principles in this portion of these comments, but encourage the reader to refer to Exhibits 10 and 11 for a fuller explication of these principles, including a discussion of "non-use" benefits. Non-use valuation is generally seen as an effort to monetize the benefits associated with preserving the existence of a resource for present or future enjoyment. Non-use values are in addition to a resource's use values, which in the context of I&E reductions generally consist of improved commercial and recreational fishing opportunities.

USEPA went to considerable lengths in the Phase II Rulemaking to develop reliable methodologies for valuing the benefits of reducing I&E impacts. This issue was the subject of extensive public notice and comments, reviews by nationally recognized resource economists, and multiple efforts by EPA to attempt to assess non-use values through various means, including habitat replacement cost methodologies, which it ultimately concluded could not be used for this purpose. 69 Fed. Reg. 41,623-25. USEPA then developed regulations and guidance for performing benefit valuation studies at individual facilities, and conducted a series of regional valuation studies as part of its national cost-benefit analysis for the Phase II Rule. Id.

Among other things, USEPA analyzed the overall economic benefits of Phase II Rule compliance in California. Exhibit 12. Based on information gathered from 20 coastal power plants, this analysis quantified California's statewide I&E impacts and conservatively estimated the annual value of increased commercial and recreational fishing to be approximately $3 million. USEPA decided that it could not quantify non-use benefits as part of this rulemaking, 69 Fed. Reg. 41,624, but based on a qualitative assessment, found that non-use values "are likely to be appreciable for the California region." Exhibit 12 p. B5-2. Non-use values are a relatively new economic concept that is controversial and difficult to quantify, 69 Fed. Reg. 41,624 and 41,647-8, but even the most ardent proponents of non-use values do not contend that they exceed three times the total use values. Exhibit 11 p. 2.

The Staff Proposal, however, summarily concludes that USEPA's benefits valuation for the California Region "dramatically underestimated the overall ecological benefit of the Phase II rule" because it valued only 2 % of the species and did not monetize non-use values. Staff Proposal at 21. This conclusion is likely incorrect for several reasons. The species not valued in the EPA California Regional study consisted of forage species and uncaught commercial and recreational species. Since these species are uncaught, they do not have commercial or recreational value, but instead only have non-use values. As explained in Exhibit 11, non-unique resources such as common fish species do not have a high intrinsic value precisely because they are common, whereas non-use values are usually significant only for rare and unique resources.

Exhibit 12 p. 7.[14] While a different conclusion would arise if there were extensive impacts to threatened or endangered species, or other critical aquatic organisms, such species generally are not directly or materially affected by most of the existing OTC plants in California.[15] Therefore, while the value of reducing the I&E impacts of California's existing OTC plants may be understated by USEPA's California Region study, it is unlikely that it as dramatically understated as the Staff Proposal suggests.

The USEPA benefits valuation for California is certainly not perfect. However, the Staff's rejection of it wrongly implies that USEPA's valuation is wholly unacceptable. Given the greatly contrasting views of this valuation and its importance to this policy, the State should perform a new, peer-reviewed statewide valuation of the Proposal's costs and benefits before it is considered by the SWRCB in order to properly inform the decision, which clearly has significant economic implications. At present, the best available information is that the economic impacts of I&E in California are relatively modest. If the benefits of the Staff Proposal are low and the compliance costs are high, as appears to be the case, the Proposal should not be adopted as California's 316(b) policy.

F. <u>The Assumption that California I&E Impacts Have Substantially Contributed to a Material Decline in the Marine Environment Must Be Examined</u>

There is an underlying assumption in the Staff Proposal that the remaining OTC power plants are significant contributors to a material decline of the marine environment, and that they have impacts which are all equally high. These assumptions are not accurate and should not be universally applied as the State adopts its Section 316(b) policy. Instead, California's 316(b) policy must provide for site-specific evaluations of marine impacts. This is so because, in California, there are coastal, bay and estuarine OTC facilities, and all of which have unique marine environments and impacts. Assuming identical local environments and impacts regardless of the specific area and other activities that may be causing impacts in an area will not produce accurate results, and is not a fair baseline assumption.

Although the Staff's Scoping Document is virtually silent on the point, its general background and prior workshops suggest a conviction that I&E impacts are significantly contributing to a material decline in the quality of California's marine environment, and that the Proposal's stringent I&E reduction standards will significantly improve that situation. It is far more likely, however, that declines in marine water quality (including declines in any commercial and recreational fishing stocks) have been caused by over-fishing, loss of habitat, pollution and invasive species, and not by I&E impacts on relatively small percentages of the

---

14 As explained in Exhibits 10-11 and 13-14 and Section V.C below, habitat replacement costs and habitat production foregone analyses cannot be used to reliably estimate use or non-use values. These systems are based on the costs of creating or restoring a resource, and those costs do not and cannot serve as a proxy for the resource's value. Value is instead defined by people's willingness to pay for the resource. For example, it might cost $100/fish to build a hatchery and produce sea bass. The value of the fish is not $100, however, but instead would be its $20 purchase price at the market.

15 The Contra Costa and Pittsburgh power plants are exceptions to this observation.

enormous number of fish and shellfish larvae and eggs present in the ocean, estuaries and bays. (Section VI below discusses in detail the reasons why I&E effects are not necessarily ecologically significant.)

PG&E is not contending that I&E never has a significant impact. Indeed, there are cases where the impacts are significant, and PG&E firmly believes that I&E effects must be studied and addressed on a site-specific basis. There is, however, a substantial body of evidence which indicates that these effects are not always significant, and it therefore would be improper to assume that I&E in California is contributing significantly to a decline in the quality of the marine environment. In short, the Staff Proposal's stringent regulations will not necessarily produce significant environmental improvements. Before a California policy is adopted, a scientifically rigorous analysis of I&E effects should be conducted, including an assessment of the true biological benefits that would be achieved by imposing different and more stringent standards on existing power plants.

There are significant economic and social costs associated with the Staff Proposal. These economic and social impacts must be carefully balanced against a factually accurate assessment of the Proposal's environmental benefits. In some cases, the environmental impacts of OTC operations are extremely low, and the Proposal's requirement to close such sources or force customer cost increases to pay for expensive retrofits would only result in extremely modest environmental improvements. This, for example, was found to be the case with respect to impingement at the DCPP, where the RWQCB staff found there that ". . .[t]he impact is so minor that no alternative technologies are necessary to address impingement at DCPP, and the cost of any impingement reduction technology would be wholly disproportionate to the benefit to be gained." This is discussed in greater detail below.

V

COMMENTS REGARDING SPECIFIC PROVISIONS OF THE STAFF PROPOSAL

This Section provides PG&E's recommendations concerning specific provisions of the Staff Proposal, and other provisions that should be included in the State's 316(b) policy.

A. <u>The State's 316(b) Policy for Existing Facilities Must Provide for Flexible, Site-Specific Performance Standards and Compliance Alternatives</u>

As discussed in Section IV, the impact of I&E can vary greatly from plant to plant depending upon CWIS design, location, construction and capacity features, and on the nature and extent of the biota living in the area. For example, the same technology can produce different results in different locations because of variations in weather and the nature of biota present. Additionally, different areas can be subject to different types and degrees of environmental stresses, which must be evaluated and differentiated from an OTC plant's I&E impacts. For example, the State Water Project's pumping facilities may have an enormous impact on fish larvae and eggs in the Bay Delta; recreational and commercial fishing have direct impacts on adult and larvae population levels, but vary dramatically from place to place; and, invasive species introduced by ships in transit and non-point source pollution can also have significant impacts on fish and shellfish populations.

These and other considerations led USEPA to conclude in the Phase II Rule that a single compliance technology and fixed I&E reduction standards could not be imposed on existing facilities, and that other, more flexible compliance standards and options were necessary. 69 Fed. Reg. 41,598 – 41,601. EPA reached this conclusion with regard to existing facilities even though it had earlier decided with respect to new facilities that a single technology (cooling towers) constituted the best technology available for reducing adverse environmental impacts at new construction sites - where cooling towers could be installed efficiently, and where companies can select locations that will accommodate such structures and avoid high impact to sensitive areas. Existing power plants generally do not have this luxury, and in many if not all cases, technological problems and the high costs of retrofitting may make cooling towers or other technologies and operating procedures impracticable.

The Staff Proposal's inflexible policy is likely to be infeasible at many plants, and will certainly produce drastic results. The Diablo Canyon Power Plant (DCPP) provides a good example. For the past 10 years, I&E impacts at DCPP have been carefully studied and analyzed under the oversight of a Technical Working Group consisting of representatives from the RWQCB, Department of Fish & Game (DFG), USEPA, independent scientists, environmental groups and PG&E. Past studies demonstrated that only about 1600 pounds of fish a year[16] are impinged at the Plant. That finding led the Central Coast RWQCB staff to conclude that:

> Impingement of adult and juvenile fish on the traveling screens in front of a cooling water intake structure at DCPP amounts to only a few hundred fish per year. This impact is so minor that no alternative technologies are necessary to address impingement at DCPP, and the cost of any impingement reduction technology would be wholly disproportionate to the benefit to be gained.

Exhibit 6 p. 2.[17] Regardless of this unique, site-specific finding, the Staff Proposal would mandate a 95% reduction of this impingement level – from 1600 to 80 pounds per year - even though the estimated cost to achieve compliance with the Staff Proposal's impingement reduction standard would be in the range of $1.3 - $1.9 billion.[18] It makes no sense whatsoever

---

16 1600 pounds is roughly equal to the combined catch of four recreational fishing party boats.

17 The RWQCB Staff's findings with respect to entrainment are discussed in Section IV.A.1.e above.

18 Earlier analyses of DCPP impingement reduction technologies evaluated alternative cooling water intake structures with an expanded intake area or inclined traveling screens, each with an estimated cost of $275 million. Exhibit 15. These systems, however, probably would not achieve the 95% reduction required by the Staff Proposal, and therefore, the only conceptual technology available to achieve the Staff Proposal's impingement reduction standard is cooling towers.

to spend $1.3 - $1.9 billion to reduce the DCPP's impingement effects which have already been found to be insignificant.

Additionally, the cost to comply with the Staff Proposal's requirement for impingement reductions would either force closure of DCPP and the permitting and construction of 2300 megawatts of new fossil fuel facilities with 8 – 10 million tons of additional greenhouse gas emissions, or, if technologically and legally feasible, the conversion of DCPP to mechanical wet cooling towers at a cost of $1.3 - $1.9 billion to PG&E's customers. Constructing a new power plant today takes approximately three years and costs approximately $939 per kilowatt in 2006 dollars.

B. <u>The State's 316(b) Policy Should Retain a Cost-Benefit Compliance Alternative for Existing Plants</u>

Part of the site-specific approach for regulating existing facilities must include a site-specific cost-benefit compliance alternative in order to prevent economically impracticable results. USEPA's Phase II Rule includes such provisions for just that reason, and requires that site-specific compliance standards be developed whenever the cost of complying with the national standards is significantly greater than the benefits. In such circumstances, the permitting agency is to impose requirements that achieve an efficacy as close as practicable to the national standards, but only to the degree that costs do not significantly exceed benefits.

USEPA's Phase II Rule establishes specific requirements for valuing the benefits of compliance. Generally speaking, the regulations require an assessment of commercial fishing, recreational fishing and non-use values associated with I&E reductions. According to USEPA, non-use benefits are difficult to quantify and controversial, and only need to be monetized in specified, unique circumstances, such as where I&E poses a significant risks to threatened and endangered species. 69 Fed. Reg. at 41,647-8. The Staff Proposal, however, precludes any consideration of costs or benefits in permitting decisions, and would instead require maximum I&E reductions at existing plants regardless of the costs or benefits. As the DCPP's peer-reviewed, benefits valuation study makes clear, a mandatory California policy that forces customers to pay for I&E reductions at DCPP at any cost would be completely unreasonable and totally unacceptable.

1. <u>Benefit Analyses for the Diablo Canyon Power Plant:</u> Two separate approaches to valuing I&E losses have been undertaken at the DCPP in recent years. One study was conducted for PG&E by Triangle Economic Research under the Phase II Rule's requirements and recommended procedures (TER Report). The other approach was undertaken at the request of the RWQCB by three independent scientists, none of whom is a resource economist (IS Report). These studies are summarized below, and are presented in full in the Exhibits 10 and 16.

a. <u>TER Report: Phase II Benefits Valuation Study:</u> TER's Phase II Study was conducted in 2005, and assessed the economic benefits of achieving the Phase II Rule's I&E reductions at the DCPP using USEPA's standards and procedures. Exhibit 10. The TER Report was recently peer-reviewed by two resource economists from the University of California at Santa Barbara (UCSB). Exhibit 14 (Professor Deacon); Exhibit 17 (Professor Kolstad).[19]

The TER Report monetized commercial and recreational fishing benefits using USEPA's valuation (or even more conservative) techniques. Since the DCPP's I&E characterization study analyzed 70% of the larvae entrained, TER "grossed up" its benefits valuation to account for all fish impinged and entrained based on very conservative assumptions. Exhibit 10 p. 2. TER also valued the benefits of increases in forage species using USEPA's trophic transfer and production foregone methods. Exhibit 10 p. 18. In essence, this approach values forage species based on the amount of increased commercial and recreational fishing that might occur if additional forage stocks were available, again based on conservative assumptions. Assuming the DCPP were to operate until 2053,[20] TER estimated the net present value of these commercial and recreational use benefits, and the ecological value of the increase in forage species, to be approximately $1 million.

Using USEPA's guidance, TER also determined that all other non-use values did not need to be monetized. Non-use values are normally associated with unique resources, and DCPP has no significant impact to threatened or endangered species, or the like. Instead, the larval losses it causes are mostly to small, near shore forage species. As a result, TER's qualitative analysis of non-use values concluded that they were likely to be low. Exhibit 10 p. 38. The UCSB peer reviewers did not disagree with this assessment, but recommended greater detail in support of the analysis. Exhibit 14 pp. 9-10; Exhibit 17 pp. 11-13.

b. IS Report: Habitat Production Foregone Analysis: At the Central Coast RWQCB's request, several independent scientists considered mitigation projects to compensate for DCPP's I&E losses. See Exhibit 16. The scientists approached the issue from the perspective of habitat replacement, and concluded that the establishment of Marine Protected Areas (MPA) or the construction of artificial reefs could offset larval losses by creating additional habitat for rocky reef fishes. The scientists asserted that the costs of MPA's or artificial reefs – which they sized using a "habitat production foregone" analysis – best reflected the value of the lost resources. They estimated MPA's to cost $6 million to $8 million, and

---

19 The Deacon and Kolstad peer reviews were completed in July and August 2006. Both endorse the TER Report's general approach to valuation, consistency with EPA standards, and overall valuations, but make specific recommendations for improvements to the analysis and its exposition. Neither peer reviewer believes that his recommendations will result in material changes to the bottom line of TER's benefits estimation. Exhibit 14 p. 12; Exhibit 17 p. 6. TER is in the process of responding to the peer review comments, and also believes that its responses will not materially affect the TER Report's bottom line conclusions.

20 Such an operating period would require renewal of the DCPP's two NRC operating licenses (one for each of the DCPP's two reactors), which do not expire until 2021 and 2025. No decision has been made as to whether to seek renewals of the NRC licenses. The assumption of license renewal was made by TER in order to provide a conservative estimate of the economic benefits that might be achieved through compliance with the Phase II Rule.

artificial reefs to cost $10.6 million to $26 million. Exhibit 16 p. 27 and 21, respectively. (As discussed below, resource economists reject habitat replacement costs as a valid means of valuing the lost resources.)

c. Even if Alternatives to the Diablo Canyon's Cooling Water System Were Feasible, Their Costs Would Be Wholly Out of Proportion to Their Benefits

The most economically accurate valuation I&E at DCPP is approximately $1 million (TER's assessment of the net present value of commercial, recreational and forage species through 2053). TER concluded that non-use values are likely insignificant in this case, and has reported that even the most aggressive proponents of non-use valuations would not project such values to be greater than two to three times the total use values. Exhibit 11 p. 2 . That the Staff Proposal would require an investment of $1.3 billion to $1.9 billion to produce a maximum of $4 million in benefits (assuming non-use benefits are $3 million, i.e., three times the total use value of $1 million) demonstrates why rejecting USEPA's Phase II Rule cost-benefit compliance alternative would *not* be a prudent policy for California. Indeed, this is true even if one were to value DCPP's I&E reduction benefits using the habitat production foregone methodology advocated by the Staff Proposal. As reported above, the IS Report valued I&E losses at DCPP to be $6 million to $26 million. Even this level of alleged benefits makes no sense in light of the exorbitant customer cost to produce them.[21]

C. The Habitat Production Foregone Method Should Not Be Used in Section 316(b) Analyses:

1. HPF Cannot Be Used to Place a Value on I&E Losses: The Staff Proposal would require the use of Habitat Production Foregone (HPF) analysis in support of State 316(b) permit decisions. As discussed above, independent scientists used the HPF approach in their assessment of DCPP mitigation options. That analysis was reviewed by three sets of resource economists – TER and Professors Kolstad and Deacon, the two UCSB resource economists who also reviewed the TER Report. All three concluded that the HPF approach violates fundamental economic principles by endeavoring to use habitat replacement costs as a proxy for the value of the lost resources. Exhibits 11, 13. and 14 pp 13-17. "Value" is not based on the costs of producing a good or service, but instead is based on people's willingness to pay for it. As TER observed, for example, the HPF approach would conclude that the "value" of lost larval resources would rise or fall with variations in any component of the costs of constructing artificial reefs. Exhibit 11 pp. 11-12. The larvae would be more valuable if the cost of gas went up, for example, and less valuable if the costs of artificial reef materials went down. This does not make sense.

---

21 Stratus Consulting Inc., a proponent of habitat replacement cost (HRC) valuations, prepared a PIER Project Report for the California Energy Commission, advocating HPF and HRC as appropriate means of scaling restoration projects to offset I&E losses. (Stratus, October 2004). As explained by TER in Exhibit 11, however, neither approach is valid for establishing the economic value on I&E losses, and the cost of the HPF or HRC-sized restoration project must still be compared with the value of the I&E losses to determine whether it should be performed under the Phase II Rule. (The validity of using restoration as a compliance option is currently being appealed in *Riverkeeper v. U.S. EPA*, No. 04-6692-ag(L) (2nd Cir.).)

USEPA recognized in the Phase II Rule that costs cannot be used as a proxy for value, notwithstanding its serious effort to use habitat replacement costs as a means of valuing I&E reductions. 69 Fed. Reg. 41,624 – 25. USEPA's Economic Guidelines for Preparing Economic Analyses also flatly reject habitat replacement cost analyses as a proxy for value:

> Alternative approaches that estimate the total value of ecosystems based on the cost of the entire ecosystem or its embodied energy . . . have received considerable attention as of late. However, the results of these studies should not be incorporated into benefit assessments. The methods adopted in these studies are not well-grounded in economic theory, nor are they typically applicable to policy analysis.

EPA 2000 Guidelines p. 98. Comparing TER's peer-reviewed benefit valuation of $1 million with the range of HPF estimates developed by the independent scientists - $6 million to $26 million – highlights the inaccuracy of cost-based valuations, which according to the resource economists can only serve as an absolute upper bound to the real value of benefits, but can never themselves be a defensible estimate of value. Exhibit 13 pp. 1-2.

2. The Habitat Production Foregone Analysis Has Methodological Flaws that Preclude Its Use for Reliably Estimating the Size of Restoration Projects: The Staff Proposal does not elaborate on what is meant by the HPF methodology. Based on our experiences with the IS Report, however, PG&E has some understanding of what is intended. Nevertheless, clarification of what is meant is necessary. For present purposes, we assume that the HPF approach intended is that which was employed in the IS Report discussed above.

As discussed in Exhibit 11 at pages 2 and 21-24, the HPF suffers from a number of methodological flaws which preclude its use as a reliable estimator of the size of mitigation projects necessary to compensate for I&E losses. As described there, the HPF methodology: (1) fails to provide a necessary linkage between I&E effects, ecological services and human services; (2) fails to consider discounting, and thus would overestimate the size of the restoration project (e.g., I&E effects terminate when a plant shuts down, but the benefits of restoration may continue in perpetuity); (3) does not account for uncertainty in its analysis; and (4) fails to consider biological compensation, especially in relationship to larval losses, and is again overly conservative for that reason as well. In sum, the HPF is an over-simplified system that at best produces overly conservative ballpark estimates.

For the foregoing reasons, the HPF methodology should not be a fundamental component of California's Section 316(b) policy.

D. PG&E Generally Supports the Concept of Expert Panels to Oversee I&E Characterization Studies

I&E characterization studies in coastal environments are complex, time-consuming, and extremely expensive. Accordingly, there should be no doubt about the study design or the sufficiency and quality of the data gathered. Having expert, multi-party input into the design and performance of these studies minimizes the possibility of inadequate studies and enhances the credibility of the results. In DCPP's case, its I&E characterization study was overseen by a technical working group with representatives from the RWQCB, USEPA, the California Department of Fish & Game, an environmental interest group, several independent scientists selected by the RWQCB with expertise in marine biology, PG&E and its expert consultants. There have been no serious questions about the thoroughness and accuracy of the DCPP's I&E characterization study.

PG&E is less certain about the prospect of having a single group of experts oversee all studies in the State, and would strongly object to any program in which the permit applicant did not have a voice. Just as permittees may be suspected of having an incentive to minimize studies because of cost considerations, project opponents and agency personnel may be suspected of having incentives to over study issues, maximize costs, and delay permitting decisions. Ultimately, the permittee must have the right to proceed with whatever study it believes should be conducted, just as the RWQCB's should retain the right to reject an applicant's study, subject only to SWRCB and judicial review.

E. The State Policy Should Not Require I&E Characterization Studies To Examine All Species

PG&E is unaware of any I&E characterization study that has ever characterized all plant and animal species potentially subject to I&E. These studies are already expensive, and this requirement could make them absurdly so, without corresponding environmental benefit. For reasons explained in Section VI below, there is simply no legitimate reason to characterize zooplankton and phytoplankton; these species are not seriously affected by I&E. There may be other species that are not worth studying - because they are rarely present in a given environment, because they are unlikely to be subject to entrainment (demersal eggs, for example), or because it is a species whose larvae have drifted into an area where they cannot survive, etc. The very purpose of having an expert panel to review I&E characterization studies is to ensure that the study results are representative of the probable I&E effects, and that money is not wasted studying that which is likely not important. There is simply no need to have requirements for both an expert panel and the study of all species, and the study of all species is clearly unnecessary if the study is approved by an expert panel.

F. The Frequency of I&E Characterization Studies Should Be Left to the Discretion of the Regional Boards

In addition to the initial I&E characterization studies, the Phase II Rule requires a verification monitoring program. If periodic monitoring demonstrates that there have been no significant changes in the nature and extent of the organisms being impinged or entrained, there should be no requirement for the complete repeat of an I&E characterization study at each permit renewal. Since I&E characterization studies must be performed for at least one year, and since permit renewal applications must be submitted six months before expiration of the five-year permit, a requirement for new studies at every renewal would require nearly continuous I&E

characterization studies throughout a plant's operating life. This is clearly unnecessary and probably an extraordinary waste. Applicants should be given the opportunity to demonstrate that prior studies are still valid based on verification monitoring data. RWQCB's will still have the right to disagree with such demonstrations, and can require new studies in appropriate circumstances.

G. The Proposal's Nuclear Safety Exemption

If operational or technological I&E reduction measures conflict with a nuclear safety requirement, the Staff Proposal would allow a nuclear plant to achieve full compliance with the upper end of the performance standards through *any* combination of operational, technological and restoration measures. It is presently unclear to what extent nuclear safety concerns may be impacted by I&E reduction measures, and in any event, the use of restoration measures as a compliance option at existing power plants may be invalidated by the court in *Riverkeeper v. United States Environmental Protection Agency*, No. 04-6692-ag(L) (2nd. Cir.). A decision in that case is expected later this year.

VI

IMPINGEMENT AND ENTRAINMENT EFFECTS ARE NOT ALWAYS ECOLOGICALLY SIGNIFICANT

As noted in Section IV above, the Staff Proposal appears to be based on the assumption that I&E impacts in California have led to substantial declines in the quality of the marine environment, including reductions in commercial and recreational fish stocks. This assumption oversimplifies the relationship between I&E impacts and the health of ocean ecosystems, and fails to recognize that the effects of I&E on marine species are likely to vary from case-to-case and species-by-species. The Staff Proposal further neglects to acknowledge that in many if not most instances, the effects of I&E on marine life can be insignificant. The following sections highlight various studies and principles which demonstrate why I&E effects are insignificant in many cases.

A. Cooling Water Intake Structures Are Known to Have Negligible Impacts on the Vast Majority of Organisms Subject to Impingement and Entrainment

As Dr. Michael Foster reported to the SWRCB staff at the September 2005 316(b) Workshop, more than 99.7% of the organisms entrained in California consist of phytoplankton and zooplankton. Exhibit 18. These microscopic plants and animals exist in extraordinary numbers, have very short life spans and regeneration times, and are widely distributed in the ocean by currents. Numerous studies have concluded that CWIS impacts on these species are negligible, that such impacts occur in the immediate vicinity of an intake structure at most, and often are not observed at all even within the immediate area. The Marine Review Committee for the San Onofre Generating Station, for example, reached this conclusion after extensive study and analysis. Exhibit 19. Numerous other studies by the NRC and other researchers have consistently reached the same conclusion.[22]

B. <u>The Entrainment of Substantial Numbers of Fish and Shellfish Eggs and Larvae Can Be Ecologically Inconsequential</u>

Fish and shellfish typically produce hundreds of thousands, or even millions of eggs or larvae, the overwhelming vast majority of which will die of natural causes before maturing to adults. EPA's fish life history tables for the California Region provide evidence of this fact. Exhibit 12 Appendix B1. Organisms with this type of life history have "density dependent" population dynamics. When population growth rates are density dependent, an increased loss of juveniles or adults is compensated for by increased survival and/or reproductive rate by the remaining population. Density dependency is a well-established principle that underlies the federal government's management of many fisheries populations. The National Marine Fisheries Service, for example, has been applying this concept for decades.

Given these biological realities, the loss of a significant number of larvae and eggs as a result of entrainment does not necessarily result in a significant ecological impact. Likewise, cessation of entrainment impacts may also have no significant ecological effect, since the un-entrained larvae and eggs are likely to die of natural causes anyway. Even if larval and egg losses were to contribute to an initial population decline, which is rarely the case, fish populations will normally stabilize themselves through increased reproductive success, faster growth, longer lives, and the like. I&E assessment procedures do not account for compensation, and therefore overstate actual impacts.

---

22 See, for example: Electric Power Research Institute (EPRI). 1979. Ecosystem Effects of Phytoplankton and Zooplankton Entrainment. EPRI EA-1038; Project 876. Palo Alto, CA; Jensen, L.D. 1981. Issues Associated with Impact Assessment. Proceedings of the Fifth National Workshop on Entrainment and Impingement. L.D. Jensen (ed.) EA Communications, Sparks, MD; Randall Melton, B. and G. M. Serviss. 2000. Florida Power Corporation – Anclote Power Plant Entrainment Survival of Zooplankton. In Power Plants and Aquatic Resources: Issues and Assessment. J. Wisniewski (ed.) Environmental Science & Policy: Vol. 3 Supplement 1S233-S248; US Nuclear Regulatory Commission, Generic Environmental Impact Statement for License Renewal of Nuclear Plants (NUREG-1437); 10 CFR Part 51; Hess, L.W., et al., 1982. The Middle Missouri River – A Collection of Papers on the Biology with Special Reference to Power Station Effects, The Missouri River Study Group, Norfolk, Nebraska; Kennish, M.J. et al., 1984. "Anthropogenic Effects on Aquatic Communities," pp. 318-38 in M. J. Kennish and R.A. Lutz, eds., Ecology of Barnegat Bay, New Jersey, Springer-Verlag, New York.; Maryland Department of Natural Resources. 1988. Power Plant Cumulative Environmental Impact Report for Maryland, PPRP-CEIR-6, Power Plant Research Program, Maryland Department of Natural Resources, Annapolis, MD.

C. Numerous Site-Specific and Regional Studies Confirm that Impingement and Entrainment Impacts May Not Be Significant Impacts

I&E effects have been reviewed by many other states and regions and these studies should be reviewed as part of the staff's assessment of the Proposal. For example, scientists from the California Polytechnic State University in San Luis Obispo recently completed a study of rock fish populations on California's central coast, an area with relative limited anthropogenic impacts on the ocean. This study concluded that "[i]n general, the south central coast rockfish resources, with the exception of bocaccio[23] (*S. paucispinis*), have not shown strong evidence of a declining trend over the past 25 years." Exhibit 20. This study's data base began five years before DCPP commenced operations (in 1985). Rock fish larvae are entrained at DCPP, and if this entrainment were having a substantial effect, one would have expected to see population-level declines in rock fish populations somewhere along the central coast. The fact that such declines have not occurred after twenty years suggests that the DCPP's impact on these species is not ecologically significant.

Additionally, several long-term regional studies have demonstrated that even the cumulative impacts of multiple power plants on a single water body may not cause significant adverse environmental impacts. Striped bass populations in the Hudson River, for example, have increased by a factor of 10 in recent years, despite the operation of five power plants authorized to withdraw up to 5 billion gallons/day of cooling water. Exhibit 21 p. S344. The recovery of these populations may have been due to fishing bans, but the point is that the continued operation of the Hudson River OTC plants likely did not suppress the striped bass populations in the first place, or prevent their recovery.

A major study of the Chesapeake Bay, where 13 power plants withdraw up to 8 billions of cooling water a day from the nation's largest and most productive estuary, also concluded that "while the operation of individual power plants impact various ecosystem elements in various ways, those impacts, taken together, have had no identifiable substantive cumulative impact on Maryland's aquatic resources to date." Maryland Power Plant Research Program 1999 Cumulative Environmental Impact Report; also see Exhibit 22.

Finally, USEPA has made a number of findings at existing facilities that significant entrainment levels are not ecologically significant. For example, the USEPA found that the entrainment of 100 billion clam larvae by the Seabrook Power Plant would only have an "insignificant effect on adult [clam] populations," see *In re Pub. Serv. Co. of N.H. (Seabrook station, Units 1 and 2)*, 1 E.A.D. 332, 1977 EPA App. LEXIS 16, at *62 (EPA June 7, 1977), and later explained that, although "[f]ish eggs and larvae may be ... subject to ... entrainment in substantial numbers," for most species "the impact of either intake entrainment or thermal discharge will be insignificant." *In re Pub. Serv. Co. of N.H.*, 1 E.A.D. 455, 1978 EPA App. LEXIS 17, at *43 (Aug. 4, 1978).[24]

---

23 Bocaccio have been over-fished. Exhibit 12 p. B2-2 (Table B2-1).

24 Other EPA permit decisions also concluded that I&E impacts were not significant. *See In re Pilgrim Nuclear Station Unit 2 (Boston Edison)*, NPDES Permit No. MA0025135,

As the foregoing discussion demonstrates, entrainment of phytoplankton and zooplankton rarely if ever results in a significant ecological injury, and these are the organisms entrained in the highest numbers. As to fish and shellfish larvae and eggs, even significant levels of entrainment can be without significant ecological effect given the typical reproductive strategies of these species and the principle of density-dependent biological compensation. This is not to suggest that entrainment is always insignificant. Indeed, there are cases where significant adverse environmental effects do occur because of site-specific considerations. As a general proposition, however, it would be incorrect to base the State's 316(b) policy on the assumption that I&E impacts are always significant, and that the Proposal's requirements will produce significant ecological benefits. In fact, reducing I&E levels at many existing OTC facilities will probably have no significant environmental benefit whatsoever.

VII

CONCLUSION

As explained above, there are substantial reasons why the Staff Proposal may be technologically, legally and economically infeasible at existing once through cooling plants, and as a result, would force the premature closure of many or all of these facilities. The loss of up to 40% of the State's electric generating capacity would destabilize the electric delivery system, increase customer electric rates, adversely impact the electric market, and likely produce significant adverse social and environmental problems, including large increases in greenhouse gas emissions. The Staff Proposal's functional equivalency document must thoroughly evaluate the Proposal's true feasibility, and costs and benefits to be sure the SWRCB does not unintentionally create drastic economic and environmental injuries through the adoption of a well-intentioned policy. The policy ultimately adopted should provide for a smooth transition from the existing OTC plants to new energy sources while effectively balancing a complex set of social, economic and environmental factors during the interim.

Thank you for providing this opportunity to comment on the Staff Proposal. Please contact Lorraine Paskett of PG&E should you have questions or desire elaboration on any of the foregoing comments. She may be reached at (916) 386-5709.

EPA Region I at 36 (Mar. 11, 1977) ("the entrainment impacts on the [representative important species] are minimal in comparison to the species population in the area of impact."); *see also Crystal River (Florida Power Corp.)*, NPDES Permit No. FL0000159, Findings & Determinations (Dec. 2, 1986); *In re Carolina Power & Light Co.*, NPDES Permit No. NC 0007064, slip. Op. (Nov. 7, 1977).

CALIFORNIA ENERGY COMMISSION
1516 NINTH STREET
SACRAMENTO, CA 95814-5512
www.energy.ca.gov

April 11, 2006

Paul D. Thayer, Executive Officer
California State Lands Commission
100 Howe Avenue, Suite 100-South
Sacramento, California 95825-8202

Dear Mr. Thayer:

Attached to this letter are responses to questions received from you and others regarding the possible effects of the State Lands Commission staff draft resolution pertaining to once-through cooling on the coastal power plant fleet. The questions are organized into three general categories:

1. California Energy Commission (Energy Commission) authorities and permitting issues for coastal power plants, and work by the Energy Commission on once-through cooling;

2. Current and anticipated operations of the coastal power plants and their contributions to California's electricity supplies; and

3. Considerations of the possible effects of the draft once-through cooling resolution on the operation and/or replacement of coastal power plants.

Please call me at 654-4496 if you have any questions or have your staff contact Chris Tooker at 653-1634 or Jim McKinney at 654-3999 if you require clarification, have questions, or further discussion is necessary.

Sincerely,

_______signed__________

B. B. BLEVINS
Executive Director

Attachment

Question 1 – What is the lead time for issuing permits for new generating capacity?

The Energy Commission has exclusive permitting authority for thermal power plants 50 megawatts (MW) or greater and serves as lead agency under the California Environmental Quality Act (CEQA) for projects within our jurisdiction. The Warren-Alquist Act specifies a mandatory 12-month time period to permit new power plants. Since deregulation of the electricity industry, the Energy Commission has permitted one retooling and three replacement power plant projects on the coast that use once-through cooling. The time it took the Energy Commission to permit these once-through cooling (OTC) projects ranged from 3 months for the Huntington Beach retooling project during the energy emergency to 43 months and 46 months for the Morro Bay and El Segundo projects, respectively. The Moss Landing project was permitted in 14 months. The Morro Bay and El Segundo Projects took far longer than the normal permitting time because of disputed issues regarding OTC and the time it took the applicants to supply requested information and address and resolve all the issues raised by the Energy Commission. Permitting time is often proportionate to the difficulty and controversy of the issues that need to be addressed, what issues are in dispute, and the level of community or intervener participation and concern.

In addition to the permit review time, applicants require about six tonine months to prepare an Application for Certification, and 18 to 24 months to construct a project. If an Energy Commission certified project is modified after certification, including modifications to the cooling system, the Energy Commission has jurisdiction over the modification and must approve the modification as an amendment to the decision. Depending on the type of modification, the amendment process normally takes two to six months to complete.

Question 2 – What is the process for re-permitting the existing plants that would be affected by this resolution?

This question raises several issues about how the coastal power plant owners may choose to respond to a State Lands Commission resolution on once-through cooling over a 14-year time period. The answer to the permit question depends on how each owner chooses to respond. Three response options are:

Option 1 – Owners choose to "only retrofit" the cooling system from once-through cooling to cooling towers or dry cooling, but not modify or replace (i.e. repower) the existing electrical generating system (including the gas and steam turbine generators).

Option 2 – Owners choose to repower the electrical generating system and switch to cooling towers or dry cooling.

Option 3 – Owners choose to replace the electrical generating system with a technology that does not require cooling, such as combustion turbine peaker units.

Under Option 1, if the power plant was not originally certified by the Energy Commission, the installation of cooling towers or a dry cooling system would either require a revision to the original local permit, or for a municipal utility owned project, a municipal utility permit, to ensure conformance with the California Coastal Act, any other affected existing permit conditions, and CEQA. If the power plant was originally certified by the Energy Commission, this option would require an amendment to the Energy Commission's decision and functionally equivalent CEQA documentation would be required and performed by the Commission. While there are environmental benefits derived from avoiding the use of once-through cooling, alternatives that require the use of cooling towers or dry cooling systems are more costly, require more space, and can result in visual and noise impacts. Cooling towers also require a source of reclaimed, ground or potable water. Current Energy Commission policy seeks to encourage the use of reclaimed or recycled water in lieu of fresh water for power plant cooling, but this policy would not apply to projects outside of our jurisdiction.

Under Option 2, an Energy Commission license would be required for facilities not originally permitted by the Commission only if the project modification resulted in a net generating capacity increase of 50 MW or more. If the Energy Commission previously certified the project, a modification of less than 50 MW would require an amendment to the original Energy Commission decision and a functionally equivalent CEQA process. If a local agency or municipal utility previously permitted the project, and the modification was less than 50 MW, the local agency or municipal utility would permit the modification and conduct the appropriate CEQA review. For example, the Los Angeles Department of Water and Power (LADWP) has self-permitted very large power plant replacement projects by keeping the net change below the Energy Commission's jurisdictional threshold.

Under Option 3 where new combustion turbines are installed, the permit requirements would be the same as for Option 2. Because cooling towers or dry cooling would not be needed, these issues would not be evaluated during the CEQA review.

Question 3 – What percentage of the energy actually used by California is generated at OTC coastal power plants? (Not the percentage of capacity). What is the capacity of plants to produce power versus the actual production? What is the relative contribution of the different types of power generators and how might that change over time?

In aggregate, the 21 large coastal power plants using once-through cooling generated 58,345 Gigawatt-hours (GWh) in 2004, which was 22 percent of total in-state electricity sales. The relative contribution of each technology is shown in the table below.
The capacity factor of a power plant is a measure of the amount of energy it generates in one year. A 100 percent capacity factor means that a facility generates around the

clock each day and hour of the year. The 2004 capacity factors of the coastal power plants with once-through cooling are summarized below.

Technology	Capacity Factor (percent)	Generation as Percent of State Total (2004)
Steam Boilers	19.4	9.0
Combined Cycles	34.9	2.05
Nuclear	79.1	11.08
Combustion Turbine	2.1	0.04

Presently, the older steam boiler power plants operate at relatively low capacity factors on an annual average basis, but provide critical capacity reserves and energy production that are needed to meet peak demand during the summer months. As such, the above table does not adequately reflect the importance of the coastal plants to the state's electricity system, since their generation as a percent of state total is significantly higher during periods of peak demand when system reliability becomes a critical issue. Most of these coastal facilities have been operating at their full capacity during the highest peak demand periods of the summer. Over time, it is anticipated that many of the steam boilers will be replaced with more efficient generating technologies.

Question 4 – Please provide information concerning individual power plants – are any proposed for shutdown by 2020? What about those plants that intend to re-power? Which of these plants seem likely candidates for conversion to non-OTC cooling? Which plants seem obviously not to be a candidate (i.e., location and water limitations)?

As discussed later in the response to Question 9, two plants are no longer operational (Long Beach and Hunters Point), and two more (Humboldt and San Diego South Bay) have announced plans to repower without once-through cooling.

Plants that have recently repowered and the nuclear facilities would encounter difficult financial obstacles if they were to pursue a new cooling technology. Conducting a site-by-site feasibility assessment of cooling technology alternatives is a task that is beyond the scope and time frame of this letter.

Question 5 – What approach has been taken by the CEC and what authority and jurisdiction does the CEC have over OTC power plants?

As discussed in our responses to Questions 1 and 2, the Energy Commission has the legal obligation to thoroughly review potential environmental effects under CEQA for each application on a case-by-case basis and determine whether the impacts are significant and mitigable. The cases involving once-through cooling that have come before the Energy Commission have presented challenging analytic issues for our agency.

The Energy Commission and its staff have created an extensive body of knowledge on once-through cooling issues through its siting, planning and PIER programs, and through Commission-level policy reports and siting case decisions. In its 2005 Integrated Energy Policy Report, the Energy Commission provided the following policy guidance on once-through cooling:

1. Work collaboratively with agencies on OTC through the Ocean Protection Council.
2. Continue research on impact assessment protocols, impact reduction and alternatives to OTC.
3. Update Memorandums of Agreement (MOA) with SWRCB, RWBs and Coastal Commission to develop consistent regulatory approaches, including investigating retrofit control technologies (BARCT)
4. Update Data Adequacy Regulations for License Applications and for California Coastal Act consistency.

Question 6 – Are OTC considerations different for the two nuclear power plants?

Yes. California's two nuclear facilities represent billions of dollars in ratepayer investments and operate in a base load mode with very high capacity factors. They are a critical element of California's electricity supply system. Potential retrofits would be expensive and present engineering feasibility challenges. Very little information on the potential costs of retrofitting nuclear facilities to use cooling towers is available. In addition, it is unknown whether adequate supplies of reclaimed or fresh water, for example, are available for cooling purposes.

Due to their size and base load operation, the two nuclear facilities also use the largest volumes of sea water. Each plant is permitted to use more than 2,500 million gallons of sea water per day, which is twice as much as the next largest facilities on the coast (Alamitos and Moss Landing). Most of the other coastal facilities are permitted to use less than 1,000 million gallons per day. Due to the low capacity factors at most of the costal plants, actual volumes of sea water used in once-through cooling are lower than their permitted levels.

Question 7 – At the stakeholders meeting, an attorney for Duke's plant at Morro Bay said there were few if any impacts – is this correct and would that be true for the other plants?

In its June 2004 Third Revised Proposed Decision, the Commission found that environmental impacts from once-through cooling to the Morro Bay Estuary from the repowered Morro Bay Power Plant would be less than from the existing plant, and therefore did not constitute a significant environmental impact as defined in CEQA. The Commission Decision also stated that the 16.2 percent proportional mortality entrainment impact from the new facility was an adverse effect and would have to be mitigated in accordance with section 316(b) of the Clean Water Act. The Commission Order directed Duke to pay $12.5 million to the Central Coast Regional Water Quality Control Board for a habitat enhancement program.

The consensus view of federal and state agency scientists that Energy Commission staff have worked with on power plant siting cases is that once-through cooling causes significant, ongoing impacts to marine and estuarine environments in California's coastal waters.

Question 8 – What is being done to insure that new power plants will use alternative cooling systems and not OTC?

There is a substantial amount of work being conducted at the Energy Commission and at other agencies on the environmental impacts of once-through cooling and on the feasibility and development of alternative cooling technologies.

At the Energy Commission, repowering applications that include the continued use of once-through cooling are subject to a thorough regulatory review that includes compliance with Clean Water Act requirements, as implemented by the Regional Water Quality Control Boards, and an examination of feasible cooling alternatives, including the use of recycled water for either cooling towers or once-through cooling. Energy Commission PIER research on alternative cooling technologies is demonstrating that dry and hybrid cooling systems are feasible and economically viable in California.

According to the Energy Commission's *2005 Environmental Performance Report of California's Electrical Generation System*, 22 percent of the new capacity that was brought on-line between 1996 and 2004 used recycled water for cooling, while 52 percent of the capacity under construction or permitting review will use recycled water. Two power plants in California use dry cooling, and a third is under construction.

The Energy Commission staff continues to conduct and sponsor research into the scientific issues associated with better understanding and documenting the environmental effects of once-through cooling.

The recent US Environmental Protection Agency Phase I Rule for section 316(b) of the Clean Water Act effectively bans new power plants, excluding repowers, from using once-through cooling. The Phase II Rule for existing large power plants sets aggressive performance standards for entrainment (60 to 90 percent reduction from baseline) and impingement (80 to 95 percent reduction from baseline). The State Water Resources Control Board has initiated a proceeding to determine if a more stringent policy to implement the federal rule is appropriate for California. Regional Water Quality Control Boards are initiating new reviews of existing National Pollution Discharge Elimination System (NPDES) permits for cooling water intake structures in accordance with the new 316(b) Phase II Rule.

Work at the Ocean Protection Council and State Lands Commission will also result in more attention to and scrutiny and awareness of the impacts of once-through cooling.

Question 9 – What information can the Energy Commission provide on the impact of this Resolution on our State's critical energy needs?

The set of issues raised by this question would depend on how coastal power plant owners choose to respond to the resolution over a 14-year time period. California energy markets and technologies are evolving dynamically and what is true in 2006 may be quite different in 2020. It is helpful to identify some basic facts and assumptions about the coastal fleet and the resolution that can be useful in thinking through a response to this question. In addition to the three response options identified earlier – retrofit the cooling system, repower to combined cycle, repower to combustion turbine – an owner could also choose to retire the plant and use the property for other purposes.

First, it is useful to divide the list of 22 coastal power plants with leases from the State Lands Commission or its grantee agencies into categories. In addition to the conditions of the lease, the type and age of the power plant, along with its location and ownership, will influence how an owner chooses to respond and the number of response options that are available. While the 10 facilities with leases from the State Lands Commission seem to have a legal obligation to comply with the proposed staff resolution, it is not clear what legal authority, if any, exists to compel compliance for the other 12 facilities. In addition, several plants have either shut down or announced that they will repower without once-through cooling systems. Furthermore, two of the plants with leases are small (Gaylord and GWF) and do not meet the 50 million gallon per day threshold for large existing power plants as defined by the US Environmental Protection Agency in its recently revised rule for section 316(b) of the Clean Water Act. The Energy Commission maintains a list of 21 large coastal power plants using once-through cooling that does not include these two small facilities. (The Energy Commission list does includes the Mandalay facility in Ventura County that is not on the State Lands Commission table of leases.)

Accordingly, it may be that just eight plants with leases from the State Lands Commission would be directly affected by the resolution: Antioch, Pittsburg, Ormond, El

Segundo, Huntington Beach and Encina, plus the nuclear facilities of Diablo Canyon and San Onofre.

In terms of technology, the 21 large coastal plants using once-through cooling can be divided into the following categories:

- Nuclear – 2
- Combined Cycle – 4
- Steam Boilers – 15 (plus the old steam units at Moss Landing)

The Diablo Canyon and San Onofre nuclear plants represent billions of dollars in ratepayer investment and provide important levels of base load electricity generation. They are also critical to maintaining system reliability from both a generation and transmission system perspective. Retrofitting these facilities to cooling towers (dry cooling does not appear to be feasible from an engineering perspective) would be an expensive engineering challenge, even if sources of fresh or reclaimed water were available to supplant the use of ocean water for cooling.

Combined cycle technology is the current state of the art for natural gas-fired power plants. Four plants use this technology. Moss Landing and Haynes were recently repowered with continued use of once-through cooling, while the Harbor Units 1a and 2a were built in 1994. Retrofitting to cooling towers or dry cooling would be technically feasible, but would be costly in light of the recent investments to rebuild these generating units.

For the 15 older steam boiler plants, owners could choose from each of the four previously described project options. Retrofitting the cooling systems to cooling towers or dry cooling would probably not make economic sense given the age and lower operating efficiencies of these units. The economic viability and technical feasibility of changing the cooling technology at the time of repowering depends on specific site considerations. The Morro Bay facility still requires and NPDES permit from the Central Regional Water Quality Control Board. Two facilities – Morro Bay and El Segundo – have licenses from the Energy Commission to repower using once-through cooling that have not been exercised. Two plants – Humboldt and San Diego South Bay – have announced that they will repower without once-through cooling. The Hunters Point facility has been granted permission from the California Public Utilities Commission to retire. Finally, the Long Beach plant has ceased generating electricity, but the once-through cooling pumps are still used to control water levels at the plant.

The location of a facility is also a consideration regarding whether to retire, retrofit or repower. Many areas in California are resource-constrained in terms of local generation and transmission. Several coastal power plants in these areas have Reliability Must Run (RMR) contracts from the California Independent System Operator (CAISO), which obligates the owner to furnish power during periods of critical demand. Nine of the coastal plants have RMR contracts for 2006 for a total of 4,058 MW.

Ownership is another consideration. Merchant generators currently need long-term contracts in order to secure the financing necessary to pay for major facility repowers or retrofits. Publicly-owned utilities, in contrast, have not had difficulty in financing their projects because of their ability to sell bonds. Calpine is in bankruptcy, and Duke is selling its California power plants to LS Power, a privately owned company. Fifteen of the 21 coastal plants are owned by private merchant generators. Passage of the resolution would probably make it more difficult for the merchant owners to secure financing for repowering or upgrading their facilities.

Any generating capacity lost by coastal plant retirements would need to be replaced for electricity supply adequacy purposes and in some cases for transmission stability requirements. If there are transmission-related considerations, the replacement generation might need to be placed in the same general area as the retired coastal plant.

Should the State Lands Commission resolution pass, those existing power plants that would be affected would have two choices, either shut down or modify their facility to eliminate the use of once-through cooling.

For the coastal power plant repowering projects subject to Energy Commission jurisdiction, developers have argued that a requirement to use an alternative cooling technology would render the project uneconomical. While Energy Commission staff has analyzed the costs associated with different cooling technologies and did not accept the assertion of the developers regarding economic feasibility, the question nonetheless remains unanswered regarding economic viability due to a number of factors described above. Consequently, it must be recognized that a State Lands Commission resolution, if passed, could eventually result in the loss of a significant amount of California's generating capacity with adverse impacts to system reliability.

There are two alternatives to once-through cooling. The first would be the continued use of water to cool the power plant, but the source would be fresh or reclaimed water. If the project were under the jurisdiction of the Energy Commission the use of fresh water is unlikely to be permitted, in conformance with a policy adopted by the Commission in its 2003 Integrated Energy Policy Report. The developer would need to use reclaimed water in lieu of fresh water, which is not always available depending on location, or use a dry cooling system. Projects not under Energy Commission jurisdiction would be permitted locally with the lead permitting agency determining what water source could be used for power plant cooling. Currently, it is the policy of the State Water Resources Control Board to discourage the use of fresh water for power plant cooling.

Dry cooling is also an alternative to once-through cooling. This technology is commercially available and has become more common in recent years, particularly in areas where water availability is an issue. However, developers are more comfortable and inclined to use wet cooling technologies because of their greater familiarity with this technology; its lower capital costs; its smaller space requirements; and its greater efficiency, particularly at higher ambient temperatures. The latter issue tends to be more important at inland sites where summer temperatures are normally much hotter than along the coast. If any of the existing coastal power plants have space limitations, dry cooling may not be an option. In addition, since dry cooling systems are noisier and larger than wet cooling systems, there can be environmental issues regarding visual and noise impacts.

In summary, because of the tremendous dynamism of California energy systems, including varied energy technologies and evolving energy markets, energy policies and environmental regulation, it is not possible to state with any certainty how power plant owners would respond to the State Lands Commission resolution over a 14-year phase in period. However, new generation would be needed to replace the loss of existing coastal power plants. New facilities may need to be located at or near some of the existing coastal power plants due to transmission constraints. Coastal generators would face regulatory and financial market uncertainty that could jeopardize the repowering of coastal plants and state goals for meeting resource adequacy in generation / transmission-constrained areas. Merchant generator ability to secure financing and long-term contracts for repowering is already uncertain. Incremental cost differences for plants with tower cooling or dry cooling could make coastal plants less competitive than other plants. Loss of nexus to coastal waters could jeapordize the coastal-dependent status for coastal plants subject to Coastal Commission jurisdiction. Finally, regardless of the staff proposed State Lands Commission resolution, the ongoing evolution of technology, market conditions, CPUC procurement and environmental regulatory changes could result in the phase-out and replacement of at least some of the coastal fleet.

Several state and federal policies are currently in place to ensure that system reliability goals are met. Load serving entities (LSEs) such as the private and public utilities have an obligation to serve customers and meet electric load. The CPUC Procurement and Resource Adequacy proceedings are intended to ensure that the LSEs have access to sufficient generating resources to meet reserve margins and resource adequacy goals. The CAISO RMR program is intended to assure adequate local generation to maintain system operation as well as to guard against the exercise of market power as was done during the Energy Crisis of 2000-2001. The Federal Energy Regulatory Commission (FERC) Must Offer Tariff requires generators to make their resources available to LSEs. However, should the resolution result in any wholesale retirements of coastal power plants, it is unlikely that these programs would be sufficient to ensure system reliability.

There are other factors to consider when trying to anticipate the effects of the draft resolution on the coastal generators over a 14-year period. The following considerations are drawn from several recent Energy Commission reports.

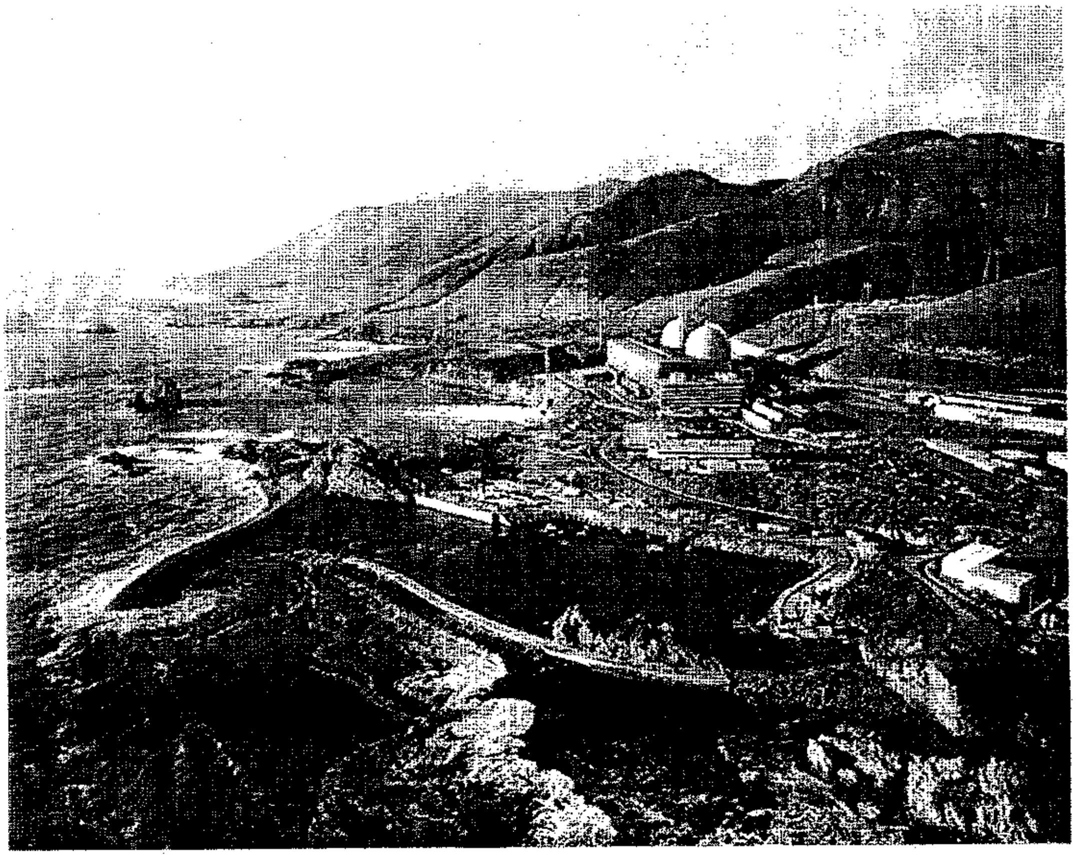
- Many plants using the older steam boiler technologies are nearing the end of their design life. Their relatively higher heat rates and higher operating costs will continue to render them less competitive over time. More than 3,800 MW of older steam boilers have retired since 2001.
- Current market and system conditions are requiring new capacity to meet peak summer loads, which means that new combustion turbine peaker units may prove to be commercially viable in the near term to serve load centers in coastal areas, rather than base loaded combined cycle facilities. The current coastal plant sites could be appropriate for some of these newer peaker units.
- Notwithstanding current market conditions, new base load generation will be needed to accommodate population growth within the decade, which will create additional demand for base loaded combined cycle units. Such increased demand may incent the owners of coastal plants to repower older facilities, but as previously indicated, decisions will be made on a case-by-case basis.
- The CAISO RMR program is a temporary solution for ensuring capacity that is intended to be phased out.
- The operations of existing coastal power plants that use once-through cooling will be influenced by the increasing scientific knowledge of once-through cooling effects on marine and estuarine ecosystems, the pending State Water Board policy implementing the US EPA 316(b) rule, and concerns over endangered species affected by once-through cooling.

DRAFT
FOR COMMENTS ONLY

FEASIBILITY OF RETROFITTING COOLING TOWERS AT DIABLO CANYON POWER PLANT UNITS 1 & 2

APRIL 11, 2003

RECEIVED 4/17/03



PREPARED BY:

Burns Engineering Services Inc.
P.O. Box 272
Topsfield, MA 01983-0272
Email: BurnsEngr@aol.com
Telephone: (978) 887-1172
Fax; (978) 887-1169

DRAFT
FOR COMMENTS ONLY

Table of Contents

DRAFT
FOR COMMENTS ONLY

I. Introduction

This report describes the findings of an independent study of the impacts and engineering feasibility of retrofitting cooling towers at PG&E's nuclear, two-unit, 2,222 MW net output Diablo Canyon Power Plant (DCPP) located near Avila Beach in San Luis Obispo County. DCPP is one of the largest two-unit nuclear power plants in the country. It occupies a relatively small industrially zoned coastal site on a narrow shelf sandwiched between the Pacific Ocean and the steeply sloped Las Canadas mountains in Central California. The DCPP cooling system currently utilizes a total of about 1,725,000 gpm of saltwater, heating it approximately 18°F in the condensers and returning it to the Pacific. Any retrofitted close-cycle cooling system would need to provide an equal amount of cooling as this current water flow to maintain the current electrical output of the plant.

At the outset, it should be appreciated that, much like the nuclear containment area of DCPP, the existing circulating water system and safety related cooling systems were designed and installed to be permanent features of DCPP. They were not constructed to allow future alterations in any significant way. In fact, only a few existing plants throughout the United States have been retrofitted with closed-cycle cooling towers. These backfitted cooling towers were for small power plants or had some accommodating physical feature that facilitated their conversion, such as at the Palisades Nuclear Plant in Michigan. In contrast, the magnitude of a cooling tower retrofit at DCPP would be of an unprecedented scale and complexity. In fact, the proposed cooling tower retrofit project would constitute the largest closed-cycle saltwater mechanical draft cooling tower installation in the United States, retrofit or otherwise.

The main focus of this report concerns the engineering, construction, performance, and environmental issues of the Tetra Tech proposed cooling towers for DCPP. Tetra Tech Inc. is based in Evergreen, Colorado. It had assessed retrofitting cooling towers at DCPP in their November 2002 report entitled, "Evaluation of Cooling System Alternatives" [1]. The approach of this study by Burns Engineering Services, Inc. of Topsfield, Massachusetts was to examine the application of saltwater mechanical draft cooling towers in depth in order to parallel the emphasis of the Tetra Tech engineering study and evaluations because of their conviction that these types of cooling towers had the most potential for installation at DCPP.

Burns Engineering Services, Inc. is a consulting firm that specializes in power plant cooling systems with a particular focus on the condenser, the cooling towers, and the other related equipment. Burns Engineering Services has provided consulting to architect-engineers, utilities, and manufacturers alike to design, evaluate, install and test cooling system equipment. Its Director has been involved in the power industry and cooling system field for the majority of his career since the late 1950's. Burns Engineering Services' evaluation of the cooling tower retrofit at DCPP contained herein is based on an examination of the DCPP design information, drawings that define the site and existing cooling & safety-related systems, and interviews of key DCPP engineers and managers.

Because site-specific factors are of prime importance in any serious cooling tower retrofit assessment study, Burns Engineering Services' site visit occurred over a full three-day period during March 11-13, 2003.

II. Executive Summary

In this report, Burns Engineering Services Inc. discusses their independent evaluation of the impacts and engineering feasibility of retrofitting cooling towers at PG&E's nuclear, two-unit, 2,222 MW Diablo Canyon Power Plant (DCPP). The plant is located on a relatively small industrially zoned coastal site between the Pacific Ocean and the steeply sloped Las Canadas mountains. Tetra Tech, Inc. had assessed retrofitting cooling towers at DCPP in their November 2002 report[1]. Because that retrofit plan had been developed and proposed by Tetra Tech, the purpose of this study is to examine the technical basis and opinions presented in the Tetra Tech report.

It should be appreciated that the main cooling systems of these power plants were designed and installed to be permanent structures, much like the nuclear containment or nuclear safety related cooling systems. No consideration for future alteration was included. In addition, only a handful of plants, all much smaller than DCPP, have experienced a cooling tower retrofit. Thus, the magnitude of a cooling tower retrofit at DCPP would be of an unprecedented scale and complexity. The proposed retrofit project at DCPP would constitute the largest closed-cycle saltwater mechanical draft cooling tower installation in the United States.

Burns Engineering Services agrees with Tetra Tech that, for a variety of reasons, dry, wet/dry and natural draft cooling towers are not feasible at DCPP. The application of saltwater mechanical draft cooling towers is examined here in depth to parallel the emphasis of the Tetra Tech engineering study and evaluations due to their assertion that these types of cooling towers had the most potential for installation at DCPP.

A summary of the major results of the Burns Engineering Services comparative analysis indicates the following:

1. **Tetra Tech's proposal overestimates the amount of available space at DCPP for the proposed towers.** Burns Engineering Services agrees with Tetra Tech that 132 large saltwater, counterflow mechanical draft tower cells would be required at DCPP to cool its 1,725,000 gpm of salt water if conversion to a closed-cycle system were required. That proposed arrangement is shown on page 15 of the Tetra Tech report[1] and is reproduced in this report under Figure 4. Rather than locate a suitable area for the cooling tower retrofit, the Tetra Tech proposal simply displaces several existing plant structures for which there is no alternative space within the industrially zoned area of the site. The net effect is that the Tetra Tech report does not adequately address the lack of available land for the project.

2. **Tetra Tech does not address a viable relocation of the existing important, permanent large structures.** These structures include a 98,000 and a 28,000 square foot building, an engineered road that significantly impacts the safety of the nuclear operation at DCPP and an alternative for parking up to 800 employees and contractors cars. This was likely not discussed because there are no practical alternatives.

3. **The Tetra Tech report is also silent regarding the enormous construction required to prepare the area upon which the proposed cooling towers would be built.** An earthwork construction plan that would be needed to level the area upon which they intend to locate the 132 cooling tower cells. The Tetra Tech construction plan basically requires excavating an extensive 1600 x 600 ft long section out of one of the Las Canadas mountains with a fill of the proposed tower site at the lower elevations. Similarly, it does not address the installation of the up to 60 ft. deep pile foundations for the towers, motor control center and pumphouse on that site to ensure a stable foundation.

4. **Tetra Tech does not investigate if a suitable substation was available local to their proposed cooling tower cells to provide the level of power needed for the cooling tower operation.** The proposed tower and pumphouse complex requires over 50 MW in auxiliary power. That is enough electrical power to supply the needs of a city of about 50,000 residents. The added costs of both the amount of power required and the design and building of infrastructure to deliver that energy to the cooling tower cells would be appreciable.

5. **Integrating the cooling towers into the existing system will take a minimum of one year with both units of DCPP offline, resulting in lost revenue of $657,000,000.** The time required for this work is double the six months that Tetra Tech estimates. This will be a more lengthy, difficult, and costly process than envisioned in the Tetra-Tech report. Referencing Figure 6, Burns Engineering Services determined that all the cooling system lines and many utilities for both units of DCPP, including the nuclear safety related accident cooling systems, are all intertwined in a very narrow buried area at the front of the common two unit turbine building. Thus, any tie-ins to the existing concrete circulating water lines and the installations of the new lines extending out to the tower would need to occur within that congested underground section while maintaining positive access and the nuclear safety related functions to the two units. As a result, the tie-in construction activities at DCPP will be very difficult, will necessarily proceed slowly and would likely raise licensing and monitoring issues with the NRC. Further, staging the construction tie-in separately to each unit under those conditions would be considered unrealistic. Based on this review and estimates at other nuclear facilities, Burns Engineering Services calculates that the tie-ins would take the entire DCPP off-line a minimum of 1 year. That conclusion causes a major increase in the estimated lost revenue to $657,000,000. This revenue estimate uses the same revenue loss figure Tetra Tech employed of $900,000 per unit per day.

6. **Plume from the cooling towers will create safety and security hazards.** The proposed Tetra Tech 132-cell wet mechanical draft design would produce a substantial vapor plume during the cool weather periods that frequently occur at DCPP. Access roads, buildings and parking lots could be blanketed by those opaque, very visible plumes. The Figure 7 photo of an actual plume illustrates that a lack of visibility occurs even with much smaller towers. The lack of visibility for this proposed site would constitute a safety and security hazard, particularly when considering transporting nuclear fuel for processing or disposal. The cool, damp, conditions common at DCPP will make the formation of these large, opaque plumes a frequent occurrence.

7. **The cooling tower retrofit will create noise pollution.** Noise pollution from the 132-cell cooling tower complex proposed by Tetra Tech, each powered by 250 HP fans with its attendant enormous water flows, would be high and pervasive unless attenuated. While there admittedly are no proximate private houses or properties, the employees at DCPP and the local fauna would be impacted. The continual outdoor noise level at the administration building will be in the vicinity of 74 dBa, a level equivalent to loud street noise (for reference, the OSHA hearing safety limit is 85 dBa). Reducing these effects through noise attenuation would require a major increase in the cost of each cooling tower and an increase in fan power consumption. This environmental aspect was not discussed by Tetra Tech and it is unlikely that the major expense of attenuating this large noise source was included in their performance or cost estimates.

8. **Salt drift from the cooling towers will be substantial, resulting in environmental and plant equipment damage.** Salt drift impacts were not addressed in the Tetra Tech report, so there is no knowledge of whether these were considered by those investigators. Assuming a standard level of drift elimination would be installed on the towers, an added 7 million lbs of salt per year would be deposited by the cooling tower complex. Due to the grand scale of the proposed cooling tower installation, this level of

airborne salt will be much greater than the natural airborne salt concentrations in that area. Besides causing a large number of electrical arcing incidences from deposits on the insulators of the 500 kva lines and increasing the level of plant maintenance costs, the salt drift would have an extreme environmental impa on the local flora and fauna.

9. **The "closed system" retrofit proposed would have its own discharge and environmental impacts.** Though total flow will be cut down significantly, a concentrated salt stream of 69,000,000 gallons per day will be discharged into the ocean. The local effects of such an effluent are not know, but could be significant. The water circulated through the cooling towers will also require chemical treatment to remove the minerals that would otherwise build up due to the evaporative process & and damage the system. Therefore, this system would result in another potential waste issue.

10. **Tetra Tech's assumption of cooling tower efficiency is based on a theoretical value not attainable at DCPP site.** Tetra Tech's report overlooks site conditions that will cut down on cooling tower performance. A key figure used in any estimate of cooling tower performance is the approach. It is the temperature difference between the ambient wet bulb temperature and the temperature of the cooled water exiting the towers. The approach signifies the effectiveness the cooling tower will have in cooling the water. The larger the approach, the less efficient the cooling process. Tetra Tech assumes a theoretical value for the approach that is unachievably small for large commercial towers given the site conditions (the low wet bulb temperature) at DCPP. In other words, Tetra Tech overestimates the cooling ability of the towers. DCPP is a relatively cool site with a low wet bulb temperature of 61°F. The typical cooling tower is specified with a design approach at much higher wet bulb temperatures that near 80°F. With the higher wet bulb temperature, a 9°F approach (the temperature difference between the wet bulb and cold water produced by the tower) is viable. However, at a 61°F wet bulb temperature, the achievable, commercially available, large utility cooling tower approach is much higher than the 9°F approach temperature that wa used by Tetra Tech as the base for its retrofit energy penalty impacts. Thus, the potentially achievable, large commercially available utility cooling tower approach is well above the 9°F between the cold water temperature produced by the towers and the local wet bulb temperature that Tetra Tech based its plant performance and retrofit energy penalty impacts upon.

11. **Because of Tetra Tech's erroneous estimate of cooling tower efficiency and recirculation effects, they underestimate the yearly lost revenue due to the retrofit imact on plant output.** Using Cooling Technology Institute data[2] with industry estimating methods[3], it was estimated that the approach at DCPP would instead be about 16°F at the design point. In addition, the topography of this constricted site, the very large numbers of closely-spaced cooling towers proposed indicates significant recirculation will occur[4,5]. This was conservatively estimated to be a minimum of 4°F. Hence the total approach of the cooling tower cold water temperature to the wet bulb would at least 20°F, or 11°F higher than that used by Tetra Tech in its evaluations. The difference indicates the station energy penalty operating with retrofitted cooling towers, including the effect of the modular condenser replacements, would increase annually to 56 MW for both units at the design conditions. Using Tetra Tech's assumed 350-day operation and parasitic loss of 25MW, with an energy cost of $34/MW hour, the total reduction resulting from implementing the cooling tower proposal would come to a yearly lost revenue of over $23 Million ([56 MW energy penalty + 25 MW parasitic load] X $34/MW hour X 24 hours/day X 350 days operation/year).

12. **Condenser modifications will be more costly and more difficult than listed in the Tetra Tech report.** To make the cooling tower retrofit viable, major condenser modifications would be required. Burns Engineering agrees with Tetra Tech that replacing the existing 22 gauge, 1 inch outer-diameter titanium

tubes with 25 gauge, ¾ inch outer-diameter titanium tubes will provide a condenser performance improvement to compensate somewhat for the loss in turbine exhaust vacuum due to the warmer return water expected from the cooling towers. But Tetra Tech has neglected several important aspects of their replacement plan. Primarily, the 25 gauge titanium tubing wall thickness (0.020 inches) is too thin to allow a rolled tube-to-tubesheet joint with sufficient mechanical integrity for this concentrated seawater, highly pressurized application. Only by welding the tubes to the tubesheets could condenser leaks be prevented. That kind of welding would consist of approximately 155,200 joints per unit & necessitates "clean room" conditions that can only be duplicated in a shop. Thus, a modular replacement of the existing tube bundles would be needed.[6] Besides being the largest modular condenser replacement project to date in the world, the complexity of moving not just plate and tubes but the large assembled bundles back into the DCPP condenser would be very difficult. It would require significant cutting of the turbine building wall to allow the large modular bundles access. A significant number of obstacles would need to be cut out of the way to allow for delivery of a modular unit. That added significant obstacle to the construction schedule is not presented by Tetra Tech and apparently is not included in its estimated costs. Burns Engineering Services estimates that this modular replacement of the existing condensers alone would take a minimum of 3 months on an aggressive, accelerated schedule.

13. **Tetra Tech's Operation and Maintenance costs are not adequately justified & too low.** Tetra Tech indicates the Operating & Maintenance (O&M) estimate is 750$/MW and did not define whether that generic cost was applicable to freshwater or saltwater installations. The value was obtained from a respected, large cooling tower manufacturer but not a cooling tower owner who must bear the annual costs. That supplier would not appreciate the 24/7 costs of the extra personnel needed for frequent inspections, upkeep, lighting, instrument, control, electrical and mechanical repairs, replacements, maintenance of the water treating systems, chemical requirements, and blowdown and makeup systems. It could for example be modestly expected that an extra staff of 10-15 people would be required with a range of craft skills from chemists to engineers to welders, instrument technicians, electricians, painters, etc. Estimating current salaries, benefits, office & manual space requirements and the supplies they would need indicates a much higher value at DCPP than the $750/MW cost listed by Tetra Tech. Burns Engineering Services would expect costs to be 6 times higher than the Tetra Tech estimate.

Conclusion: Burns Engineering Services has determined that the Tetra Tech alternative cooling system retrofit proposal and evaluation was too generic and did not properly take into consideration the unique site and design conditions at DCPP. Hence, the major conclusions of the Tetra Tech report are unsound and unrealistic. As a result of our review process, it became evident that retrofitting cooling towers at DCPP would be impractical, have significant negative effects on the plant safety and current generation, and produce adverse airborne environmental impacts. Each of these items will add significantly to the costs of the project presented by Tetra Tech and also make permitting difficult if not impossible.

III. Evaluation of Cooling System Alternatives

A. Overview of Potentially Applicable Systems

The Tetra Tech report considers different types of cooling water systems as alternatives for the retrofit and evaluates them based on land and water availability for the cooling system, regulatory constraints, and technical compatibility with the existing plant. Burns Engineering Services and Tetra Tech are in agreement on the incompatibility of many of the alternatives for the conditions at DCPP and that mechanical draft towers would be least-worst alternative to consider for Diablo Canyon. In this section, we will comment upon the some of the other cooling system alternatives and their applicability to the DCPP case, particularly the air cooled condenser, natural draft tower, and wet/dry tower.

As an overview, a retrofitted direct dry steam condenser, also termed an air-cooled condenser (ACC), would be too large and cause too great an additional turbine exhaust steam pressure drop. These major operational and efficiency problems would need to be addressed. In addition to those retrofit considerations, in a competitive market, the poor efficiency and auxiliary power requirements of a dry system makes this alternative cooling technology the least favorable. This is especially true during warm periods, when the production value of electricity is greatest.

Based on a projection of experience from other smaller projects that have utilized direct air-cooled steam condensers, it was estimated that the size of the towers needed by the two units of DCPP would be an aggregate of about 350 cells. The plan area projection of each cell would be approximately 45ft by 45ft and these cells would correspondingly be served by 350 large diameter fans. This size estimate is essentially in accord with Tetra Tech. Comprised of a total of 175 cells per unit, the inherent size of each DCPP ACC arrayed in smaller unit clusters would be about 5 times the size of the typical current commercial installations. A large separation would also be required between these tower clusters to minimize exhaust air interference and recirculation. The physical characteristics of the ACC installation by themselves preclude their application at the comparatively small DCPP site.

Another major technical problem for the ACC, (in this instance, mentioned by Tetra Tech) would be the length, size and routing of the steam distribution line(s) along with its impact on generation from the large turbine steam duct between the tower clusters and plant. An approximately 40 ft by 40 ft duct under an extreme vacuum load would be needed to supply the steam from the three large working ends of the two existing central turbine exhaust locations to the cooling tower clusters. In any event, our conclusion was in general agreement with Tetra Tech that a direct air-cooled condensing system would not be feasible or viable at DCPP.

In their report, Tetra Tech appears to confuse a patented parallel wet & dry system that only one manufacturer (GEA) markets for very small plants (typically generating 50 MW or less) with what the rest of the cooling tower industry refers to as a wet/dry cooling tower. However, we agree with Tetra Tech that installing the patented parallel wet/dry tower at DCPP is not applicable or feasible due to technical concerns associated with the distribution of large amounts of steam, land requirements, O&M costs, lack of performance and other cost constraints.

We also concur with Tetra Tech that any wet cooling tower system designed to use freshwater makeup would not be a suitable alternative at DCPP because of the lack of adequate freshwater supplies in the region. Unless a substantial source of water becomes available for industrial use at a later date, this alternative cannot be considered.

Like Tetra Tech, Burns Engineering Services determined that natural draft cooling towers would not be a viable cooling alternative at DCPP. Numerous factors suggest the non-viability of an installation of a total of 10 of these large concrete structures, each 37 stories tall, at the DCPP site. Application of this technology to DCPP would create the largest natural draft complex in the world. In addition to the Tetra Tech reasons for rejecting natural draft towers as a candidate system, the estimated 9°F approach Tetra Tech used as a base for the energy penalty is unattainable. This occurs because of the previously cited low wet bulb temperatures at DCPP, but also because natural draft towers have inherently poor performance compared to mechanical draft towers. In fact, Burns Engineering Services estimates indicate a natural draft approach temperature could be as high as 25°F, rather than the 9°F listed by Tetra Tech. To realize any effective natural draft, the condenser would have to be modified to two-pass units with a temperature rise of 36°F. No related discussion by Tetra Tech was evident.

DRAFT
FOR COMMENTS ONLY

B. Mechanical Draft Retrofit Feasibility Review

1. Land & Space Considerations

This section of the report deals with the challenges in locating and constructing the proposed cooling tower retrofit compatible with the existing plant and conforming to the geographic and zoning conditions of the site.

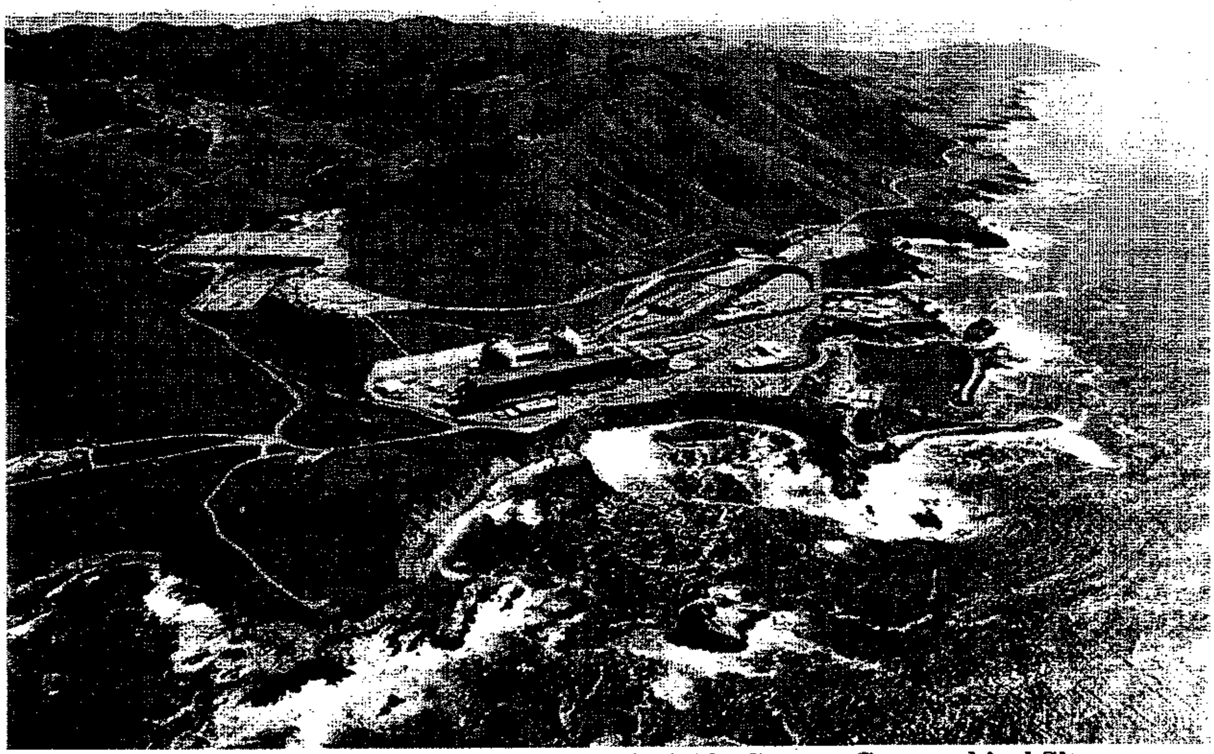


FIGURE 1- Overview of Diablo Canyon Geographical Site

The surroundings upon which Diablo Canyon Power Plant (DCPP) is built are unique. The plant sits on a marine terrace surrounded by cliffs on one side and steep mountains on the other. Due to a combination of factors, including the relatively small amount of the lot zoned for industrial use, geologic stability of different site areas for construction, underlying material, steep mountain gradient, and existing use of buildable space, there is very little land available for building. Insertion of any major new construction, such as the 132

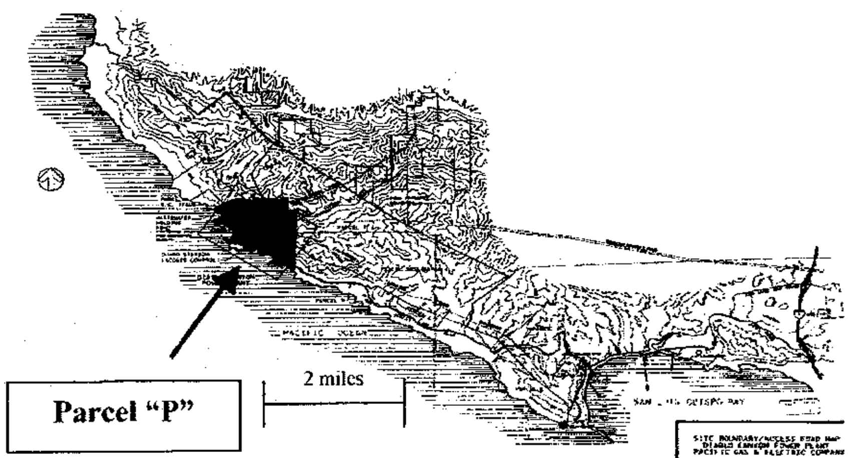


FIGURE 2- Industrially Zoned Area

cooling towers proposed by Tetra Tech, is virtually impossible. An understanding of the geographic and geologic characteristics of the Diablo Canyon site is critical to be able to accurately consider any building or retrofit plans for the site.

As shown in Figure 1, the topography upon which Diablo Canyon sits is extraordinarily challenging in terms of lending itself to development. Construction cannot be carried out too close to the cliff edges, where erosion would endanger the safety of any large surface structure. Beyond this perimeter, there is only a small swath of land before the mountains rise steeply. Even this land is terraced, which limits the area available for any large project without a gargantuan leveling effort.

Not only do natural barriers to construction abound- zoning restrictions severely limit the area which can be considered for the cooling tower sites or any other buildings, parking lots, or roads that might be relocated by the tower construction. Although PG&E owns a vast amount of area, most of it is off limits to any construction. Only parcel P is zoned for industrial use, & is therefore the only area that can be practically considered for this project. As can be seen from Figure 2, Parcel P represents only roughly 5% of the area owned by PG&E at this site.

Things get even worse from there. Most of Parcel P is occupied by steep mountains that rise rapidly from the plateau. The summits surrounding Parcel P reach heights of between 1231 feet and 1573 feet. Most of Parcel P is unusable due to its steep gradient (see Figure 3 below).

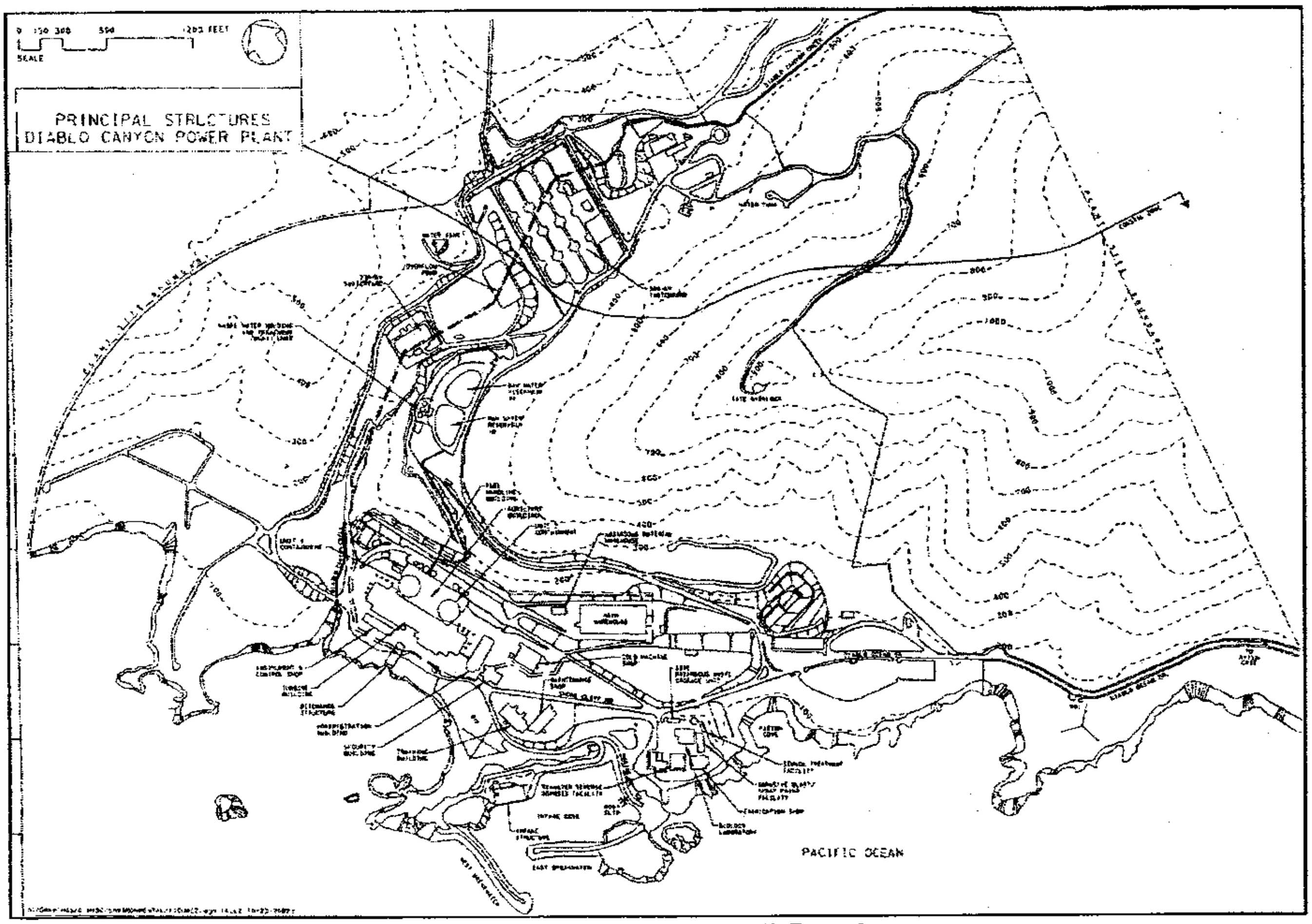


FIGURE 3- Parcel P Detail

Roughly 25% of the land in Parcel P is able to support construction. The gradient of the rest is simply too stee[p]. Existing structures and parking lots already occupy nearly all of the usable space.

Most of the land remaining is not available for construction due to its steep gradient, or geologic unsuitability. Desirable underlying geology, such as exists under the reactor and turbine building, is hard rock. Other parts are composed of a clay matrix, which requires reinforcement in order to be able to support any building.

Tetra Tech has proposed displacing a substantial area in the center of the marine terrace for construction of the cooling towers (see below). Each of the cooling towers proposed have a 60' x 60' footprint. The total area required would be roughly 1600' long and 600' wide. The construction would be a massive project, extremely costly in terms of both money and time.

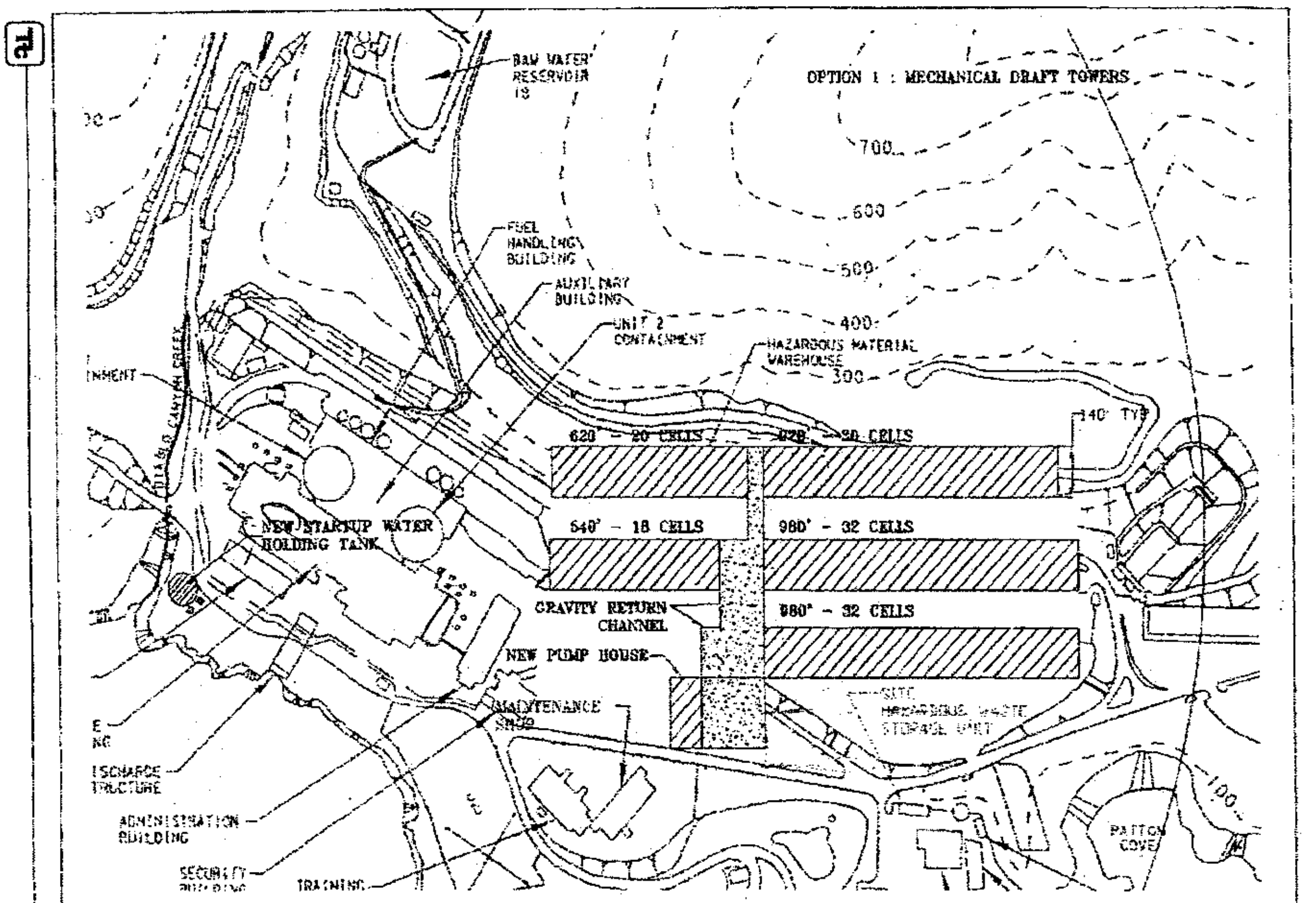


Figure 2: Mechanical Draft Cooling System Layout

Diablo Canyon Power Plant, Evaluation of Cooling System Alternatives

15

FIGURE 4 - Tetra Tech's Proposed Siting of the Cooling Towers[1]
(This is a duplicate of Figure 2 from Tetra Tech's November 2002 report)

The parking lot area is "underlain by a thick sequence of older colluvial fan deposits consisting of gravelly clay colluvium up to about 60 feet thick."[7] To prepare the site, pilings penetrating this level would need to be installed to maintain ground stability.

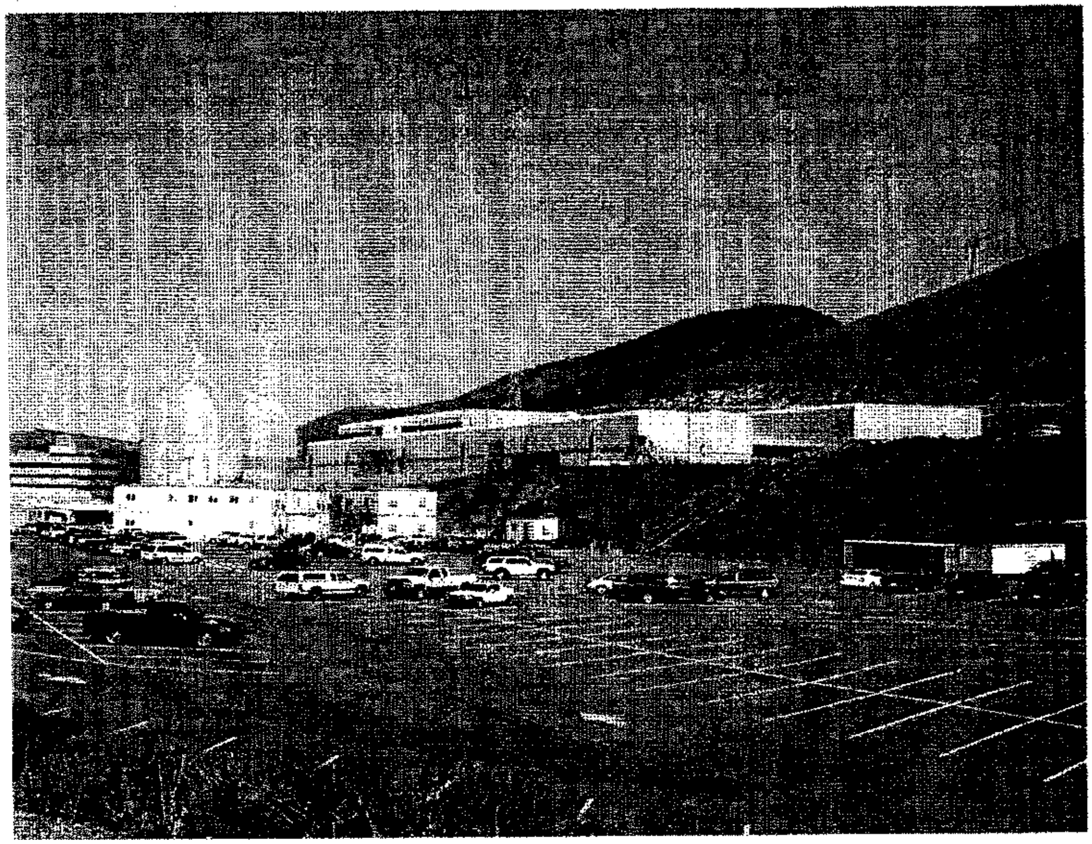


FIGURE 5 - Gradient Between Parking Lot & Warehouse.

This area between the main parking lots 7&8 would need to be leveled to accommodate the proposed cooling towers as opposed to maintaining its current terraced configuration. Towers could not be built on the two existing terraces because exhaust from the lower level (where the current main parking lot stands) would too easily recirculate into the cooling towers on the upper level and destroy their ability to supply any cooling.

Tetra Tech's proposed cooling tower build site is currently occupied by the warehouse, the machine shop, main parking lots 7 & 8, and the access road and transportation route. The warehouse is not a simple building as the name implies. It is a permanent structure 475' X 207'[8] that stores parts required for plant operations & maintenance and also provides a number of offices. The only area large enough to accommodate the warehouse inside the industrial area is located across from the reservoirs on land already claimed for a used fuel storage area.

This bank of 132 cooling towers would eliminate current means of transport and access to the plant and would require major changes. The access road that would be destroyed to make way for the new cooling towers is the engineered route taken to carry the very heavy spent nuclear fuel casks to the site storage area. For safety reasons, such a road may not have a gradient exceeding six percent. With the leveling of the area to build the cooling towers, it is hard to conceive how the access road could be redesigned to remain serviceable. Further, loss of the parking lots would require the construction of a replacement facility and a new transport entry system somewhere offsite.

In conclusion, the following disturbances to the site caused by the building of the cooling towers would need to be addressed:

- The areas that currently are at different levels would need to be leveled. This will require a large amount of backfill.
- The cooling towers will need to be supported with pilings that pass through the layer of soft, claylike material down to the rock.
- A massive retaining wall will have to be built to maintain the slope behind the cooling towers.
- A way would need to be found to build a new access road, sufficiently hardened, around the new site without a gradient so steep as to make the transportation of radiological material hazardous.
- The massive permanent warehouse and large parking lots would need to be relocated. The space does not exist to do so in the area zoned for industrial use.
- Construction of the towers would effectively surround the plant with construction, both for the installation of the actual cooling towers, and for routing of the circulating water tunnels and lines. During construction, a safe means of access into the plant would need to be devised.

2. Retrofit Construction of CW System

Implementation of the cooling tower retrofit project would require modification of the CW lines and tunnels to handle the higher CW pressures of the closed-cycle system. New tunnels would have to be dug in order to direct the flow of water from the condensers to the new bank of cooling towers, with connections to the inlet and outlet water flows established in the area in front of the turbine building.

The underground section of that area has been heavily utilized with a labyrinth of service connections laid in below ground in layers that reach 50 feet under the surface. These include safety related systems, CW tunnels & electrical lines. The cooling water tunnels are substantial ~12' X 12' and are underneath a nest of conduit and safety systems in front of the unit two turbine building. Connections to these would need to be made to provide service to the new proposed bank of cooling towers. This work would have the potential to damage safety related systems.

A sense of the complexity of the existing lines in this area is given in Figure 6. No less than 46 discrete electrical and plumbing systems converge here. The lines in this relatively small area in front of the turbine are so dense that one could only be able to follow the tangle of interwoven systems with an oversized 30"x40" drawing. Any construction here would be painstakingly difficult, to say the least. Carefully avoiding and selectively removing parts of the existing infrastructure is a far more difficult and expensive task than building everything new.

In addition, excavating this area would significantly impede access to the turbine building, and would raise issues of safety both in terms of plant access and operation. The operation of both units one and two would be severely impacted by any such construction. For the aforementioned reasons, it is unlikely safe operation would be allowed to continue during the excavation and construction efforts.

DRAFT
FOR COMMENTS ONLY

CHECKING ON SECURITY ISSUES BEFORE PROVIDING
FIGURE 6

FIGURE 6 - Plan View of Tie- in Underground Construction Conditions in Front of Turbine Building

The majority of heat exchangers from the service cooling water system (SCWS), component cooling water system (CCWS) and auxiliary saltwater system, or safety system, (ASWS) have been identified as requiring some major modifications or replacement if the alternative closed-cycle system were implemented. These exchangers include hydrogen coolers, and numerous closed-cycle component exchangers. This is mainly due the substantial increase in supply temperatures well above their design basis. Either Tetra Tech's relatively low supply temperature of 70°F, or a more realistic temperature of ~81°F as shown in Table 1, would force many of these heat exchangers outside of their performance and design limits. A thorough, detailed evaluation of each heat exchanger and its effect on component/system performance would be required to identify the many modifications or replacements necessitated by the proposed cooling tower retrofit.

The conversion to a closed-system would also require a new facility to treat the highly concentrated and chemically charged blowdown. The closed-system saltwater cooling towers would use a number of chemicals to prevent build-up of biological or scale formation in the relatively warm circulating seawater. Any build-up or scale on the fill would reduce fill performance. In an effort to keep the cycles-of-concentration ratio at 1.5 or below, the plant would continually blowdown or discharge a large volume of circulating water ~48,000GPM. This discharge would need to be treated before being released back into the Pacific. Hence, there is a requirement for a new water treatment facility. No costs or construction schedule for this new multi-million dollar facility is included in the Tetra Tech report.

3. Condenser Modifications

Another significant condenser retrofit project that will take a minimum outage of 3 months was not directly mentioned in the Tetra Tech report. The main project stems from the requirement of using thinner-wall 25 BWG titanium tubing to partially offset the thermal efficiency losses of conversion to a closed-cycle system.

As will be discussed later, the Tetra Tech backpressure estimate at design is flawed due to, among other things, use of an unusually optimistic low cooling water approach temperature and lack of sufficient compensation for recirculation and interference effects. These create a misconception that the design inlet temperature to the condenser will be in the vicinity of 70 °F, as reported by Tetra Tech. Actually, the Tetra Tech conceptual design basis should be at an inlet circulating water temperature of ~81°F. The result of this large miscalculation by Tetra Tech is to increase the turbine backpressure by ~.8 inHg from the data shown in the USFAR (1.71 inHgA) [13] and by ~1.0 inHg from the actual design. The Tetra Tech CW inlet temperature with its correspondingly lower estimate of backpressure minimizes generation losses. Also, it appears that Tetra Tech overestimated generational losses at the 1.89 inHgA backpressure from the Westinghouse exhaust pressure correction curves [11].

Table 1 below shows the skewed energy penalty result one obtains by minimizing the CW inlet temperature data compared to an accurate site-specific representation of the performance of the closed-system. The performance variation in total generator output between the proposed conceptual closed-system and the existing once-through design is a reduction of 55.9 MWe. These estimates are only valid at the full load design point.

Applying the same economic factors listed in the Tetra Tech report to the 55.9 MWe, we determine an annual performance penalty or reduction in revenue to be ~ $11,625,000 in addition to the figure of $13,000,000 presented by Tetra Tech. Therefore, a realistic annual energy penalty associated with performance losses for conversion to the proposed wet mechanical draft system with retrofitted modular condenser to be $24,625,000.

However, as noted above, an important practical aspect of the proposed condenser retubing has been neglected in the Tetra Tech estimate. Since the replacement tube-tubesheet joints would need to be welded for this conceptual pressurized, highly concentrated seawater application, the conventional method of field retubing on-site could not be employed. Instead, modular factory fabricated tube bundles would need to be installed.

A typical modular retubing involves removal of the existing tube bundles, tubesheets, support plates, & any other lines or interferences inside the shell. An entire tube bundle including tubesheets, support plates & supports is factory fabricated to be a self-supporting structure that is then shipped via truck or rail to the site. Shipping bracing of these bundles is then cutoff as they are inserted directly into the shell, aligned & installed. All connections must then be reattached.

TABLE 1. – ENERGY PENALTY ESTIMATES OF PERFORMANCE - DCPP UNITS 1 & 2

Parameter	**Conceptual Closed - System Modular Condenser (Tetra Tech*[1])**	**DCPP Site-Specific Conceptual Closed-System Modular Condenser (BES)**	**Difference between Burns Engineering Services Versus Tetra Tech estimates**	**Difference between Existing Once-Through Design and Conceptual Closed-System (BES)**
Cooling Tower Approach Temperature	9 °F	16 °F	7 °F	Not Applicable
Interference & Recirculation Temperature	0 °F	4 °F	4 °F	Not Applicable
Approach plus Interference & Recirculation	9 °F	20 °F	11 °F	Not Applicable
Condenser Inlet Water Temperature	70 °F	81 °F	11 °F	24.5 °F
Backpressure	1.89 inHgA	2.55 inHgA	.66 inHg	1.05 inHgA
Generation Losses*[2]	**15.2 MWe**	**55.9 MWe**	**40.7 MWe*[3]**	**55.9 MWe**

*[1] - *Data provided from Tetra Tech report – November 2002 save the value of 15.2 MWe. Tetra Tech provided 21 MWe based on 1.89 inHgA backpressure. BES estimates 15.2 inHgA at the same point.*
*[2] - *Based on Westinghouse Electric LP Turbine Exhaust Pressure Correction Factors[11] for Units 1 & 2.*
*[3] - *Based on the correct value from column 1 instead of Tetra Tech overestimate at 1.89 in hga of 21 MW.*

Tetra Tech fails to mention that both Unit 1 & 2 condensers are not easily accessible. Both condensers sit on the lower floor of the turbine building. A large hole in the turbine building will need to be "cut open" to allow access for the new ¾" outside diameter tube bundles. Based on the tubing parameters and surface area of 617,536 square feet provided by Tetra Tech, it is estimated there will be ~77, 600 tubes per unit.

Each condenser would most likely be comprised of a quantity of 8 modular bundles, each bundle having ~ 9,700 tubes. Special hoist & rigging would be necessary to convey the large tube bundles through the opening in the turbine building walls. The most probable access route would be to first bring a modular bundle to the turbine mezzanine. For both Unit 1 & 2, all interferences would be required to be cut out down to the basement floor and also a path cleared to access the front of the discharge waterboxes. The welded inlet waterboxes would be cut off from the shell and stored out of the way. Similarly, the area in between the NE & SE bundles and the NW & SW bundles for each unit would need to be cleared of all interferences.

For each unit, the inside bundles (qty. 8) would then be lowered one-by-one and pushed on rails through the outer bundles and inserted into the inside bundles. The outside bundles (qty. 8) would then be lowered from the turbine mezzanine and inserted into the discharge end of the waterboxes. The condenser waterboxes, circulating water CW lines and their connections would all have to be removed and stored out of the way. Another smaller project of the retrofit which was overlooked would require modification of the existing waterboxes to support the higher CW pressures of the closed-cycle system.

Burns Engineering Services believes that the construction and retrofit activity for replacing the existing condensers would pose a safety hazard and therefore not allow operation of either unit while another was being worked on. None of these items drew mention in the Tetra Tech report. The modular rebundling by itself for both condensers would take a minimum of 3 months on an aggressive, fast track schedule. This retrofit activity will add substantially to the costs & scheduling requirements of the proposed alternative.

4. Cooling Tower Performance

Wet cooling towers function because of the evaporative effect that occurs between the warm water of the condenser when it comes into direct contact with the cooler air flowing through the tower. The physics of the process is governed by the inherent ability of the air to absorb moisture and that is determined by the local wet bulb temperature. The higher the wet bulb temperature, the closer the temperature of the cooled water can "approach" that wet bulb and the lower the wet bulb temperature, the larger the "approach" of the cooled water to the wet bulb temperature. Hence, wet cooling towers can perform without freezing in below zero climates because their approach is perhaps 50 °F to the low associated wet bulb. Conversely, at high wet bulb temperatures where cooling towers are traditionally specified by architect-engineers for large cooling projects, an approach of about 8°F is considered practical.

At DCPP the highest wet bulb temperature is ~61°F and so a potentially achievable commercial approach for a large utility cooling tower is well above the 9°F suggested. Based on Cooling Technology Institute data [2], it was estimated that the approach at DCPP would be about 16°F at the design point and not the 9°F that Tetra Tech used in its evaluations. That additional 7 °F approach temperature with recirculation and interference (discussed below) effects directly increases the turbine exhaust pressure(s) by ~1.0 inHgA and correspondingly reduces the station generation to a much larger 55.9 MW. This is almost 3 times the value Tetra Tech estimated.

Recirculation occurs when the warm exhaust air gets drawn back into the tower inlets effectively raising the inlet wet bulb temperature of the air above the ambient condition and negatively impacting tower performance. Undoubtedly, the recirculation and interference effects would be substantial at this densely packed site of 132 cells. The back-back tower arrangement, spacing, tower orientation relative to wind, tower length and wind speed would make this tower susceptible to a large amount of recirculation. An educated estimate of the tower recirculation on the proposed Tetra Tech design would likely be at a minimum of 4–5 degrees. Burns Engineering used a conservative estimate of a total of 4 °F for the recirculation and interference effects. Again, Tetra Tech failed to include or compensate for the enormity of this critical effect on increases to the cooling water approach temperature or even mention its occurrence in their report. The effect of this 4 °F recirculation is an energy penalty of 17.5 MW. Using Tetra Tech's assumptions of 350 day operation and power at a cost of $34/MW hour, recirculation will cost DCPP $5 million in lost revenue per year.

Finally, another important design aspect that Tetra Tech did not mention was the large amount of noise emitted from a cooling tower complex of its 132 cells, each with a 250 hp fan. The noise emitted from those fans would be appreciable and would be required to be substantially attenuated. A typical 10 cell utility cooling tower would produce 66 dBa at a distance of 400 ft. from the tower. Propagating the noise from this simple model for132 similar cells at DCPP to the greater distances of the site Training Building or the Administration building, suggests that the continual, outdoor noise level will be in the vicinity of 74 dBa, a level that would be unacceptably high. The use of low noise fans and other attenuation air-side features on this site would likely be a requirement. An attenuation device would also probably be required to reduce the noise from the huge volume of cascading tower water, 1,725,000 gallons per minute. To provide the requisite noise reduction, it could also be necessary to increase the tower size or fan power to compensate for the greater resultant air pressure drops. No mention of these important noise design issues were brought forward in the Tetra Tech report.

5. Operating & Maintenance

Tetra Tech indicates their Operating & Maintenance (O&M) estimate is 750$/MW and whether applicable to freshwater or saltwater installations was not defined. The value they obtained was from a respected, large cooling tower manufacturer but not a cooling tower owner who must actually bear the annual costs. That supplier would not appreciate the 24/7 costs of the extra personnel needed for frequent inspections, upkeep, lighting, instrument, control, electrical and mechanical repairs, replacements, maintenance of the water treating systems, chemical requirements, blowdown, and makeup systems. It could for example be modestly expected that an extra staff of 10-15 people would be required with a range of craft skills from chemists to engineers to welders, instrument technicians, electricians, painters, etc. Estimating current salaries, benefits, office & manual space requirements and the supplies they would need indicates a much higher value at DCPP than the $750/MW cost listed by Tetra Tech.

Because the makeup consisting of 35,000 PPM TDS (total dissolved solids) salt water is concentrated by the cooling tower evaporation effect to be about 1.5 times that value, the water treatment is more demanding than a freshwater cooling system. In addition, the discharge water chemistry and temperature, including intermittent chlorine, would be required to be within EPA and State mandated guidelines. Water treatment would require a separate, dedicated facility. The concentrated salt drift would mandate a major increase in outdoor maintenance at the plant. All vehicles parked on-site, including those of the plant and employees alike, will be blanketed with salt and subject to its corrosive effects. They will deteriorate faster and require more extensive washing and maintenance. Air moving equipment will require continual maintenance. Because of the immense size and added complexity of the closed-cycle cooling system at DCPP, the cost of supplies, testing, sampling and replacement equipment alone could be significant.

Other cost indicators of the maintenance, based for example on using 1% of the capital cost of the cooling system annually, suggest the Tetra Tech maintenance cost estimate is low by a factor of 6 times the $1,700,000 estimate proposed by Tetra Tech for both units.

6. Energy Penalty

The energy penalty is the loss in electrical generating capacity incurred because the retrofitted cooling system is unable to perform at its previous once-through levels. It is manifested by a comparative increase in the turbine backpressure. The seasonal temperatures of the water of the Pacific Ocean would control the performance of the existing once-through system. However, the performance of the proposed retrofitted mechanical draft cooling system is linked to the local wet bulb temperature, the tower approach, the recirculation and interference effects and the improved performance of the condenser. In aggregate, that results in a higher turbine backpressure and a loss in generation. Though in the power industry parlance, the auxiliary power to run the retrofitted cooling tower fans and pumps is considered an operating cost, to stay aligned with the Tetra Tech report method, it will be assumed as a component of the energy penalty. Furthermore, like Tetra Tech it will be assumed the retrofit CW pump power is similar to that of the existing CW pumps.

The estimated energy loss for both units at the design conditions of the retrofitted cooling towers is listed on Table 1. Calculation methods for determining the loss in turbine backpressure have been outlined in the Condenser Modification Section 3. That estimate resulted in a relative turbine backpressure increase above the existing once-through system performance of 1.0 inHg at retrofit design conditions and represents about a 33% increase more than the Tetra Tech estimate. The corresponding loss in generation for both units at DCPP would be about 56 MW, almost three times the Tetra Tech loss estimate. In any event, adding the 25MW auxiliary power required by the 132, 250 BHP fans results in a total generation loss at the design conditions of 81 MW for both units.

Since 81 MW would therefore be unavailable by the installation of the proposed retrofitted cooling system, these losses would need to be compensated by either an increased annual operation at another station or at the cost of replacement power.

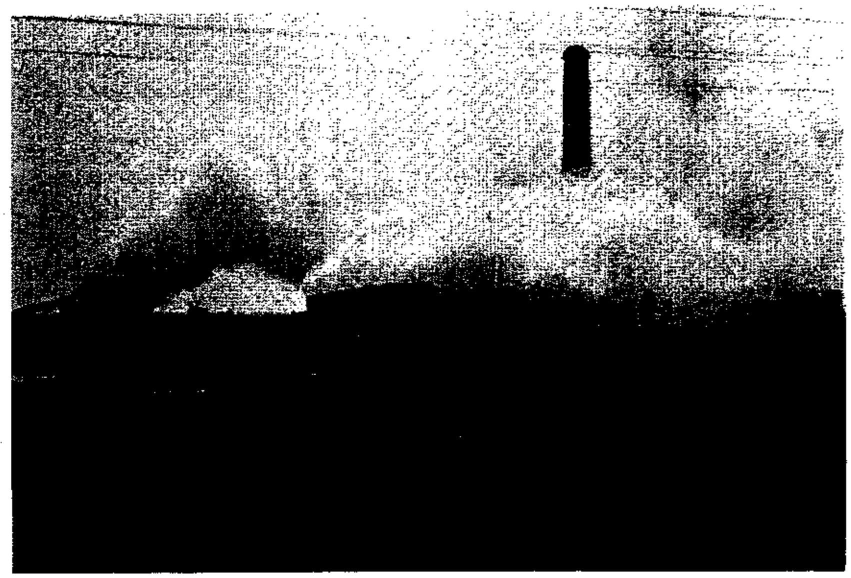


Figure 7- Plume of a Modest Wet Mechanical Draft Cooling Tower

7. Plume Incidence

The proposed Tetra Tech ~132 cell wet mechanical draft design as shown in Figure 2 of their report would produce a substantial plume during certain periods. A plume looks like a massive cloud of smoke that would rise from the tower stacks and would be more than just an aesthetic nuisance. A plume is formed when the relatively warmer saturated exhaust air mixes with cooler ambient air after leaving the stack. The frequency and intensity of a plume are related to heat load and atmospheric conditions. The measure of visible intensity or opacity of a plume is exacerbated when the ambient air temperature becomes cooler as colder air cannot hold as much moisture.

All access roads, buildings and parking lots would be blanketed by a plume during certain atmospheric conditions with the proposed Tetra Tech design – a condition aptly termed ground fogging. The lack of visibility along the access roads to the turbine building would constitute a grave danger. This condition could not be allowed by the NRC or PG&E for obvious safety and security reasons.

The potential in the Tetra Tech proposed design for the plume to envelop DCPP restricting site access and disrupting operations is immense. Low visibility on the access road to DCPP would hinder safe transport of people and materials to and from the site. Poorly designed or situated cooling towers in other places have enveloped nearby facilities, resulting in the shutdown of the plume-generating plant. The Tetra Tech report did not mention the hazardous impact of this proposed cooling tower design on plant safety and security.

Beyond the serious risks plumes could pose to safety and security, aesthetics of the plume formation could create permitting obstacles. Plume visibility is often unacceptable to communities surrounding the plants. During cold, clear days with light winds, the plume created from the monstrous bank of mechanical draft towers proposed in this retrofit would rise many thousand feet into the atmosphere and be visible from tens of miles away. Plume visibility is a highly sensitive environmental and aesthetic issue that must be dealt with during the permitting process.

A wet/dry tower would help to eliminate a visible plume. However, a wet/dry tower is not as efficient as the proposed wet tower. Hence, the wet/dry tower would require a larger footprint, and use more auxiliary power. All things equal, the wet/dry tower typically has a cost of approximately 2 times that of the more efficient wet tower. As the area needed for such an installation is so great as to be ruled out for this case, no further estimate of the wet/dry tower was made.

8. Salt Drift

Heat removal in a cooling tower is accomplished through the process of evaporation. In addition to the large amount of water absorbed into the air and expelled through this process, a corresponding amount of minerals in solution will also be carried by the fans with the exhaust and settle in areas over which the plume travels. The exhaust plume will carry with it the salt & disperse it in the form of droplets like rain in the vicinity of the tower with a composition representative of the circulating water. In the case of the proposed seawater-cooled tower, huge amounts of salt drift will be sent into the atmosphere and deposited in a pattern corresponding to that of the exhaust travel. Thus, the phenomenon is known as salt drift.

The circulating water will be concentrated seawater at no more than 1.5 cycles-of-concentration. Any structures surrounding the tower will likely be permanently coated with salt and other mineral deposits. Salt deposits will rapidly corrode any unprotected structures. The amount of salt drift will depend upon the selected tower design and the amount of evaporation that occurs.

The magnitude of the salt to be deposited by the new cooling towers proposed would be enormous. Commercially available drift eliminator design guarantees were used to estimate the drift from this proposed design. Although only ~0.002% of the concentrated salt water CW flow would become an entrained drift in the exhaust, the vast scale of this proposed retrofit project means that appreciable salt will be dispersed into the atmosphere and deposited. Assuming the plant operates on average at 90% capacity factor, the new cooling towers would spread over 6.8 million pounds of salt over the area per year.

Tera Corp. [14] has modeled likely patterns of drift for mechanical draft cooling towers sited in the general area proposed by Tetra Tech for the cooling towers. See Figure 6 on the following page. Salt will blanket an area extending beyond the plant boundary to the north and south. The center of highest salt deposition will occur approx. 1/3 mile south of the cooling towers within the plant boundary at the southeast section of parcel P. However, a substantial amount will settle over the agricultural zone as well.

As a figure for comparison, salt deposition along the ocean shoreline is only about 86 lb/acre per year [12]. Even the lowest concentration boundary of the Tera study shows a salt concentration of more than five times the natural salt deposition from the sea. Salt will disperse beyond this outer boundary in concentrations lower than that figure, but, given the massive volume of salt, it will impact the local terrestrial ecosystem in the areas surrounding the plant even beyond Parcel P.

Another overlooked engineering discussion in the Tetra Tech report is the close proximity of the 500 kva transmission lines that run from the back of the turbine building for both units up the hill to the switchyard. The probability of arcing due to salt drift depositing itself on and coating insulators of these nearby 500 kva transmission lines is very real. A recent rash of arcing has occurred at brackish and saltwater plants throughout the country. In all cases, the cause of the arcing was attributed to drift from a nearby cooling tower whose drift deposited salt on the insulator. Salt will inevitably settle upon the closely situated insulators of the 500 kva power lines resulting in forced shutdown of the facility and higher maintenance costs.

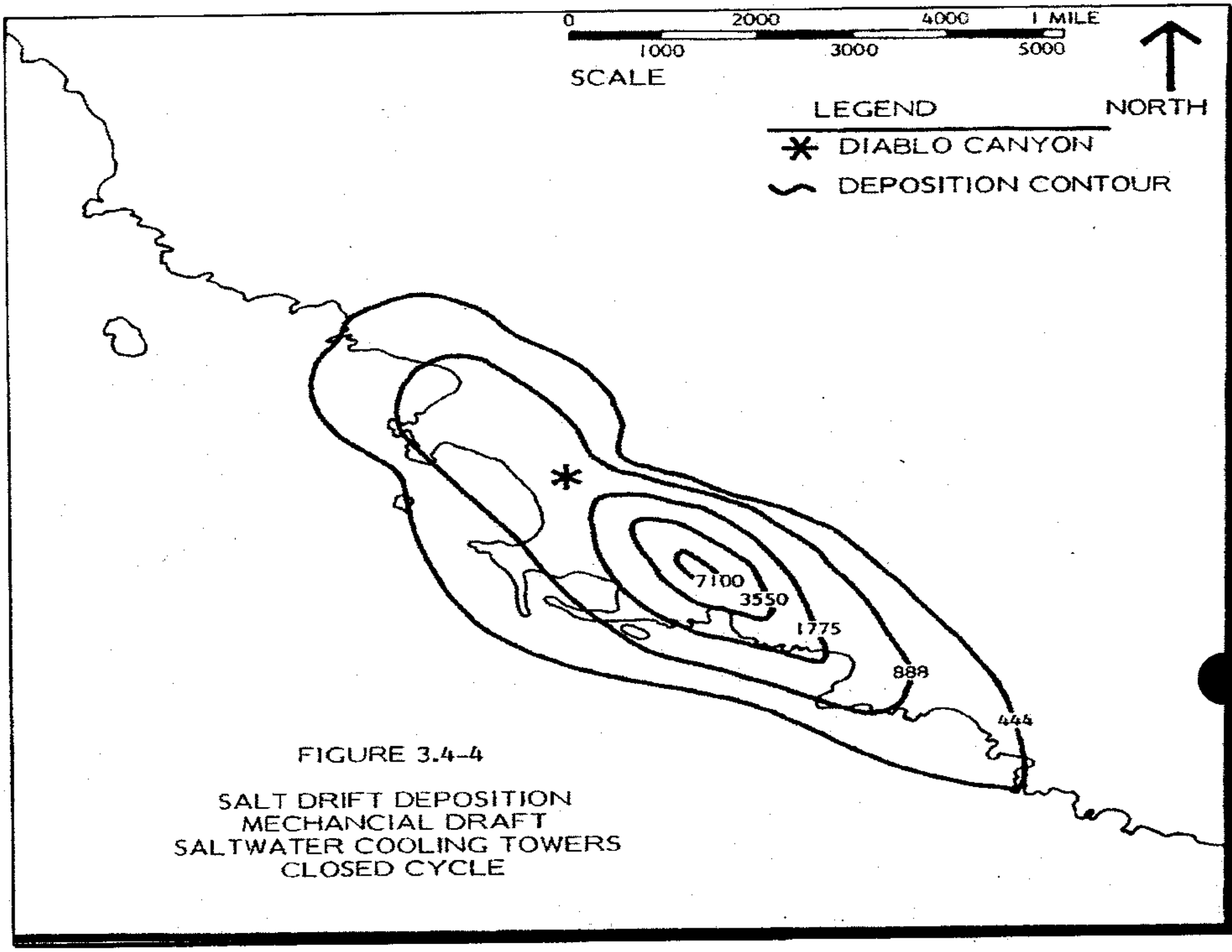


FIGURE 8- Salt Drift Patterns from Tera Corporation Report, lb/acre-yr
(In contrast, typical ambient salt deposition from ocean ~86 lb/acre-year)

IV. References

1. Evaluation of Cooling System Alternatives, Diablo Canyon Power Plant, Rev 2., Tetra Tech Inc., Evergreen CO, November 2002.

2. Cooling Technology Institute, Cooling Tower Performance Curves, MRI, 1967.

3. Burns, JM. and Brocard, D., "Cooling Towers", Section 4.8, Handbook of Energy Systems Engineering, Reference Text, J. Wiley & Sons, NY, 1985.

4. Wilbur, K. and Burns, JM., "An Examination of the Evolution and Substantiation of ASME's Proposed Test Code On Atmospheric Water Cooling Equipment", ASME Winter Annual Meeting, 1979.

5. Reisman, JI., "A Study of Cooling Tower Recirculation", ASME Winter Annual Meeting, 1972.

6. Burns JM., Corsi, L., and Stevens RL., "Modular Surface Condenser Retubing Considerations" Joint Power Generation Conference, 1987.

7. William Lettis & Associates, Inc., "Report on ISFSI Screening study of Firing Range and Parking Lot 8 Sites, PG&E Diablo Canyon Power Plant," Jan. 5, 2000.

8. PG&E, "Architectural Ground, Mezzanine, and Upper Floor Plans- NPO Permanent Warehouse," DWG # 472087, rev.12.

9. Heat Exchange Institute Standards for Steam Surface Condensers, 9th ed., 1995.

10. Diablo Canyon Power Plant, "Assessment of Alternatives to the Existing Cooling System", Tera Corporation, March 30, 1982.

11. Westinghouse Electric Corporation, DCPP Unit 1 & 2 L. P. Turbine Exhaust Pressure Correction, AV953-0087 and AV015-0199.

12. UFSAR, Diablo Canyon ISFSI, Figure 10.1-2, Typical Heat Balance Diagram Full Load, November, 2001.

13. DCPP USFAR, Revision 12 - September 1998.

14. Wilber, K. et al, "Measurement and Characterization of Cooling Tower Drift" ASME, 1974.

Evaluation of Cooling System Alternatives
Diablo Canyon Power Plant

Prepared for the
California Regional Water Quality Control Board
Central Coast Region
81 Higuera Street
San Luis Obisbo, California 93401

Revised Draft

Prepared by
Tetra Tech Inc.
27972 Meadow Drive
Evergreen, Colorado 80439

November 2002

CONTENTS

FIGURES

TABLES

I. Introduction

Tetra Tech Inc. has been requested by the Central Coast Regional Water Quality Control Board (Board) to provide cost estimates for cooling system alternatives that will minimize environmental impacts associated with the once through cooling system of the Pacific Gas & Electric Company's (PG&E) Diablo Canyon Power Plant (DCPP), located in Avila Beach, San Luis Obisbo County, California. In response to this request, the following report provides an independent analysis and approximate cost estimates for conceptual cooling system alternatives for the DCPP, to enable the Board to consider feasibility and determine if additional analysis of alternatives is warranted. Although an independent report, it has been prepared with input from PG&E plant personnel, who have provided meaningful site-specific information and insight. Tetra Tech, Inc. has also visited the plant site on October 18, 2002 in order to provide a meaningful analysis.

In 1982, TERA Corporation prepared the *Diablo Canyon Power Plant Assessment of Alternatives to the Existing Cooling Water System* for PG&E. The primary objective of that comprehensive assessment included the reduction of heat in the facility's cooling water discharge, whereas the primary objective of this assessment is to examine alternatives that will reduce impingement of aquatic organisms on components of the plant's cooling water system and reduce entrainment of aquatic organisms within the system. With reduction of impingement and entrainment a primary objective, feasible cooling system alternatives must significantly reduce the power plant's cooling water flow requirement and/or limit the number of aquatic organisms that come into contact with or pass through the power plant's cooling water intake structure.

Although Tetra Tech, Inc. has considered a wide range of cooling system alternatives for the Diablo Canyon Power Plant, only two get considerable attention within this report – the use of fine mesh traveling screens with fish handling and return systems at the cooling water intake structure and the use of mechanical draft, wet cooling towers using seawater makeup. Other methods of cooling, such as natural draft wet cooling towers, dry cooling towers, and hybrid (wet/dry) cooling towers have been given consideration but are not discussed in great detail, due to their technical limitations or the practical difficulties that would be encountered during their construction and use at the Diablo Canyon facility. Other intake technologies, such as cylindrical wedgewire screens, fish net barriers, and louver systems have also been given consideration; however, most such technologies have never been used on a scale that would be required at the Diablo Canyon Power Plant and/or would have significant technical limitations in the unique physical setting of this facility. Many cooling system alternatives considered in the TERA Corporation's 1982 report have simply not been considered here, because they were viewed as a means to reduce thermal discharges and would not meet the objective of this assessment to evaluate technologies for reducing impingement and entrainment of aquatic organisms.

For this analysis, Tetra Tech Inc. has used, to some degree, EPA's cost projections for cooling water intake technologies and for alternative cooling systems, presented in the Agency's *Technical Development Document* (TDD) and in its *Economic and Benefits Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule* (EPA 821-R-02-003 and EPA 821-R-02-001, both April 2002). Tetra Tech Inc. has also worked with the engineering firm of Hatch &

Associates Ltd (Hatch) to develop capital cost projections for closed cycle cooling alternatives based on approximate cooling requirements and ambient meteorological conditions of the DCPP. And, Tetra Tech, Inc. has received site-specific information from PG&E that has been considered in developing costs estimates.

II. Background[1]

The DCPP is a two-unit nuclear power plant sited on 585 acres owned by PG&E, approximately 12 miles west southwest of San Luis Obisbo. Units 1 and 2, which began commercial operation in May 1985 and March 1986, respectively, are operated as base loaded units and have gross rated capacities of 1,133 and 1,165 MW and net outputs of 1,103 and 1,119 MW, respectively. Ocean water for cooling is pumped through an intake structure in Intake Cove and then through two steam condensers per unit, with the total cooling water flow rate for Unit 1 ranging from 778,000 to 854,000 gallons per minute (gpm) and for Unit 2 from 811,000 to 895,000 gpm. During 1977 – 1986, daily mean seawater temperature ranged from approximately 10.5°C in May to approximately 15°C in September. The maximum seawater temperature during 1972 – 1982 was 18°C (64°F).

With the plant at full load, the temperature of once through cooling water is raised approximately 11°C (20°F) as it passes through the power plant. Each unit has two, single speed, cooling water pumps, each driven by a 13,000 horsepower, 238 rpm motor. Auxiliary cooling systems account for approximately one percent of the facility's total cooling water volume. After exiting the condensers, approximately 2.5 billion gallons of cooling water per day flow by gravity to a discharge structure on the shoreline of Diablo Cove, which is north of Intake Cove.

The shoreline intake structure for the DCPP contains inclined bar racks and travelling screens along with auxiliary and main cooling water pumps. At the face of the intake structure, a concrete curtain extends 7.75 feet downward, below mean sea level, to keep out floating debris. After entering the structure, water flows through inclined bar racks, consisting of flat bars, 3 inches x 3/8 inches on 3 3/8 inch centers, which create 3 inch openings in the racks, designed to exclude large debris. From the bar racks, ocean water flows through a series of pump bays, which house vertical travelling screens of 3/8 inch stainless steel mesh. Six travelling screens per unit, each at 10 feet (width) x 30 feet (depth), filter seawater ahead of the two main circulating water pumps per unit; and a smaller travelling screen, with 150 square feet of filter surface, precedes the auxiliary pumps. Screens can be set to rotate at 10 or 20 feet/minute and can be washed manually or automatically, with high-pressure spray. Material is washed from the screens into sloping sluiceways that empty into a refuse sump before being discharged to the ocean.

Two single speed, main circulating pumps per unit, each capable of supplying 433,500 gpm, move water through two 11.75 feet square conduits to the top of a coastal bluff at an elevation of 85 to 105 feet, where it is vented and routed through the plant's condensers. Approximate cooling water velocities are:

[1] Background information has been assembled from the *Staff Report for Regular Meeting of July 13, 2000, Diablo Canyon Nuclear Power Plant, Resolution of Thermal Discharge and Entrainment/Impingement Impacts,* California Regional Water Quality Control Board, Central Coast Region (June 6, 2000); *Section 2.0, Diablo Canyon Power Plant 316(b) Study, Draft Evaluation of Alternative Intake Technologies,* Engineering Services, Pacific Gas and Electric Company (Dec. 10, 1999); *Chapter 2, Diablo Canyon Power Plant, Cooling Water Intake Structure 316(b) Demonstration,* Tenera Environmental Services (April 28, 1988); and *Diablo Canyon Power Plant, Revised 316(b) Study Plan,* Tera Corporation (June 13, 1983); Comments of September 2002 provided to Tetra Tech, Inc. by PG&E DCPP plant personnel in response to a Preliminary Draft Evaluation of Cooling System Alternatives for the Diablo Canyon Power Plant.

Through bar rack	1.1 feet per second (fps)
Approaching travelling screens	1.0 fps
Through 3/8 in. travelling screens	1.95 fps
From intake structure to condenser	7.0 fps
Through condenser	7.0 fps
Through discharge conduits	7.0 fps
Discharge structure exit channel	8.5 fps

Based on comprehensive entrainment studies performed at the DCPP between October 1996 and June 1999, there is potentially a high loss of larvae of near shore species attributable to the once through cooling system at the DCPP. Offshore species, which include more sport and commercial species, were not entrained in significant amounts during these studies. And, impingement studies, performed in 1985 and 1986, showed that very few adult fish were actually impinged on the travelling screens at the DCPP cooling water intake structure.

Several features of the DCPP's physical location are important to the consideration of cooling system alternatives.

- The DCPP is located on a coastal terrace above a rocky shoreline. Normal wave activity is in the 5 to 10 feet range, with storms generating waves between 20 and 30 feet. During the storm season between September 1997 and August 1998, peak swells exceeded 10 feet on 64 days.
- The DCPP cooling water intake is located in an area of significant production of marine algae, including surface kelp and understory algae. Kelp growth can reach two feet per day during the growing season between June and October.
- The DCPP is located in a "wet marine" weather environment where ocean winds are commonly 10 to 25 miles per hour and can reach 40 to 50 miles per hour. Rainfall averages 20 inches per year; and the normal daily weather pattern is characterized by wet/foggy conditions in the morning and mild to strong winds in the afternoon.
- Bathymetry in the vicinity of the DCPP is characterized by a sloping bedrock bottom with steep relief, rocky pinnacles, and prominent rocky ridges.
- The area of the DCPP, in general, exhibits steep topographic relief. The plant itself lies on gently sloping, narrow, coastal terrace at an elevation of 85 feet (MSL) above a rugged coastline, with the Irish Hills rising steeply behind the facility, to the east. Figure 1 shows the plant site, including topography surrounding principal structures.
- A protected archeological site, north and adjacent to Diablo Creek, exists on the plant site.

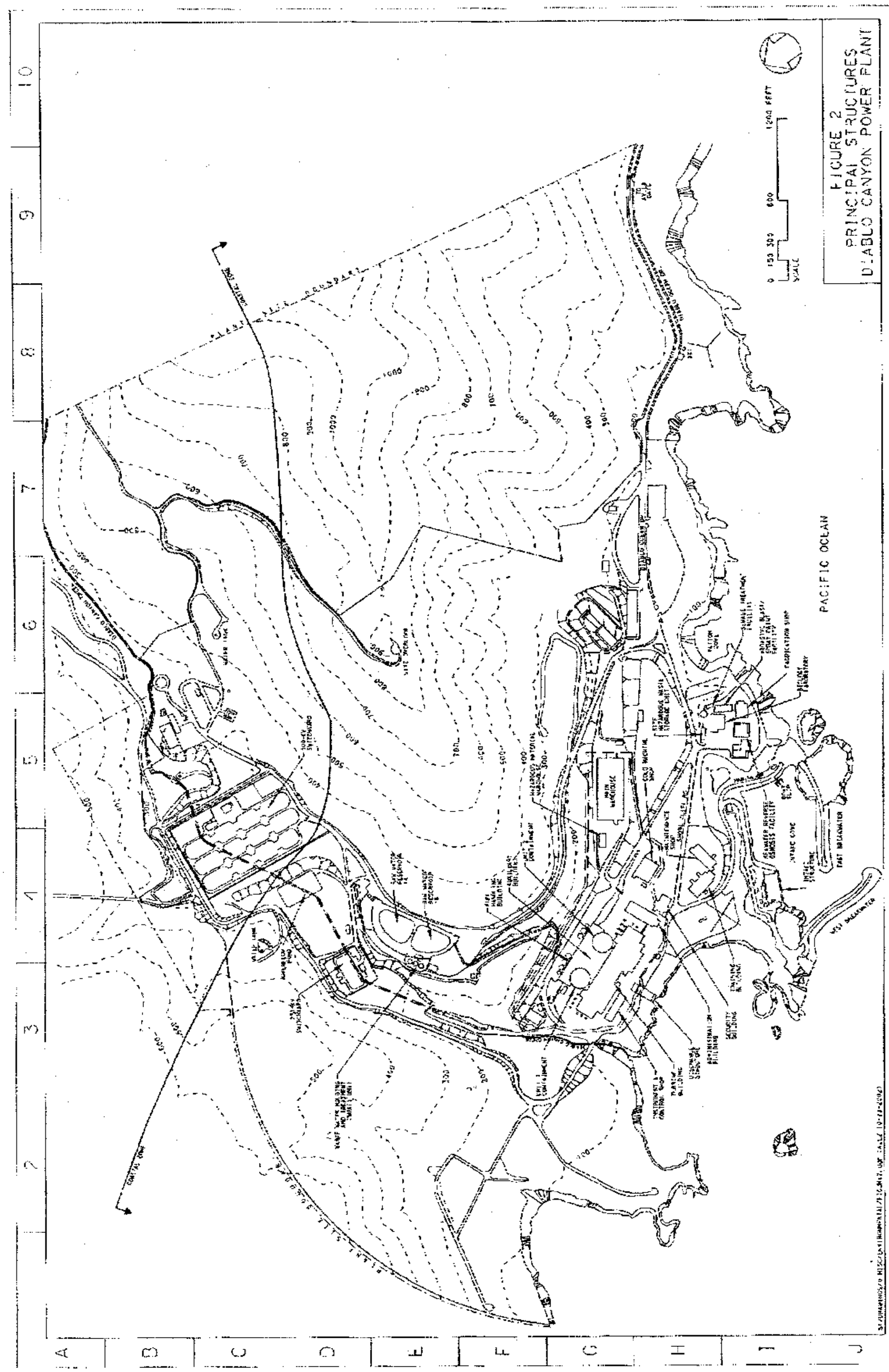


Figure 1: Diablo Canyon Power Plant, Site Drawing

III. Summary of Cost Estimates

Table 1, below, provides a summary of cost estimates for the two cooling system alternatives considered viable for further consideration at the Diablo Canyon Power Plant. Sections IV and V provide discussion of each alternative, including how costs were determined.

Table 1 - Summary of Cost Estimates for Cooling System Alternatives at the DCPP - $MM

	Fine Mesh Screens With Fish Handling and Return Systems	Mechanical Draft, Wet Cooling Tower System Using Seawater Makeup
Capital Cost	23	822
Annual O&M	1	1.7
Total Annual Energy Penalty	NA	13
Lost Revenue During Construction	660	330
Net Present Value[2]	- 650	- 1,320
Annualized Cost[3]	663 (first year) 3.2 – 3.9 (thereafter)	422.5 (first year) 92.6 – 94.2 (thereafter)

NA = not applicable

[2] Assumes a 20 year project life

[3] Assumes capital costs amortized over 20 years

IV. Evaluation of Cooling System Alternatives – Modification and/or Additions to the Once Through System

At the DCPP, studies of both impingement and entrainment activity appear to show that modifications to the cooling water intake system must focus on reducing entrainment, as impingement effects were insignificant in studies performed by PG&E in 1985 and 1986. Intake technologies, with the potential to reduce entrainment, include fine mesh screens with fish handling and return systems and aquatic microfiltration barriers (both addressed in this section), as well as cooling systems that would significantly reduce the cooling water requirement – wet, dry, and hybrid (dry/wet) closed cycle cooling designs (addressed in Section V).

A. Fine Mesh Travelling Screens with Fish Handling and Return Systems

Fine mesh screens of 5 mm or less can be mounted on conventional, continuously operated, traveling screens to exclude eggs, larvae, and juvenile fish from intake structures. A low-pressure screen wash is typically used to gently release impinged eggs, larvae, and juvenile fish to a bypass/return system; and a high-pressure spray wash then removes debris.

0.5 mm fine mesh screens have been used on Units 3 and 4 of the Big Bend Station of Florida Power and Light (FP&L) since the mid 1980s. After evaluation of intake velocities and screen rotational speeds, and recognizing that frequent manual cleaning was necessary to avoid biofouling, the FP&L system has generally demonstrated long-term success at reducing entrainment. Fish eggs are screened at greater than 95 percent efficiency, with latent survival for predominant species between 80 and 93 percent. Larvae are screened at 86 percent efficiency, with latent survival at approximately 65 percent.

Fine mesh, 0.5 mm, screens have also been successfully used in a marine environment at the Barney Davis Station in Corpus Christi, where impingement mortality has been reduced significantly, although entrainment performance data is unavailable. In periods of limited use or study, fine mesh on two of four screens at the Brunswick Power Plant in North Carolina showed 84 percent reduction in entrainment as compared to conventional screens, while similar results were seen in pilot studies at the Chalk Point Generating Station in Maryland and at the Kintigh Generating Station in New Jersey. In pilot studies in the 1970s, the Tennessee Valley Authority showed reductions in striped bass entrainment up to 99 percent using 0.5 mm mesh screen and reductions of 75 and 70 percent using 0.97 mm and 1.3 mm screen size, respectively.

Of the plants mentioned above that have actual experience or have conducted pilot studies using fine mesh screens, the Barney Davis, Big Bend, Brunswick, and Chalk Point Stations each utilize salt water or brackish water for cooling. Data for the Big Bend Station of the Tampa Electric Power Company is cited from two impingement and entrainment (I&E) studies performed between 1976 and 1980. Those studies, like the 316(b) Demonstration Study for the Diablo Canyon Power Plant, were conducted in accordance with EPA guidelines, which propose identification and focus on target or "representative important species" (RIS). Such species are targeted for study because, in general, they are commercially valuable, recreationally important, and/or locally abundant. Fifteen taxa were targeted in the Big Bend I&E studies, and sixteen taxa were listed as RIS in the Diablo Canyon Demonstration Study.

Attachment 1 of this report contains two tables, which present detailed life cycle information for the RIS targeted in the Big Bend and Diablo Canyon studies. The RIS taxa can be summarized as:

Big Bend	Diablo Canyon
1 swimming crab species	2 Cancer crab species
1 stone crab species	1 herring species
1 Penaid shrimp species	1 anchovy species
6 drum species	1 scorpionfish/rockfish species
1 herring species	1 scorpionfish/rockfish complex
1 grunt species	1 combfish species
2 porgie species	3 sculpin species
1 pufferfish	1 drum species
	1 prickleback species
	1 kelpfish
	1 goby species
	1 Paralichthyid flounder species
	1 lefteyed flounder species

Based on the near absence of overlap of Big Bend and Diablo Canyon RIS at the family and species levels, there would appear to be very little opportunity to predict success for fine mesh screens at Diablo Canyon based on results at Big Bend. The only taxa common to both locations are drums and herrings. Closer examination of life cycle histories of both sets of RIS, however, shows that most of the RIS at both facilities are nearshore spawners and/or utilize the nearshore as nursery habitat. Another possible level of comparison (not performed for this assessment) would be to look at egg sizes and/or size ranges of larvae to see whether the primary species in both locations are similar in size.

When considering the comparability of Big Bend experience with potential effectiveness of fine mesh screens at Diablo Canyon, the strongest statement, from a biological perspective, is that both facilities are dealing primarily with species that spawn in nearshore areas, have buoyant eggs, and/or planktonic (detached/floating) larvae. Diablo Canyon may have a few more species known to have demersal (sinking) eggs, but those species also have planktonic larvae, more subject to the currents and vulnerable to entrainment.

Although the limited experiences described above suggest that 80 percent reduction in entrainment could potentially be achieved at the DCPP, through the use of fine mesh screens, any further consideration of such technology would require pilot studies to take into account site specific variables, including local species of concern and the potential for screen fouling with kelp and algae.

Use of fine mesh traveling screens at any facility would need to be optimized. The potential for fouling by kelp and algae at the DCPP would be significant, and intensive maintenance should be anticipated to avoid biofouling. Applications of this technology also suggest that intermittent, rather than continuous use of fine mesh, during periods of larvae and egg abundance, may be appropriate at some facilities. The example facilities, discussed above, do not have cooling water flow requirements near that of the DCPP. Tetra Tech Inc. acknowledges that these examples demonstrate limited full-scale use of the technology and have resulted in limited performance data.

At the DCPP, there are currently 6 travelling screens per unit, each 10 feet (width) x 30 feet (depth). With an average cooling water flow of 835,000 gpm per unit, through screen velocity is calculated at 1.0 fps, or approximately 2 fps, when a 50 percent screen efficiency is assumed. For the purpose of cost estimates, below, the screen surface area at the plant is doubled to allow a through screen velocity closer to 1 fps at a 50 percent screen efficiency. Such a reduction (50 percent) in through screen velocity would also reduce, rather than raise, concerns regarding possible impingement effects caused by alternative screen technology.

In its *TDD for the Proposed Section 316(b) Phase II Existing Facilities Rule* (EPA 821-R-02-003, April 2002), EPA estimates capital and operation and maintenance (O&M) costs for travelling screens with fish handling features at various well depths and screen widths. The Agency arrives at cost estimates for retrofitting an existing facility with such technology by determining costs for a new plant and then applying a retrofit factor (1.3), a construction factor for nuclear facilities (1.65), and a regional cost factor (1.081). The retrofit factor accounts for needed changes to existing cooling water and intake structure systems; and the construction factor takes into account differences in construction costs between nuclear and non-nuclear facilities and differences in installation costs between the various cooling water intake technologies.

Although EPA is conservative in developing its cost figures, it does not address cooling water intake facilities with the very large intake flows required of the DCPP and acknowledges that flows greater than what the Agency considered could require a custom design. Nevertheless, to arrive at an approximate cost estimate, Tetra Tech Inc. has extrapolated EPA's cost figures presented in Table 2-11 of the TDD to arrive at a figure of $870,000 per screen for the DCPP. After applying the regional, retrofit, and construction cost factors, total capital costs are estimated at $1.8 MM per screen or $21.4 MM to retrofit the DCPP intake structure with fine mesh travelling screens having an effective through screen velocity of 1 fps.

O&M costs for travelling screens will vary by type, size, and mode of screen operation. In the TDD for existing facilities, EPA projects O&M costs for travelling screens to range from 5 percent of their total capital cost (before cost factors are applied) for the largest travelling screens to 8 percent for the smallest travelling screens, since O&M costs would not increase proportionately with screen size. Using EPA's costing methodology and the worst-case scenario of 8 percent, costs to operate and maintain fine mesh travelling screens on the main circulating water system at the DCPP would be approximately $835,000 per year. PG&E has indicated, however, that O&M costs for its existing screen technology are already close to $1 MM per year; and it is reasonable to assume that O&M costs at the Diablo Canyon Power Plant for fine mesh screens would be unusually high due to high algae and kelp production in the vicinity of the facility's cooling water intake structure. This would be especially true during the first years of operation (like at Big Bend) during system optimization. Based on best professional judgment, Tetra tech, Inc. has assumed that EPA's O&M estimate of $870,000 per year would be in addition to the $1 MM currently spent by PG&E.

Tetra Tech, Inc. and Hatch estimate that both units would be off line and not generating, simultaneously for approximately thirteen months during construction and retrofitting activity. Although a staged construction, where only one unit at one time would be off line, would be possible, total downtime has not been projected for such a construction scenario. Over a thirteen month period, in which both units would have been off line for scheduled outages of 1 month, PG&E would lose revenue of approximately $660 MM. This figure was determined with a revenue estimate provided by PG&E for the DCPP of $900,000 per unit per day; and it is in line with Tetra Tech, Inc.'s independent estimate based on a net plant output of 2,222 MW over 364 days and a wholesale price of electricity of $34 per MW. Before modifying the main cooling water intake structure, a smaller intake for auxiliary salt water (ASW) pumps will also be required, as the ASW system is a safety related system that cannot be shut down, when the facility is off line. Costs for implementing a new ASW intake would be approximately $1.6 MM (resulting in a total capital cost figure of $23 MM). These costs would include new ASW pumps, trash rack, traveling screens, pit, enclosed structure, and electrical components. 24 inch hyprescon piping would be installed underground to connect the ASW pumps with the existing ASW supply piping. The structure would be suitable for saltwater application and would be seismically qualified per UBC 1997 Code Zone 4.

The net present value (NPV) of this alternative, assuming a twenty year project life that takes into account capital and *additional* O&M costs is $650 MM. Net present value (NPV) is often referred to as the "value" of an asset. In this case, Tetra Tech, Inc. is using it to reflect the long-term cost of each alternative in terms of current dollars. Annual costs, assuming amortization of capital costs over twenty years and additional O&M costs inflated by three percent each year, would be $663 MM in the first year and $3.2 to 3.9 MM thereafter. A twenty year project life is used based on a twenty year duration for the facility's operating license, as reported by PG&E.

For comparison, in the *Diablo Canyon Power Plant 316(b) Demonstration Report* (March 2000), TENERA Environmental Services estimates capital costs of $51,000,000 just to reduce intake flow velocities by increasing the area of the intake structure. TENERA provided a separate cost estimate to modify travelling screens and add a fish handling system ($12 MM) and a separate estimate to employ fine mesh screens ($7 MM). TENERA also contends that both units would be out of production for about one year, while modification to the intake structure was taking place, thus adding a significant figure for lost revenue to total project costs.

B. Aquatic Microfiltration Barriers

Aquatic microfiltration barrier systems rely on a filter fabric that allows water to pass into a cooling water intake structure (CWIS) while excluding aquatic organisms. These systems are designed to be placed at a considerable distance from the CWIS and have very large filter surface areas, and as such, velocities through the filter remain very low. Gunderboom, Inc. produces a full-water depth, 20 micron mesh filter curtain that is suspended by flotation billets at the surface and anchored to the substrate below. Gunderboom's system uses periodic bursts of air to maintain the filter fabric.

Although the use of microfiltration barriers near cooling water intake structures has been limited and is considered experimental in nature, the technology does show significant promise as a method for reducing entrainment of aquatic organisms within cooling water systems. The only power plant where the Gunderboom system has been used at a full-scale level is the Lovett Generating Station along the Hudson River in New York. At this facility, entrainment reductions up to 82 percent have been maintained for extended periods between 1999 and 2001, while several operational difficulties, such as tearing, overtopping, and clogging, have been overcome through design modifications.

Gunderboom Inc. estimates that with 20 micron mesh, at intake flows of 100,000 and 200,000 gpm, its microfiltration barrier would need to be 500 and 1,000 feet long, respectively, assuming a depth of 20 feet. Based on these estimates, intake flows at the DCPP (1.6 million gpm) would require a filter area of approximately 160,000 square feet or a filter length of 8,000 feet at a depth of 20 feet. In addition, as discussed in Section II, normal wave activity in Intake Cove is 5 to 10 feet, and storms can generate 20 to 30 foot waves. The potential for overtopping at the DCPP would be much greater than at the Lovett Station, where its location on the Hudson River protects the intake area from significant wave activity. With such a large filter area, the steep and irregular bathymetry of the near shore sea bottom, significant wave activity, and potentially extreme maintenance requirements, such a system cannot be viewed, at this time, as a proven and realistic means, for further consideration, of reducing entrainment at the DCPP. In the *Diablo Canyon Power Plant 316(b) Demonstration Report* (March 2000), a microfiltration barrier was not evaluated as an alternative technology for minimizing entrainment at the DCPP.

V. Evaluation of Cooling System Alternatives – Alternative Methods of Cooling

Tetra Tech, Inc. has considered several alternative methods of cooling for the DCPP that would significantly reduce the volume of seawater needed for cooling. These alternatives include the use of dry cooling towers, which rely on air cooled condensers to dissipate heat; wet cooling towers, which rely on evaporation of cooling water to dissipate heat; and hybrid (wet/dry) cooling systems. Both fresh water and seawater makeup sources have been considered, as well as mechanical and natural draft, wet cooling towers. Most of these alternatives have received limited attention, however, due to technical limitations and/or the unique physical setting of the power plant, which would present serious obstacles to their successful construction and implementation at the DCPP.

Dry cooling systems have not been evaluated as a viable alternative for the DCPP. Preliminary analysis determined that eight air-cooled condensing systems would be required, each occupying an area of 316 feet by 197 feet with an overall height of 119 feet. Each condenser would use forty, 150 hp fans; and the resulting turbine backpressure would be in the range of 3.5 to 4 inches HgA, considerably higher than the facility's design value of 1.5 inches HgA. Based on discussions with GEA Energy Technology Division, a leading designer of dry cooling systems, "the length of duct for an air-cooled condenser should be limited to a distance less than or equal to 200 feet."[4] Because of limited available land area at the DCPP, however, cooling system configuration to keep duct lengths less than 200 feet would not be possible. A dry system located

[4] Memo of Nov. 4, 2002 from Jamie Clark of GEA Energy Technology Division to Bernard Bruman of Hatch.

in the area suggested for a wet cooling tower system, described below, would have duct lengths of approximately 500 to 1,000 feet. These duct lengths would result in significantly larger pressure drops, a need for even larger air-cooled condensers, and difficulties arising from thermal expansion. GEA has not designed or constructed dry cooling systems with comparable duct lengths. Based on these considerations, dry cooling systems did not receive further attention as an alternative for the DCPP.

At the DCPP, which has limited space available for additional facilities, hybrid (wet/dry) cooling systems were also not evaluated as a viable, alternative means of cooling. Design of a hybrid cooling system at the DCPP would encounter the same difficulties related to duct lengths, as described for dry cooling systems.

Cooling systems using freshwater makeup were also not evaluated as viable alternatives for the DCPP. Although wet cooling tower systems using fresh water makeup would use far less water than cooling tower systems using seawater makeup, there is no adequate source of fresh water within 25 miles of the facility. The costs and logistical difficulties of piping such a quantity of freshwater, or even treated wastewater, to the plant preclude serious consideration of such alternatives.

The possibility of producing freshwater from seawater at the power plant site, for use as makeup to a wet cooling tower system, was also not given serious consideration as an alternative to the existing once through cooling system. Freshwater makeup to wet cooling towers would reduce the power plant's cooling water requirement to below 50,000 gpm, which would represent a reduction of greater than 95 percent, and a proportionate reduction in impingement and entrainment. These reductions in cooling water requirement and impingement and entrainment, would come, however, at a disproportionately high cost. Not only would the power plant need to be retrofitted with a wet cooling tower system, but an appropriate desalinization facility would also need to be constructed. Such a facility would have high initial and operation and maintenance costs; there is limited land available to locate a desalinization facility; and concentrated brine wastes resulting from the production of freshwater would present disposal concerns.

The following analysis of alternative cooling systems for the DCPP focuses on the use of mechanical and natural draft cooling towers using seawater makeup. The use of wet cooling towers allows some recirculation of cooling water, thus cooling water makeup requirement is reduced, as compared to a once through system. Impingement and entrainment losses are reduced proportionately to the reduction in makeup water requirement.

Wet cooling towers rely on evaporation of water to dissipate heat; and as pure water is lost to evaporation, dissolved and suspended solids present in cooling water are left behind and increase in concentration. A wet cooling tower using seawater makeup will operate in the range of 1.1 to 1.5 cycles of concentration, meaning that solids will be allowed to build up to concentrations approximately 1.1 to 1.5 times greater than their levels in makeup water. This type of cooling tower operation, at 1.1 to 1.5 cycles of concentration, at the DCPP would result in a cooling water makeup requirement of approximately 100,000 to 340,000 gpm, total (both units). Thus, wet cooling towers using seawater makeup at the DCPP would reduce cooling water requirements by approximately 80 to 94 percent; and a corresponding reduction in impingement and entrainment losses could be expected.

This section presents cost estimates for both natural and mechanical draft, wet cooling tower systems. Much greater detail is provided for mechanical draft systems, as this type of cooling tower appears to be much more appropriate at the DCPP, given the potential seismic activity in the area, the limited land area available near the power plant, and the probable visual impacts of natural draft towers,

Costs considered for each alternative include capital, O&M, and energy penalty costs, as well as estimates of lost revenue that would occur during the downtime needed for retrofitting the power plant.

A. Wet Cooling System – Mechanical Draft Cooling Towers

Capital Costs

Estimates of capital costs for a mechanical draft cooling tower system at the DCPP are presented in Table 2. The design basis for these estimates includes the following.

- 2 unit, nuclear facility
- 7599.6 MM BTU/h thermal load condenser
- 61°F design wet bulb; exceeded less than 1 percent of the time
- 9°F approach to design wet bulb temperature for cooling tower sizing
- 1,725,380 gpm, total cooling water flow rate
- Cooling water supply temperature at 70°F; cooling water return temperature at 87.6°F
- Blowdown and makeup rates based on 1.5 cycles of concentration
- Seismic design per Zone 4 of the 1997 Uniform Building Code

Table 2 - Capital Costs, Mechanical Draft Cooling Towers

	Capital Cost ($MM)
Mechanical Draft Cooling Towers	140
Recirculating Water Pumps and Piping	32
Makeup Water Pumps and Piping	10
Startup water Holdup Tank, Pumps and Piping	3
Condenser Replacement Bundles	20
Cooling Tower Supply Piping/Risers	18
Civil Works	248
Electrical	17
Process Control and Instrumentation	39
Total Direct Costs	527
Project Indirects (30% of Direct Costs)	158
Contingency (20% of Direct and Indirect Costs)	137

Total Capital Costs	822

Mechanical draft, cooling tower costs are based on a cooling system with 132 cells, each using one 250 hp fan. The cooling system layout, considered by this analysis, is presented in Figure 2. Other potential locations at the site were considered less optimal due to topography and other physical constraints, including the location of an archeological site, north of Diablo Creek. Cooling towers would be concrete, with a counter flow design, utilizing materials suitable for saltwater application. Individual tower cells would use film fill, rather than splash fill, to take full advantage of available space (film fill provides a greater cooling surface area than splash fill) and would be 60 feet by 60 feet, with a (concrete) basin depth of 4 feet, and an overall tower height of 65 feet. Cells would be laid out in a back-to-back arrangement; and cooling water risers would be equipped with one isolating valve per riser.

Capital costs reflect a cooling water pumphouse constructed of concrete, suitable for saltwater application. There would be 4 recirculating cooling water pumps of the prefab, concrete volute design, total - 2 for each generating unit. The pumphouse would be equipped with a 75 ton overhead crane. These costs also include a 120 feet diameter by 40 feet high startup water holdup tank and two supply pumps. All cooling tower supply lines and risers, as well as pump discharge piping is included. Capital costs reflect costs of three, vertical, turbine type makeup water pumps (two running, one standby), which would be located in the existing pumphouse, after three existing, circulating pumps are removed to make room for the new pumps.

Estimates for electrical components include costs for a main substation, an additional transformer, switchgear, and cabling and services for the new pumphouse.

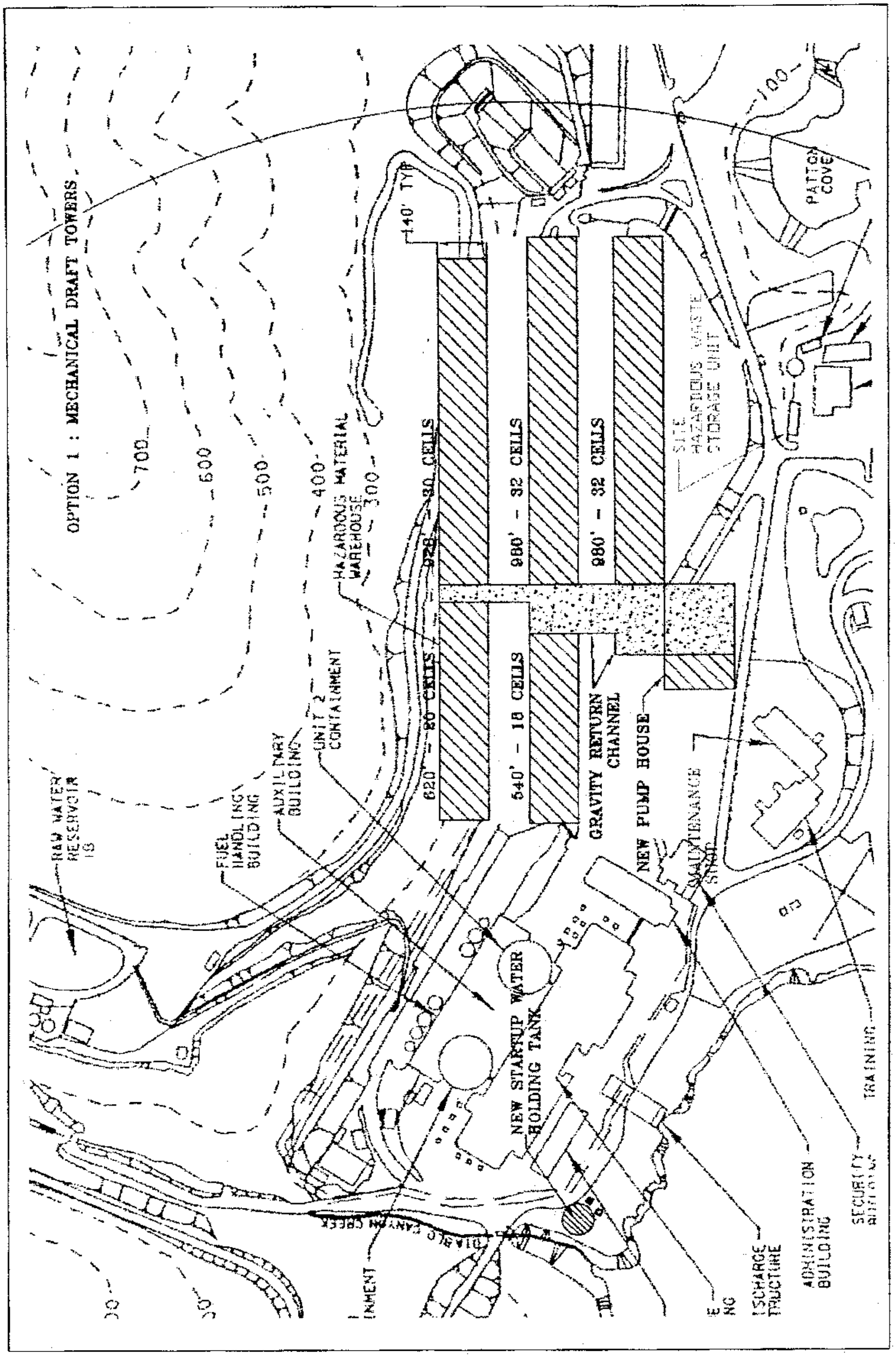


Figure 2: Mechanical Draft Cooling System Layout

Civil work contemplated in developing the capital cost estimates include:

- Clearing, grubbing, roadwork, and general landscaping and dewatering.
- Cooling tower concrete basins
- Cooling water supply and return conduits, including tie-ins to the existing condenser supply and return conduits.
- Demolition of the existing warehouse, southeast of the generating building and installation of a new warehouse, roadways and parking
- Demolition of the existing hazardous materials warehouse and construction of a new warehouse and associated roadways and parking
- Excavation, including rock work, on the hillside where the cooling tower system would be located, and installation of a retaining wall approximately 1,800 feet long by 100 feet high
- A new, cooling water pumphouse
- Concrete duct banks
- Miscellaneous structures, including a substation and a powerhouse building.

Costs for condenser replacement bundles include costs of tube sheets, tubes (3/4 inch diameter, 25 BWG B338/2 tubes with a total condensing surface of 617,536 square feet), support plates and structural stiffeners. No other material is included to support the bundles within the existing condenser shells. Costs for solid titanium, B265/2 tube sheets are included.

The condenser design for which these costs estimates were developed, were proposed by Alstom, formerly Ingersoll Rand, and were based on a 70°F cooling water supply temperature, which would yield a condensate temperature of approximately 100°F and a condenser backpressure of 1.89 inches HgA. Condenser performance could possibly be optimized to achieve a backpressure closer to the current design of 1.5 inches HgA; however, a very formal analysis of condenser and turbine performance would be required, and a backpressure of 1.5 inches HgA may still not be attainable. Based on condenser performance curves specific to the DCPP, as it currently operates, an increase in condenser backpressure to 1.89 inches HgA, would cause a loss in efficiency of 21 MW, over both generating units.

Capital cost figures in Table 2 include $158 MM for indirect costs, calculated as 30 percent of the direct costs. This very conservative indirect cost figure is meant to cover such items as design and engineering, construction management, owner's cost, vendor's assistance, startup and training. The total capital cost figure from Table 2 also includes $137 MM (20 percent of direct and indirect costs) for contingencies, or unanticipated, unexpected costs.

Some items not considered in this capital cost estimate include the impact of increased condensate temperature on the performance of hydrogen coolers and the possibility of hazardous waste removal or soil decontamination, if necessary, preceding construction activity.

As shown by Figure 1, the DCPP is located within the Coastal Zone; and any project, such as the cooling alternative considered here, would require approval by the California Coastal Commission. Tetra Tech, Inc. recognizes that such a land use approval process can be timely and expensive.

Operation and Maintenance (O&M) Costs

O&M costs for a wet cooling system at the DCPP utilizing mechanical draft cooling towers, as described above, are estimated to be approximately $1.7 MM per year. This figure is based on $750 per MW and a gross generating capacity of 2,298 MW, and is an approximation derived from information provided by Marley Cooling Technologies (a leading supplier of wet cooling towers) and from previous cost estimates developed by Tetra Tech, Inc. for the evaluation of alternative cooling systems at other power plants. These O&M costs are meant to take into account the costs of chemical treatment, routine operation and maintenance, and long-term equipment replacement, as appropriate.

Energy Penalty

Energy Penalty costs occur, because alternative methods of cooling, when compared to the existing once through system, will reduce plant efficiency. In a steam driven turbine, power is extracted from steam as it passes from high temperature and pressure conditions at the turbine inlet to low temperature and pressure conditions at the outlet. When steam exits the turbine, it is condensed to water by the steam condenser. The process of condensing steam to water assists to draw steam through the turbine and is very important to overall plant efficiency. The temperature of the steam condensing surface is dependent on the design and operation of the condensing system but is especially dependent on the temperature of the cooling water or air that removes heat from the condenser. And thus, the use of different cooling systems will affect the temperature maintained at the condensing surface and will affect plant efficiency. Any resultant loss in efficiency, when using alternative cooling systems in place of a very efficient once through cooling design, is referred to as the energy penalty associated with turbine efficiency.

As stated earlier, the mechanical draft cooling tower system for which cost estimates have been developed would result in a backpressure of 1.89 HgA, indicating some loss in efficiency, when compared to the plant's design backpressure of 1.5 HgA. Based on performance curves for the DCPP's operation, such a loss in efficiency would correspond to an energy penalty of 21 MW.

Use of alternative cooling systems will also result in a second energy penalty – that associated with increased in-plant power requirements needed to operate equipment such as fans and pumps required by the alternative cooling system. This energy penalty is also called the parasitic load.

Differences in the parasitic load seen in alternative cooling systems are due primarily to the different uses of fans and pumps. Once through and wet cooling tower systems have nearly offsetting energy requirements for cooling water pumps; however, a mechanical draft cooling tower system will have significant power requirement for the fans, which create the "mechanical draft." The mechanical draft cooling tower system presented in this report would use 132 fans at 250 horsepower each. Based on an energy requirement of 0.746 KW per horsepower, the total parasitic load at the DCPP would be approximately 25 MW, following implementation of such a cooling system. This figure is generally in line with EPA's calculations of penalties attributable to cooling system energy requirements, as presented in the *TDD for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities*, November 2001 (EPA-821-R-01-036). Table 3-20 in the TDD includes a factor of 0.92 percent as the parasitic load associated with a mechanical draft, wet cooling system when compared to a once through cooling system at nuclear facilities. With EPA's factor of 0.92 and a gross generating capacity of 2,298 MW at the DCPP, the parasitic load would be 21 MW. For these cost estimates, Tetra Tech, Inc. has used the more conservative parasitic load determination of 25 MW.

The total energy penalty associated with implementation of a mechanical draft, wet cooling tower system at the DCPP is estimated as the sum of the penalties attributed to decreased turbine efficiency and the parasitic load, or 46 MW.

In this evaluation of alternatives, the total energy penalty, in MW, is converted to a figure representing annual lost revenue (S) attributable to the energy penalty. The conversion uses a wholesale electricity price of $34/MWh – a figure forecast by the U.S. DOE in 1999 using POEMS (the Policy Office Electricity Modeling System) and then adjusted to 2001 dollars using the Electric Power Producer Price Index.

Based on operation 350 days per year, the annual revenue loss attributable to the energy penalty for this alternative, using a wholesale electricity price of $34/MWh, is estimated at $13 MM per year.

Lost Revenue Due to Shutdown During Retrofit

If a cooling alternative such as the one discussed here were implemented at the DCPP, the facility would experience a temporary and one time loss in generation (and revenue), when the plant was brought off line for construction and retrofitting activity. During and after the site visit on October 18, 2002, Tetra Tech, Inc. and Hatch reviewed detailed site diagrams for the existing cooling water system, related units, and other facilities which would be impacted by retrofitting. It is important to recognize that the cooling water piping (intake and discharge) is located in areas with significant other operational equipment, utilities, etc. Moreover, extra care is required when working in a nuclear facility. Therefore Tetra Tech, Inc. and Hatch estimated that the power plant would be off line for 6 months in these circumstances. For this period, Tetra Tech, Inc. further estimates that PG&E would lose revenue of approximately $330 MM. This figure was determined with a revenue estimate provided by PG&E for the DCPP of $900,000 per unit per day. It is in line with Tetra Tech, Inc.'s independent estimate based on a net plant output of 2,222 MW over 182 days and a wholesale price of electricity of $34 per MW. It is possible that construction and retrofitting activity could be staged to allow one unit to remain operational for much of the time that the other unit was being modified.

Total Costs

The net present value (NPV) of the mechanical draft, cooling tower alternative presented here, with a twenty year project life, that takes into account capital, O&M, plus energy penalty costs, as well as lost revenue that would be incurred during construction and retrofitting is $1.32 billion. Annual costs, assuming amortization of capital costs over twenty years and O&M costs inflated by 3 percent each year, would be $422.5 MM for the first year and would range from $92.6 to $94.2 MM for the following nineteen years. First year costs are higher because of the one time loss of revenue due to shutdown for retrofitting.

In the *Diablo Canyon Power Plant 316(b) Demonstration Report* (March 2000), TENERA Environmental Services acknowledged that natural and mechanical draft cooling towers, using saltwater makeup, have been demonstrated on a scale required for a closed loop system at the DCPP, and that such a system could reduce cooling water makeup requirement by 80 percent. That report provides a capital cost estimate of $658 MM for a hyperbolic, natural draft system but did not specifically evaluate a mechanical draft cooling system.

B. Wet Cooling System – Natural Draft Cooling Towers

Capital Costs

Estimates of capital costs for a natural draft cooling tower system at the DCPP are presented in Table 3. The design basis for these estimates includes the following.

- 2 unit, nuclear facility
- 7599.6 MM BTU/h thermal load condenser
- 61°F design wet bulb; exceeded less than 1 percent of the time
- 9°F approach to design wet bulb temperature for cooling tower sizing
- 68% relative humidity; 10% of the time relative humidity will be less than or equal to 68% when the wet bulb temperature is approximately 61°F
- 1,725,380 gpm, total cooling water flow rate
- Cooling water supply temperature at 70°F; cooling water return temperature at 87.6°F
- Blowdown and makeup rates based on 1.5 cycles of concentration
- Seismic design per Zone 4 of the 1997 Uniform Building Code

Table 3 - Capital Costs, Natural Draft Cooling Towers

	Capital Cost ($MM)
Natural Draft Cooling Towers	500
Recirculating Water Pumps and Piping	32
Makeup Water Pumps and Piping	10
Startup water Holdup Tank, Pumps and Piping	3
Condenser Replacement Bundles	20
Cooling Tower Supply Piping/Risers	9
Civil Works	396
Electrical	11
Process Control and Instrumentation	30
Total Direct Costs	1,011
Project Indirects (30% of Direct Costs)	304
Contingency (20% of Direct and Indirect Costs)	263
Total Capital Costs	1,578

The cooling system for which these capital costs estimates were developed would include five cooling towers per unit, each with a shell diameter of 208 feet and a shell height of 450 feet. These capital costs estimates were developed in a manner similar to those for a mechanical draft cooling system. The condenser retrofit for this system would result in a condenser backpressure of 1.89 inches HgA. O&M costs, energy penalty costs, and lost revenue incurred during construction and retrofitting activity would be similar to those figures developed for a mechanical draft cooling tower system.

Further analysis of a natural draft, wet cooling system for the DCPP is not presented in this report, as such an alternative does not appear to be viable. As highlighted by Tables 2 and 3, capital costs for a natural draft system will be approximately two times the estimated capital costs projected for a mechanical draft cooling tower system. Further, the performance of a natural draft, cooling tower is dependent on relative humidity. In the vicinity of the DCPP, the relative humidity falls below 68 percent about 10 percent of the time (when the wet bulb temperature is 61°F). When this occurs, tower performance will be reduced and plant efficiency will be further impacted. The visual impacts of 450 foot high towers would also be significant. Finally, Marley Cooling Technologies strongly recommended not using very large, hyperbolic, natural draft cooling towers in an area of potentially significant seismic activity, like the area of the DCPP.

As stated previously, TENERA Environmental Services in the *Diablo Canyon Power Plant 316(b) Demonstration Report* (March 2000), provided a capital cost estimate of $658 MM for a hyperbolic, natural draft system but did not specifically evaluate a mechanical draft cooling system.

VI. References

Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities, United States Environmental Protection Agency, EPA-821-R-01-036, November 2001.

Economic Analysis of the Final Regulations Addressing Cooling Water Intake Structures for New Facilities, United States Environmental Protection Agency, EPA-821-R-01-035, November 2001.

Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule, United States Environmental Protection Agency, EPA-821-R-02-003, April 2002.

Economic and Benefits Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule, United States Environmental Protection Agency, EPA-821-R-02-001, April 2002.

Diablo Canyon Power Plant 316(b) Demonstration Report, TENERA Environmental Services, March 2000.

Staff Report for Regular Meeting of July 13, 2000, Subject: Diablo Canyon Nuclear Power Plant Resolution of Thermal Discharge and Entrainment/Impingement Impacts, California Regional Water Quality Control Board.

Diablo Canyon Power Plant Cooling Water Intake Structure 316(b) Demonstration, TENERA Environmental Services, April 1988.

Diablo Canyon Power Plant 316(b) Study, Draft Evaluation of Alternative Intake Technologies, Engineering Services of the Pacific Gas and Electric Company, December 1999.

Diablo Canyon Power Plant, Revised 316(b) Study Plan, TERA Corporation, June 1983.

Diablo Canyon Power Plant Assessment of Alternatives to the Existing Cooling Water System, Tear Corporation, March 1982.

Attachment 1.

Table A-1 : Major Aquatic Species Vulnerable to I&E at Big Bend

Species	Scientific name		*ADULT*	*Juvenile*	*EGG*	*Spawning*
Atlantic blue crab	Callinectes sapidus	*Portunidae*	*Most abundant near bays and river mouths, but are found in brackish or fresh water.Found in shallower water in summer, deeper water in summer. Reach maturity at 130-139mm*	*Usually found at base of estuaries and seagrass beds.*	*Approx 0.025mm*	*Eggs carried externally by female. Hatch near high tide, larvae carried to sea by current.*
Black drum	*Pogonias cromis*	Sciaenidae	Schooling species. Adults found in offshore waters and enter estuarine habitats only to spawn. Mature at approx 650mm.	Larvae inhabit bottom waters during the day and rise to upper areas of the water column at night. 1.8 – 7.3mm	Buoyant, 0.8 - 1.0mm diameter.	Spawning in Tampa Bay takes place in the lower Bay or nearshore waters during the evening. Spawning peaks in April or March.
Florida stone crab	*Menippe mercenaria*	Xanthadae	Approx 140mm CW. Nocturnal. Found in coastal marine to estuarine environments. Require substrate suitable for refuge. May also dig burrows as deep as 1m.	Juveniles often found on oyster clumps. Larvae are free swimming and planktonic. Larvae pass through five zoeal stages.		Females carry egg masses.
Gulf menhaden	*Brevoortia patronus*	Clupeidae	Peak Gulf-ward migration occurs between October and January.	Larvae spend 3- 5 weeks in offshore waters before moving into estuaries at 9-25mm SL[2].	Eggs float near surface	Spawning occurs October through March, in Gulf of Mexico waters from 2 to 168 m deep but concentrated in waters of less than 18m deep.
Northern kingfish	*Menticirrhus saxatilis*	Sciaenidae	Prefers hard sandy bottom and forms large schools that occur in coastal waters, occasionally entering estuaries. Reach maximum length of 17 inches	Larvae are transported inshore to estuarine nursery areas by currents and winds.	Pelagic eggs	Spawning occurs in the spring and summer: April and May off North Carolina, and from June through August off the coast of Maine.
Pigfish	*Orthopristis chrysoptera*	Haemulidae	demersal; oceanodromous; brackish; marine ; depth range - 10 m. Inhabits coastal waters, over sand and mud bottoms. Forms schools. Mainly nocturnal and non-		buoyant (pelagic)	

Species	Scientific name		*ADULT*	*Juvenile*	*EGG*	*Spawning*
			burrowing.			
Pinfish	*Lagodon rhomboides*	Sparidae	Prefer deeper water (40 feet- 180 feet) in bays, passes, and on offshore reefs.	Prefers bays and estuaries around structure, vegetation, and reefs		Adults spawn offshore in schools in early spring, abandoning the eggs to the current. As young hatch, they swim into bays and estruaries where they grow and mature. Mature fish (over 8") head to deep water reefs.
Pink shrimp	*Penaeus duorarum duorarum*	Penaidae	Found in highest densities at depths of 11 to 35m, but abundant to 65 m. Can be found as deep as 310m. prefer firm or hard sandy or mixed substrate bottoms. Primarily nocturnal. Mature approx 65mm TL.	0.34 – 0.61mm. Found in seagrass substrates. Not nocturnal.	0.23-0.33mm.	Spawn in deeper offshore waters, at depths of 3.5 to 50m.
Puffer spp.	*Sphoeroides* spp.	Tetraodontidae	Most often in clear, shallow, tropical waters, over sand, sea grass, and around small appatch reefs; most abundant inshore.	Grass flats with bare sandy patches.	Maculatus spp.-demersal	Maculatus spp.-Occurs in shoal waters near shore.
Sand seatrout	*Cynoscion arenarius*	Sciaenidae	predominantly found inshore residing in bays and inlets but may move offshore during winter months;	Occur inshore in shallow bays. Sand seatrout have been reported to use estuarine areas and nearshore gulf waters as nursery grounds		prolonged inshore spawning season extends through spring and summer
Sheepshead	*Archosargus probatocephalus*	Sparidae	Bottom-loving, frequenting oyster beds and muddy shallow waters, particularly about inlets, also frequents piers, breakwaters, and wrecks; often runs far up rivers; does not typically school, but forms feeding aggregations. Occurs inshore from spring to fall in North Carolina; probably present throughout the year in the Tampa Bay area.	Larvae are pelagic, smallest (6mm) taken at surface near sandy shore; later stage taken in shallow areas over grass beds. Juveniles inhabit grass beds; eventually leave grass beds to establish themselves in adult habitat.	Buoyant; diameter about 0.8mm, transparent; incubation period is 40 hours at 24-25 degrees C.	Reported to spawn in Florida on sandy beaches, but more recent evidence indicates spawning probably occurs offshore during the spring.

Species	Scientific name		*ADULT*	*Juvenile*	*EGG*	*Spawning*
Silver perch	*Bairdiella chrysoura*	Sciaenidae	Mature at approx. 95mm. Found in shallow coastal areas outside Tampa Bay. During colder months, move to deeper bay or offshore waters.	1.5 -1.9mm. Remain planktonic for several weeks then sink to the bottom. Prefer structural habitats such as seagrass beds, rocks, piers, jetties, and seawalls. During colder months, move to deeper bay or offshore waters.	Buoyant, 0.59-0.82mm.	Spawn in deeper areas of bay and estuary, although eggs have been found in offshore waters.
Southern kingfish	*Menticirrhus americanus*	Sciaenidae	Found in abundance in the surf area along the beach. demersal; brackish; marine ; depth range - 40 m. 50.0 cm TL.	Juveniles occur usually in water of lower salinity in shallow water habitats. Juveniles are primarily bottom-dwelling over soft mud and decaying vegetation. Spend first summer in shallow water habitat. Open surf on sandy beaches; inshore in estuaries; apparently gradually move towards ocean as they mature.		Spawning occurs largely or entirely offshore in 9-36 m May-June in Tampa Bay area. Some indication of second fall spawning season; year-round in Everglades.
Spotted seatrout	*Cynoscion nebulosus*	Sciaenidae	Mature by 200mm TL. Found in nearshore vegetated seagrass areas	1.3mm. Found in deeper central areas of Tampa Bay	0.9mm	
Drum/croaker spp.	Family Sciaenidae	Sciaenidae	Inhabit deep offshore waters during the winter months and move into bays and estuaries during the spring, summer and fall	Juvenile croaker tend to prefer low salinity to freshwater habitats and open-water rather than submerged aquatic vegetation areas.		

Table A-2. Major Aquatic Species Vulnerable to I&E at Diablo Canyon

Species	*Scientific name*		*ADULT*	*JUVENILE*	*EGG*	*SPAWNING*
Brown rock crab	Cancer antennarius	Cancridae	Habitat extends from the low intertidal zone to depths greater than 100 m, and includes substrates of rocky shores, subtidal reefs, and coarse to silty sands	Larvae hatch as prezocae and molt to first stage zocae in less than 1 h. They advance through six stages of successive increases in size-fivezoeal and one megalopal. Juvenile brown rock crabs are common in the intertidal zone, where they may be exposed to the air daily for several hours. Mortality is unlikely, however, provided they are shaded from direct sunlight beneath algae, or protected in rock crevices. During their planktonic existence, crab larvae become widely distributed over the continental shelf. Early stage larvae of rock crabs generally occur on the bottom, or in depths up to 80 m, during the day; late stage larvae, however, were more abundant near the surface.	Shallows with emergent vegetation [littoral zone]	***The eggs are fertilized internally as they are extruded, about 11 weeks after the mating, and are carried by the female during development.***
Slender crab	Cancer gracilis	Cancridae				
Pacific sardine	Sardinops sagax	Clupeidae	pelagic	3.5 – 3.8mm; Inshore congregations, near beach	buoyant (pelagic), non-adhesive	
Northern anchovy	*Engraulis mordax*	Engraulidae	found in coastal waters within about 30 km from shore, but as far out as 480 km, forming large,	2.5 – 3.0 mm	buoyant (pelagic), non-adhesive. The oblong eggs float vertically at first,	Spawns either in inlets or offshore , throughout the year but mainly in winter

Species	*Scientific name*		*ADULT*	*JUVENILE*	*EGG*	*SPAWNING*
			tightly packed schools. Enters bays and inlets.		then horizontally	and early spring, depending on hydrological conditions (preferably at 10 to 23.3° C in upper water layers and around 22.00 hours).
Blue rockfish	*Sebastes mystinus*	Scorpaenidae	May be found near the surface or off the bottom, generally over shallow reefs, but also around kelp and over deep reefs. 61.0 cm TL max size	3.8 mm planktonic Juveniles are pelagic, Form schools		
Kelp/Gopher /Black-and-Yellow rockfish (KGB rockfish complex)	*Sebastes spp.*	Scorpaenidae				
Painted greenling	*Oxylebius pictus*	Zaniolepididae	Found in rocky areas, from the intertidal to 49 m. demersal; marine ; depth range - 49 m	planktonic		
Smoothhead sculpin	*Artedius lateralis*	Cottidae	demersal; marine ; depth range 0 - 13 m. Occurs in the intertidal (common) and to 13 m depth May remain out of water under rocks or seaweeds Breathes air when out of water	planktonic		
Snubnose sculpin	*Orthonopias triacis*	Cottidae	10.0 cm TL max size, demersal; marine. Occurs from intertidal rocky areas to about 30 m depth.			

Species	*Scientific name*		*ADULT*	*JUVENILE*	*EGG*	*SPAWNING*
Cabezon	*Scorpaenichthys marmoratus*	Cottidae	99.0 cm TL max. Inhabits rocky, sandy and muddy bottoms as well as kelp beds	planktonic		
White croaker	*Genyonemus lineatus*	Sciaenidae	41.0 cm TL, benthopelagic; marine ; depth range - 183 m. Found over sandy bottoms. Prefer shallow water near shore. Inhabits both inshore and offshore waters up to 100 meters in depth	Ca. 2.2-2.8 mm TL or less. Found in open water and shallows inshore of embayments, estuaries, and coastal waters. Juveniles found mostly near bottom. Early juveniles remain in the bay and estuary; most large juveniles gradually move to the ocean.	0.5-0.9 mm Most eggs are found over sand-gravel bottoms. Pelagic. Nonadhesive	
Monkeyface prickleback	*Cebidichthys violaceus*	Stichaeidae	76.0 cm TLmax, demersal; marine ; depth range - 0 m. Common inshore, in tidepools or shallow rocky areas, from the intertidal zone to 24 m depth. May remain out of water under rocks or seaweed. Breathes air when out of water. Crevices of rocky pools in bays or on outer coast	7.5-8.0 mm TL. Pelagic, found in San Francisco Bay near Angel Island, Potrero Power Plant, and in Horseshoe Cove. Juveniles prefer intertidal areas near bottom.	Ca. 2.7 mm Adhesive, adhering to rocks, Demersal.	spawning occurs from January to May
kelpfishes				Hatching size is ca. 7.0 mm TL or slightly less. Pelagic, shallow inshore water (Gibbonsia sp.)	Unfertilized mature eggs, ca. 1.3 mm; fertilized eggs 1.4-1.7 mm. Demersal. Assumed adhesive (Gibbonsia sp.)	demersal eggs deposited in the kelp beds and rocky areas (Gibbonsia sp.)

Species	*Scientific name*		*ADULT*	*JUVENILE*	*EGG*	*SPAWNING*
Blackeye goby	*Coryphopterus nicholsi*	Gobiidae	15.0 cm TL, demersal; marine ; depth range - 106 m, Found usually in sandy areas near rocks. Occurs from intertidal areas to 106 m depth. Prefers subtidal and intertidal coastal waters may occur in bays.	2.5-2.8 mm TL. The larger juveniles (ca. 21-28 mm TL and greater) gradually settle into their demersal habitat in rocky reefs.	Long axis 2.10 mm, short axis 0.84 mm Deposited on substrate in single layer. Deposited on substrate in single layer. Demersal.	spawn from January through August.
Sanddabs	*Citharichthys spp*	Paralichthyidae	41.0 cm TL, demersal; marine ; depth range 0 - 549 m, Found on sand bottoms	Young may occur at depth less than 9 m		
California halibut	*Paralichthys californicus*	Bothidae	Shallow coastal waters. Prefer a sandy bottom although they can be found on the hard bottom areas, muddy bottom areas, gravel bottoms, sand dollar and clam beds, and even around structure such as reefs, rock piles, kelp, and lobster traps.	2.0 mm TL Bays, harbors, and leeward sides of points and islands can produce warmer water temperatures and create a stable growth environment.	Average, 0.9 mm Pelagic, nonadhesive	California Halibut will move up into shallower water to spawn in Spring and Fall months.

April 4, 1994

Prepared for:

U.S. Environmental Protection Agency
Office of Wastewater Enforcement and Compliance
Permits Division
401 M Street S.W.
Washington, D.C. 20460

Prepared by:

3. INTAKE TECHNOLOGY REVIEW

A total of 25 intake technologies were identified in the literature as being appropriate to install at cooling water intake structures to minimize environmental impacts. Each technology was researched and reviewed to evaluate its application at cooling water intake structures and to assess its potential and efficacy to minimize adverse environmental impacts. The 25 intake technologies were classified as falling under one of three system categories. The technologies were identified as being: (1) an intake screen system, (2) a passive intake system, or (3) a fish diversion or avoidance system.

Table 3-1 presents technologies classified under each of the three categories. The general purpose of these technologies, in addition to the frequency of their use and performance, is summarized in the text below. Fact sheets supplying additional detail regarding each technology are provided in Appendix A. The fact sheets furnish information in the following areas: general technology description, testing facilities and/or facilities using the technology, research/operational findings, design considerations, advantages and limitations of using the technology, and supporting references. Additional references are also provided for some of the technologies. These additional references were not reviewed during this research effort because of time and budget constraints; however, these references should be considered for review at a later date so that the efficiency of the technologies is thoroughly evaluated.

3.1 Intake Screen Systems

The technologies classified as intake screen systems in Table 3-1 are mainly those devices that screen debris mechanically as compared to the passive intake systems where little or no mechanical activity is required. The intake screen systems category includes technologies currently in use at steam electric generating units. The system category also includes alternative screen technologies, which are not currently in use at U.S. steam electric facilities. Although the intake screen system technologies were not designed with fish protection in mind, they may provide a certain level of protection. They are, therefore, presented so that their use may be considered under subsequent Section 316(b) regulatory activities.

3.1.1 Summary of Findings: Intake Screen Systems

Single-Entry, Single-Exit Vertical Traveling Screens: These conventional traveling screens are the most widely used screening device for removal of debris. They are used by 60 percent of all the steam electric generating units in the United States (EEI, 1993). Their use is based on the collection and removal concept, high screenwell velocities, entrapment areas in the screenwell, and the handling of impinged fish as debris. These screens are most commonly associated with devices that cause entrainment and impingement impacts (Fritz, 1980). Some major United States steam electric power plants have experienced problems in debris handling when these screens have been used (Richards, 1988).

Modified Traveling Screens (Ristroph Screens): These are conventional traveling screens modified so that fish impinged on the screens can be removed with minimal stress and mortality. An essential feature of such screens is continuous operation during periods where fish are being

Table 3-1. Cooling Water Intake Technologies by System Category (with corresponding fact sheet number)

CATEGORY OF INTAKE CONTROL SYSTEM	FACT SHEET NO.	TYPE OF INTAKE CONTROL TECHNOLOGY
Intake Screen Systems	1	Single-Entry, Single-Exit Vertical Traveling Screens (Conventional)
	2	Modified Vertical Traveling Screens (Ristroph Screens)
	3	Inclined Single-Entry, Single-Exit Traveling Screens
	4	Single-Entry, Double-Exit Traveling Screens
	5	Double-Entry, Single-Exit Traveling Screens (Dual Flow)
	6	Horizontal Traveling Screens
	7	Fine Mesh Screens Mounted on Traveling Screens
	8	Horizontal Drum Screens
	9	Vertical Drum Screens
	10	Rotating Disk Screens
	11	Fixed Screens
Passive Intake Systems	12	Wedge-Wire Screens
	13	Perforated Pipes
	14	Radial Wells (Ranney Collectors)
	15	Porous Dikes
	16	Artificial Filter Beds
Fish Diversion or Avoidance Systems	17	Louver Barriers
	18	Velocity Cap
	19	Fish Barrier Nets
	20	Air Bubble Barriers
	21	Electrical Barriers
	22	Light Barriers
	23	Sound Barriers
	24	Cable and Chain Barriers
	25	Water Jet Curtains

impinged compared to conventional traveling screens, which operate on an intermittent basis. Most of the impingement performance studies conducted for these screens at a number of steam electric power plants indicate a high initial survival rate for impinged fish (EPRI, 1989, Fritz, 1980). However, limited information was obtained during this research effort regarding the long-term survival of impinged fish on these screens. Since modified screens have been shown to lower fish impingement and mortality over conventional screens, the modified screens have been installed at several facilities as best available intake technology (EPRI, 1989). Eight currently operating, once-through steam electric generating units use this technology at their cooling water intakes (EEI, 1993).

Single-Entry, Single-Exit Inclined Traveling Screens: This technology uses conventional traveling screens but places them at an angle to the incoming flow. The angle placement improves the overall effectiveness of the screen since fish tend to avoid the screen's face. A fish bypass facility with independently induced flow must be provided with this technology to direct fish away from the intake device. Limitations include higher costs than the conventional traveling screen and a need for stable water elevation at the intake structure (ASCE, 1982).

Single-Entry, Double-Exit Vertical Traveling Screens: In this screen (also known as the Passavant screen), water enters the center of the screen and passes from the inside to the outside of the screening surface. The screen surface is theoretically double the size of a conventional, vertical traveling screen. This type of screen, which was developed in Europe almost 30 years ago, is currently in operation at only a few major U.S. steam electric plants. The velocity of flow entering between the screen faces is usually high, which leads to increased impingement and entrainment (Richards, 1988). Such screens can contribute to higher impingement because the required screen well can act as an entrapment device. From a fish protection standpoint, this screen does not offer any advantage over the single-entry, single-exit vertical traveling screen.

Double-Entry, Single-Exit Vertical Traveling Screens (Dual Flow Screens): In the double-entry, single-exit (dual flow) vertical traveling screens, water enters from both the ascending and descending sides of the screens and discharges from the downstream end between the faces while the upstream end is blocked off. The unit is turned so that the approach flow is parallel to the faces of the screen. Several utilities have recently completed installation, or are planning to install, dual flow screens because of their debris handling capabilities (EPRI, 1989). The performance evaluation of dual flow screens available from several in-plant studies does not indicate any real increase in impingement survival over conventional vertical traveling screens, especially when incorporated at an intake designed with low approach velocity (EPRI, 1989). Data from the EEI Power Statistics Database indicate that nine once-through steam electric generating units currently use this technology.

Horizontal Traveling Screens: Horizontal traveling screens are continuously moving screens that span the intake area in water source being screened. The screens rotate horizontally in the waterway with the upstream face placed at an angle to the flaw. This placement guides fish in a manner similar to louvers and angled screen systems. Horizontal traveling screens form a complete physical barrier and have a high fish diversion efficiency in that they also release impinged fish into a bypass without passing the air-water interface. However, the requirement of continuous operation, at much higher speeds than the conventional vertical traveling screens, has created mechanical problems that have not yet been resolved (ASCE, 1982). Because of this operational limitation, the screens are not currently manufactured. Application of this type of screen to a large industrial intake would require extensive and costly research (EPA, 1976).

Fine Mesh Screens Mounted on Traveling Screens: Fine mesh screens mounted on traveling screens are used to exclude eggs, larvae, and juvenile forms of fish from intakes. These screens rely on gentle impingement of organisms on the screen surface or retention of larvae within the screens. The success of an installation using fine mesh screens is contingent on the application of satisfactory handling and recovery facilities to allow the safe return of impinged organisms to the aquatic environment (Pagano et al., 1977; Sharma, 1978). In situ studies on the use of fine mesh on conventional traveling screens and modified traveling screens have indicated that these mesh screens reduce entrainment. However, these screens have not been demonstrated to be effective for reducing mortality or entrainment losses (EPRI, 1989).

Horizontal Drum Screens: Horizontal drum screens, which are widely used outside the United States, are screens placed on large revolving wheels. The screens are placed with their longitudinal axes horizontal across the intake channel. They are considered more efficient in debris removal and more reliable than conventional traveling screens. The main advantages of drum screens are their simplicity, fewer moving parts than in conventional traveling screens, their ease of maintenance, and the elimination of any possibility of debris carryover. The main disadvantage of horizontal drum screens is their capital cost. The screens themselves are usually less costly than the conventional traveling screens, but the cost of the screen structures is much larger. The total differential costs are $821,000 (1982 dollars) in favor of the conventional traveling screens (Richards, 1988). Drum screens are not currently used at U.S. steam electric plants. There is little evidence to indicate that these screens offer any fish protection advantage over the conventional traveling screens (ASCE, 1982).

Vertical Drum Screens: The vertical revolving drum screen technology consists of a screen placed on a vertical revolving drum, which is located across an intake opening in front of the pumps. This arrangement operates well under conditions of fluctuating water levels. Vertical drum screens are not used at U.S. power plants. They have been used for fish diversion in irrigation canals and in British steam electric stations for protection of salmonids with variable success (Eicher, 1974). Since larger types have not been developed, their reliability is unknown (ASCE, 1982).

Rotating Disk Screen: The face of the rotating disk is covered by mesh at right angles to the water channel. The disk rotates around a horizontal axis, bringing the dirty screen face above water where high pressure sprays wash the debris into a trough. This screen is only suitable for relatively small flows and small water level variations. The rotating disk screen is not currently used at U.S. steam electric plants. This device has a minimum number of moving parts and, thus, is inexpensive to buy and maintain. However, the high probability of fish impingement, the need of high pressure sprays to remove fish and debris, and the need of very large screen structures to limit screen approach velocities make it unattractive for use at cooling water intakes. Such a screen has no advantage over other common screens from a fish protection point of view (EPA, 1976; ASCE, 1982).

Fixed Screens: The most common type of fixed screen is the vertically installed device placed in front of the intake pumps. The screens, generally mounted in a frame, are installed in vertical tracks on the intake channel walls and are usually lifted out of the water for cleaning. Their use is limited to intake locations where suspended debris is negligible. Most of the fixed screens are installed at small steam electric plants. The major limitations of these screens are that operators must be available at all times to maintain the screens. Long impingement times between cleaning periods may result in total mortality of fish. Data from the EEI Power Statistics Database indicate that 13 once-through steam electric units and 31 closed-cycle steam electric units currently in operation in the United States use this technology.

3.1.2 Conclusions: Intake Screen Systems

The main finding with regard to intake screen systems is that they are limited in their abilities to minimize adverse aquatic impact. In fact, conventional traveling screens (the most widely used screening device at U.S. steam electric plants) and most of the other types of traveling screens have been installed mainly for their debris handling capabilities. In addition, the conventional traveling screens have not even been proved to be reliable for the removal of debris at U.S. steam electric plant intakes. In fact, many major U.S. steam electric plants experience problems as pointed out by Richards (1988): "... *and many of our major power plants have been in serious trouble because of cooling water conditions which our U.S. screening system cannot cope. This is becoming more apparent today when special efforts are being made to improve plant performance, rather than build new plants.*" In other words, the need of any alternative technology to replace the conventional vertical traveling screen will be dictated by economic reasons and not by a necessity for aquatic life protection. The Electric Power Research Institute (EPRI) recently stated that very little work is being conducted or sponsored by utilities to mitigate entrainment and/or impingement at cooling water intake structures. This reflects the condition that most generating stations are in compliance with biological conditions contained in their operating permits (EPRI, 1989).

The steam electric industry has examined mitigation measures to minimize the environmental impact at cooling water structures and has mainly concentrated on the modification of conventional through-flow traveling screens so that fish that are impinged on the screens can be removed with minimal stress and mortality. These modified traveling screens have been shown to be effective at lowering fish impingement and mortality over conventional screens at several locations and have been installed as the best available technology at several locations. There has also been an interest in the use of fine mesh mounted on traveling screens for the minimization of entrainment. However, the use of fine mesh mounted on conventional traveling screens has not been demonstrated as an effective technology for reducing mortality or entrainment losses (EPRI, 1989).

Finally, even though site-specific studies have reported impact mitigation using alternative screen technologies, a review of these technologies, in general, indicates that, from an aquatic protection standpoint, the technologies are not any more efficient than the conventional, through-flow traveling screens. In addition, the amount of reduction attributable to any of these devices has been found to be site- and species-specific (Richards, 1988; EPRI, 1989; Uziel, 1980).

3.2 Passive Intake Systems (Physical Exclusion Devices)

Passive intake systems are those devices that screen-out debris and biota with little or no mechanical activity required. Most of these systems are based on achieving very low withdrawal velocities at the screening media so that organisms will avoid the intake. Highlights of the important elements for each passive intake device are summarized below.

3.2.1 Summary of Findings: Passive Intake Systems

Wedge-Wire Screens: Wedge-wire screens are mainly designed to reduce entrainment of fish eggs and larvae by physical exclusion and by exploiting hydrodynamics. Physical exclusion occurs when the mesh size of the screen is smaller than the organisms susceptible to entrainment. Hydrodynamic exclusion results from maintenance of a low, through-slot velocity which, because of the screen's cylindrical configuration, is quickly dissipated, thereby allowing organisms to escape the flow field. In situ and laboratory studies have shown that impingement is virtually eliminated and that entrainment is considerably reduced when wedge-wire screens are used (Hanson, 1978; Weisberg et al., 1984; Heuer and Tomljanovitch, 1978; Lifton, 1979; Delmarva Power and Light, 1982; and Weisberg et al., 1983). This device also offers some advantage in debris removal (Richards, 1988). However, it is presently limited to relatively small flow withdrawals such as make-up water for closed-cycle cooling systems. Data from the EEI Power Statistics Database indicate that a total of five closed-cycle steam electric generating units use wedge-wire screens at their intake structure (EEI, 1993).

Perforated Pipes: Perforated pipes draw water through slots in a cylindrical section placed in the waterway. The term "perforated" is applied to round perforations and elongated slots. Clogging, frazil ice formation, biofouling and removal of debris limits this technology to small flow withdrawals. These devices have been used at locations requiring small amounts of water such as make-up water. However, experience at steam electric plants is very limited (Sharma, 1978).

Radial Wells: Radial wells are developed in the same manner as conventional wells. This intake consists of a vertical pump caisson, which is sunk below the water table near the surface water body (e.g., river). Several perforated collector screen pipes (radial wells) are then jacked out through wall ports into the surrounding porous aquifer. Radial well intakes, long represented by the Ranney Collector, have a long history of successful performance and offer maximum protection to aquatic organisms of all sizes. (EPA, 1976; ASCE, 1982). One main limitation is that radial wells are only suitable where there is a porous aquifer. This consideration, and the associated costs of pumps and a large piping network, currently limit the radial wells for once-through application (Mussalli et al. 1980). Data from the EEI Power Statistics Database indicate that two closed-cycle steam electric generating units in the United States currently use radial wells (EEI, 1993).

Porous Dikes: Porous dikes are filters resembling a breakwater surrounding a cooling water intake. The core of the dike consists of cobble or gravel, which permits free passage of water. The dike acts both as a physical and behavioral barrier to aquatic organisms. Tests conducted to date have indicated that the technology is effective in excluding juvenile and adult fish. The major problems associated with porous dikes come from clogging by debris and silt, ice build-up and frazil ice, and fouling by colonization of fish and plant life. The porous dike technology is still being developed, and its use is actually limited to small flow intakes. Data from the EEI Power Statistics Database indicate that two once-through steam electric generating units in the United States currently use this technology (EEI, 1993).

Artificial Filter Beds: Artificial filter beds utilize a prepared granular filter material to prevent entrance of debris and aquatic life into a water withdrawal facility. Artificial filter beds can only be sited on water bodies that have low concentrations of suspended particles and where potential for clogging and biofouling is low. Although this technology or concept has high screening potential, operational difficulties and limited intake capacity characteristics have discouraged any further research and development for use at steam electric power plant intakes (Richards, 1978; ASCE, 1982).

Nearshore Marine Filter Beds: A modified sea water intake filtration system has been patented by Elarbash Systems of Libya and M&S Systems International of Malta. This system has been used, thus far, to provide uncontaminated water to large-scale desalinization facilities in the Middle East. General performance data provided by the manufacturer indicate that the system does not entrain or impinge aquatic organisms. The system uses physically and chemically stable non-biodegradable materials for its filtering system. The system is buried 5 to 10 meters from the shoreline and is covered with 10 to 90 centimeters of site sand. The system reportedly uses wave motion to prevent clogging and does not require backwash or routine maintenance. The system is constructed in modular form and can be constructed to meet widely varying flow demands (Elarbash, 1991b). Many details regarding construction and performance were unavailable because of proprietary constraints. Because of the limited information available, a fact sheet was not developed for this technology.

3.2.2 Conclusions: Passive Intake Systems

The main findings for passive intake systems are that available technologies that effectively reduce fish eggs and larvae entrainment are extremely limited. In fact, from all of the passive intake system technologies reviewed, only the radial wells (Ranney Collectors) offer an effective protection to aquatic organisms of all sizes and provide a degree of screening that far exceeds the requirements for cooling water supplies. However, their major limitation is that the radial wells are only suitable where there is a porous aquifer. The other limitation is that for larger cooling water intakes, the cost of radial wells is considerably greater than that required for a conventional intake.

The other alternative that appears to offer a potentially effective means of reducing fish losses is the wedge-wire screen. Testing of wedge-wire screens has demonstrated that fish impingement is virtually eliminated and that entrainment of fish eggs and larvae is reduced. However, limitations due the physical size of the screening device restrict the application of wedge-wire screens to closed-cycle make-up or other small flows.

Testing of porous dikes has revealed that this technology is effective in excluding juvenile and adult fish. The major problems associated with porous dikes are clogging by debris and silt, ice build-up and frazil ice, and fouling by colonization of fish and plant life. The technology of the porus dikes is still being developed, and its use is actually limited to small flow intakes.

<u>Light Barriers</u>: Light barriers consist of controlled application of strobe lights or mercury vapor lights to lure fish away from cooling water intakes or to deflect their natural migration patterns. This technology is based on research that has shown that some fish avoid light. However, because it is known that some species are attracted by light, it is generally accepted that the effectiveness of light barriers is species-dependent. Although this is an inexpensive technology to install, the species distribution and fish response at a particular location must be evaluated in a pilot demonstration to select the optimum design. Apparently, no light barriers are currently in use as fish deterrents at cooling water intakes. Several facilities have tested the technology and, although the results are inconsistent, the general consensus is that light barriers are ineffective in deterring fish from entering cooling water intakes.

<u>Sound Barriers</u>: Sound barriers are non-contact barriers that rely on mechanical or electronic equipment to generate various sound patterns to deter fish from entering industrial water intakes and power plant turbines. Although sound barriers as fish deterrents have been extensively researched, this technology is not currently in use at existing U.S. cooling water intakes. Several types of sound barriers have been developed and tested, including the pneumatic air gun or "popper", which is a modified seismic device that produces high amplitude, low frequency sounds to exclude fish. Closely related devices include "fishdrones" and "fishpulsers" (also called "hammers"). The fishdrone produces a wider range of sound frequencies and amplitudes than the popper. The fishpulser produces a repetitive sharp hammering sound of low frequency and high amplitude. In general, however, studies have shown that these instruments have limited effectiveness in the field.

A recent development, the "Fishstartle System," is an acoustical fish barrier developed by Sonalysts, Inc. This device depends on sophisticated sound patterns generated on a site-specific basis for target fish species. Several research projects indicate that the Fishstartle System may be a viable technology to reduce entrainment and impingement of fish at cooling water intakes.

<u>Cable and Chain Barriers</u>: This technology consists of barriers of cables or chains that are suspended vertically across the front of a cooling water intake. These systems are designed to take advantage of fish behavior, that is, of fish tendency to avoid objects moving through water (Ray et al., 1976). Conclusions of most of the testing conducted to date indicate that cable and chain barriers show little promise as a technology for diverting fish at cooling water intakes. No facilities in the EEI Power Statistics Database reported using cable and chain barriers.

<u>Water Jet Curtains</u>: Water jet curtains typically consist of a row of vertical pipes, fitted with evenly spaced jet nozzles, that are then placed in front of a cooling water intake. The jets produce a curtain of high pressure water, which is intended to deter fish from entering the intake area. Water jet curtains have not been used in many actual applications to date. Testing has not revealed the efficiency of the technology to be appropriate for use alone to divert fish from cooling water intakes. However, the technology may be used in conjunction with other technologies to provide an efficient fish diversion system. No facilities in the EEI Power Statistics Database reported using water jet curtains.

Louvered 360° Radial Intake: A modified intake structure has been developed by Elarbash Systems of Libya and M&S Systems International of Malta; this systems is reportedly "virtually invisible to suspended matter, fish and seafloor sand." This system utilizes a 360 degree radial intake structure that provides equipotential intake velocity increases as water approaches the structure. The intake structure also incorporates a louver system within the intake head to guide fish to a return flow conduit (Elarbash, 1991a). Because of the proprietary nature of the system, detailed construction and performance data were not available; thus a fact sheet was not developed.

3.3.2 Conclusions: Fish Diversion and/or Avoidance Systems

The main finding relative to fish diversion and/or avoidance systems is that none of the corresponding technologies protect organisms and/or fish that are non-motile or in early life stages. In addition, because fish diversion and avoidance devices rely on the behavioral characteristics of fish, the effectiveness and performance of the devices is species-specific. Therefore, site-specific testing is required in most cases where these devices are to be used. As a result, modification of the technology to be used may be required.

Many of the fish diversion and avoidance devices are appropriate for seasonal entrainment problems in that they provide flexibility to be used during certain times of the year. For example, barrier nets may be put in place during certain times of the year when fish are migrating past the intake structure.

Louvers and velocity caps have been proved effective in diverting fish away from intakes at numerous facilities. Velocity caps are used almost exclusively for offshore intake facilities. Louvers are often used in conjunction with other intake technologies such as screens and fish handling devices. Water jet curtains and cable and chain barriers have not been as successful as the other technologies.

Barrier nets and electrical barriers are effective with certain applications. Electrical barriers are effective for upstream migrating fish. If such fish are stunned by the electric shock, they are carried away from the intake. Electrical barriers, however, are not appropriate for downstream migrating fish. If such fish are stunned, they are carried with the flow into the intake. Barrier nets are effective if the fish to be diverted are of similar size.

Air bubble barriers, light barriers, and conventional sound barrier technologies have limitations as effective fish diversion and avoidance devices. Field applications of air bubble barriers have generally been unsuccessful and inconsistent. Light barriers have proved to be ineffective in some cases because these devices actually attract certain species of fish; some sound barrier technologies have demonstrated limited success in the field because some species acclimate to the sound patterns.

Submitted To:
Pacific Gas and Electric Company

Final Report

Comments on Revised Tetra Tech Evaluation

Prepared By:
Peter Hindley

Submitted By:
Nexant

MAY 2003

Comments on Revised Tetra Tech Evaluation

1 Conclusions

The Tetra Tech Evaluation leaves significant unresolved issues for both the Fine Mesh Screens and Mechanical Draft Wet Cooling Towers alternatives:

Issues Affecting Both Alternatives

- Neither technology has been demonstrated as a retrofit on a plant similar to DCPP in size and site conditions.
- The Tetra Tech Evaluation does not demonstrate the feasibility of either alternative.
- Both projects would involve major construction efforts that would require multiple levels of additional environmental review and approval by a number of federal, state, and local agencies. This process would take years to complete, the necessary approvals might not be given, and years of litigation could follow any decisions that are reached as a result of the CEQA process.
- The costs to PG&E's customers of both alternatives are uncertain but clearly are very high. For each alternative we present cost estimates for two cases: the Tetra Tech Evaluation costs, and costs using revised data that we believe is more realistic.
  - For the Fine Mesh Screens alternative, the Tetra Tech Evaluation estimated the discounted total cost to be $650 million, equivalent to (our estimates based on Tetra Tech Evaluation data) $730 million undiscounted and level annual costs of $66 million. We believe that the actual costs will be higher. The discounted total cost is likely to be more in the range of $770 million ($848 million undiscounted), equivalent to level annual costs of $100 million.
  - For the Mechanical Draft Wet Cooling Towers alternative, the Tetra Tech Evaluation estimated the discounted total cost to be $1,320 million, equivalent to (our estimates based on Tetra Tech Evaluation data) $2,188 million undiscounted and level annual costs of $125 million. We believe that the actual costs will be higher. The discounted total cost is likely to be more in the range of $1,819 million ($2,483 million undiscounted), equivalent to level annual costs of $269 million.

Fine Mesh Screens Only

- It is highly uncertain whether fine mesh traveling screens would produce a net biological benefit at DCPP. First, it is unclear what level of entrainment reduction could be achieved through installation of fine mesh screens. Further, organisms not entrained will be impinged, and each step in the process of trapping organisms on the screens, lifting them out of the water for a limited period of time, washing them from the screens into a sluiceway, and returning them to the ocean beyond the intake cove could cause substantial mortality.
- Fine mesh screens have not been used before in an exposed coastal location such as exists as DCPP.

- There are significant operation and maintenance issues with fine mesh screens because of the potential for fouling, invertebrate colonization, increased resistance to flow, screen wear and tear and damage due to storm surge, and the marine environment generally.

Mechanical Draft Wet Cooling Towers Only

- The Tetra Tech Evaluation states that this alternative will reduce entrainment by 80 – 94%. However, there will be many other negative environmental impacts that partly or entirely offset this improvement, including:
  - The construction impacts of a massive project.
  - The high salinity blowdown water discharge.
  - Land use issues with such a large project.
  - Air quality and terrestrial impact issues due to salt drift.
  - Ground fog at times, a water vapor plume rising thousands of feet in the air and visible for miles at other times.
  - Noise due to cooling tower fans and falling water.
  - Visual impacts of the towers themselves and the plume.
- The magnitude of a cooling tower retrofit at DCPP would be of an unprecedented scale and complexity.
- It is highly uncertain whether available land is adequate to build the cooling towers and related systems at the DCPP site.

2 Introduction

The Central Coast Regional Water Quality Control Board (Board) requested Tetra Tech Inc. to provide cost estimates for cooling system alternatives that potentially could reduce some of the environmental impacts associated with the once through cooling system at PG&E's Diablo Canyon Power Plant (DCPP). On September 24, 2002 PG&E provided comments on a preliminary draft report. Tetra Tech delivered a Revised Draft "Evaluation of Cooling System Alternatives, Diablo Canyon Power Plant" (the Tetra Tech Evaluation) in November 2002 that incorporated some of PG&E's comments. The Tetra Tech Evaluation's analysis concluded that two alternatives to the current once through cooling system warranted further consideration:

- Fine Mesh Traveling Screens with Fish Handling and Return Systems, which we refer to as the Fine Mesh Screens alternative.
- Wet Cooling System – Mechanical Draft Cooling Towers, which we refer to as the Mechanical Draft Wet Cooling Towers alternative.

The Board's staff requested PG&E to provide the Board with additional comments on the Tetra Tech Evaluation or other information that might assist the Board in evaluating the cooling system alternatives. PG&E contracted with Nexant to prepare comments on the revised Tetra

Tech Evaluation. This report (Comments on Revised Tetra Tech Evaluation), prepared by Nexant, responds to the Board's request.

The focus of this report is on the feasibility, costs, and biological impacts of the two Tetra Tech Evaluation alternatives, especially as compared to the existing system. The general approach to the work was to review the Tetra Tech Evaluation and supporting documents, review other related information, and develop comments on the key issues.

For an alternative to the existing cooling water system to be feasible, it must be able to perform its intended functions adequately. Thus it must meet the following requirements:

- It must meet the necessary cooling requirements for DCPP.
- It must be a commercially available, demonstrated technology.
- It must deliver net environmental benefits.
- It must be able to be built on the existing site.
  - Obtain the necessary permits.
  - Be completed in a timely manner.
- If it delivers net environmental benefits, its costs must not be wholly disproportionate to the benefits.

The inability to do any one of these items would render an alternative infeasible. As important questions or uncertainties arise in several areas at once, their collective impact also could cause infeasibility.

Fine mesh traveling screens and mechanical draft wet cooling towers using salt water have been used elsewhere. However, they have not been demonstrated as retrofits on plants as large as DCPP in an exposed coastal location. Thus the question of their technical feasibility is primarily one of the uncertainties in their performance and impact on the existing plant.

As noted above and discussed later in this report, the ability of the Fine Mesh Screens alternative to deliver net environmental benefits is uncertain. The Mechanical Draft Wet Cooling Towers alternative will reduce entrainment by 80 – 94%. However, there will be many other negative environmental impacts that partly or entirely offset this improvement.

Implementing either alternative will require time for permitting and design, and procurement and construction. Furthermore, for an alternative to be feasible the necessary permits must be obtained – otherwise it cannot be built. There is considerable uncertainty as to whether the necessary permits for either project could be obtained given the massive construction effort that would be required, the numerous federal, state, and local permitting agencies that would be involved, and the likelihood of protracted judicial reviews of any permitting decisions that are made.

An alternative also cannot be built if the plant site cannot accommodate it. It is highly uncertain whether available land is adequate to build the cooling towers and related systems at the DCPP site.

Additionally, the overall costs of either alternative will be at least hundreds of millions of dollars. The costs are estimates based on conceptual designs and are uncertain. The amounts are so high that the level of costs is perhaps the key issue. This report does not attempt to compare the costs to a quantification of the benefits in dollar terms, but we do comment on the cost estimates presented. For a detailed economic analysis of the potential environmental benefits of cooling towers, please see ASA Analysis and Communication, "Estimation of Potential Economic Benefits of Cooling Tower Installation at the Diablo Canyon Power Plant", April 2003 (final draft).

The balance of this report is organized as follows:

- Section 3 provides background on DCPP and its current cooling water system.
- Section 4 summarizes the Tetra Tech Evaluation, concentrating on the areas where this report provides comments.
- Sections 5 and 6 discuss the Fine Mesh Screens alternative and the Mechanical Draft Wet Cooling Towers alternative. The emphasis is on describing the Tetra Tech Evaluation's assumptions or results and providing comments on them.
- Appendix A provides a report written by TENERA, one of PG&E's consultants, on Potential Use of Fine Mesh Screens for the Cooling Water Intake Structure at Diablo Canyon Power Pant.
- Appendix B provides a report written by ASA Consulting, one of PG&E's consultants, that provides Notes on Fine Mesh Screens.
- Appendix C provides supporting information for the cost and financial results.
- Appendix D provides a list of references.

3 Background – Current Diablo Canyon Cooling Water System

3.1 *Reference System*

The existing DCPP cooling water system is the reference for the remaining discussion in this report. The two alternative systems are compared to its performance, environmental impacts, costs, and other relevant factors.

Performance

Table 1 summarizes information on the DCPP in general and the cooling water system in particular.

The alternative systems reduce net output and annual energy production in three ways: reduced efficiency due to warmer cooling water delivered to the units' condensers, increased auxiliary power demands for uses such as pumps and fans, and lengthy shutdowns during construction. These reductions impose costs on PG&E and its customers because the lost output must be obtained and paid for from elsewhere. Therefore, costs based on the differences in output and annual energy production will apply.

Environmental Impact

The existing intake structure and traveling screens were designed with an objective of creating as little impingement as possible. Virtually no impingement occurs. However, all organisms that cannot move away from the traveling screens pass through them and are entrained.

Costs

The existing system's capital costs are sunk costs. The capital costs of each alternative system would be in addition to these sunk costs. The O&M costs of each alternative system replace those of the existing system, and the increment above the existing system's O&M costs is used in the calculations.

Table 1 – Diablo Canyon Power Plant Data

	Unit 1	**Unit 2**
Unit net rated capacity, MWE	1,103	1,119
Lifetime to date average capacity factor, %	83%	85%
Refueling outage (typical), days	30	30
Mode of operation	Base load	Base load
Year Nuclear Regulatory Commission license expires	2021	2025
Number of circulating water pumps	2	2
Number of traveling screens	6	6
Main cooling water flow (typical), GPM	835,000	835,000
Condenser temperature rise (typical), degrees Fahrenheit	20	20
Auxiliary cooling water flow, GPM (1% of main flow)	8,350	8,350

3.2 *Description of Current Diablo Canyon Cooling Water System*

The once through cooling system at DCPP cools the two units' main condensers and other plant components. Each unit has a separate system, relying to some extent on common components at the intake and discharge ends. Water enters the intake structure serving both units by passing beneath a concrete curtain that extends 7.75 feet below mean sea level (MSL), intended to keep out floating debris. Water then flows through inclined bar racks with three-inch openings designed to exclude large debris. It then flows into pump bays and through traveling screens that filter the ocean water before it passes through the main circulating water pumps.

The pumps increase the water's pressure and velocity so that it can flow through two 11.75-foot square conduits to the top of the coastal bluff where the main plant buildings are located. The water flows into condenser inlet water boxes at elevations 85 to 105 feet and through one-inch titanium tubes in the condensers in the turbine building, where the condenser heats it typically about 20^0 Fahrenheit (F). From the discharge of the condenser water boxes at about elevation 60 feet the water flows through discharge conduit to the discharge structure that serves both units, where it cascades in stair-step fashion through a series of concrete boxes to Diablo Cove. Total transit time from the intake structure to the discharge structure is approximately five minutes.

Each existing traveling screen consists of 57 two foot by ten foot panels of 3/8-inch stainless steel mesh. They extend vertically from 30 feet below mean sea level to 25 feet above. The panels are linked to form a continuous screen that rotates around sprocket wheel assemblies at the top and bottom that power and support the screen. They normally rotate intermittently at ten or twenty feet per minute, lifting any impinged debris to a water wash area. During high-debris loading storm conditions they operate continuously. Relatively high-pressure jets using ocean water wash debris from the screens. The debris and wash water flow into refuse troughs and through debris grinders into a refuse sump, from which they are pumped through discharge piping to a discharge point north of the base of the west breakwater.

Water velocities entering the intake structure up to the traveling screens vary from 0.8 feet per second (fps) to 1.1 fps as the cross sectional area of the intake structure changes. As the water approaches the screens the velocity is 1.0 fps. However, the wires forming the mesh in the screens effectively reduce the cross sectional area available for water flow, increasing the through-screen velocity to 1.95 fps. In the Tetra Tech Evaluation's terminology, this amounts to a "screen efficiency" of 1.0 / 1.95, or about 50%.

Organisms that pass through the bar racks can be impinged (trapped) on the traveling screens or be entrained in the water that passes through those screens. However, studies have indicated that nearly all of the organisms that are so large they cannot pass through the 3/8-inch mesh on the existing traveling screens are able to move away from it and are not impinged on it.

Any organisms that pass through the traveling screens are entrained and flow with it through the circulating water pumps and the rest of the system.

4 Tetra Tech Evaluation

The Tetra Tech Evaluation summarizes the results of the work done at the Board's request.

The Tetra Tech Evaluation includes a description of DCPP and its existing cooling water system, summaries focusing on cost estimates of the Fine Mesh Screens and Mechanical Draft Wet Cooling Towers alternatives, and a list of references. It does not include a comprehensive evaluation of the impact of the alternatives in reducing entrainment, but does provide some information relating to that subject.

The Tetra Tech Evaluation provides information on two alternatives, but does not demonstrate the feasibility of either alternative, because its objective was to provide cost estimates, not to evaluate feasibility. The Tetra Tech Evaluation acknowledges this through statements such as characterizing its cost estimates as "... approximate cost estimates for conceptual cooling system alternatives for the DCPP, to enable the Board to consider feasibility and determine if additional analysis of alternatives is warranted."

The Tetra Tech Evaluation notes that modifications to the existing cooling water intake system must focus on reducing entrainment, as impingement effects are insignificant based on studies performed by PG&E in 1985 and 1986. The organisms that pass through the existing traveling screens are entrained in the cooling water system. The Tetra Tech Evaluation does not specify the survival rate of these organisms, but does note that there is potentially a high loss of larvae of near shore species attributable to the once through cooling system at the DCPP.

The Fine Mesh Screens alternative reduces entrainment by capturing on a modified traveling screen many of the organisms that otherwise would pass through the cooling water system, then washing them off and returning them to the ocean.

The Tetra Tech Evaluation devotes most of its discussion of this alternative to experience with fine mesh screens at other power plants, a listing of "representative important species" at DCPP and Big Bend Station, biological issues associated with fine mesh screens, and costs. It contains very little discussion of the design of the system. For example, it does not directly state what mesh size is used. Most of the systems at other plants it refers to use 0.5 millimeter (mm) mesh, so presumably this is what is contemplated.

The existing 3/8-inch mesh corresponds to about nine mm. This alternative involves replacing the existing traveling screens with new screens with (presumably) 0.5 mm mesh. The Tetra Tech Evaluation does state that the screen area would be doubled, producing through screen velocities of one foot per second. However, this assumes 50% screen efficiency, the same as for the existing 3/8-inch mesh screens. It seems highly unlikely that the same screen efficiency would be achieved with the fine mesh screens as with the existing screens. As mesh size decreases the fraction of overall screen area blocked by the strands of mesh increases, and the finer mesh also increases the amount of debris captured and is more subject to colonization by invertebrates; all these effects decrease screen efficiency. It also estimates that construction would require that the plant be shut down for thirteen months. The units otherwise would have to be off line for refueling for one month each, so the net added downtime is twelve months.

The circulating water in the existing once through system transfers DCPP's heat to the ocean. The Mechanical Draft Wet Cooling Towers alternative provides cooling by transferring heat to the atmosphere primarily through evaporative cooling as circulating water falls through a cooling tower. Fans pull air through the tower. This alternative reduces entrainment by reducing the flow through the intake structure. The makeup water needed for the cooling towers is much less than the full circulating water flow used in the existing system.

The Tetra Tech Evaluation provides much more design information on this alternative than on the Fine Mesh Screens alternative. The Tetra Tech Evaluation refers to makeup water requirements for both units combined of 100,000 to 340,000 GPM, or 6% to 20% of typical existing system flow rates. Thus entrainment would be 6% to 20% of current levels. The conceptual design presented appears to be based on makeup water requirements of 100,000 GPM for both units combined, plus about 16,700 GPM for the auxiliary cooling systems. Thus the amount of water entering the main cooling system would be 100,000 GPM instead of about 1,670,000 GPM. Water discharges (blowdown) from the main system would be about 67,000 GPM and would be 1.5 times as saline as ocean water.

There would be 132 cells, each about 65 feet high and with a footprint of about 60 feet by 60 feet. As laid out by the Tetra Tech Evaluation, the cooling towers and supporting systems would cover most of a land area about 1,600 feet by 700 feet starting fairly close to the turbine building and extending nearly to Patton Cove. Several existing structures, parking areas, and roads would have to be relocated. A retaining wall approximately 1,800 feet long by 100 feet high would be required. Because the cooling water would be warmer than the existing system and thus reduce system efficiency, turbine output would decrease by about 21 MW (both units combined). The system would require about 25 MW more power for operation than the existing system, primarily for fans to pull air through the towers.

The plant could continue operation during much of construction, but power generation would have to cease while the new system is tied into the existing system. The Tetra Tech Evaluation estimates that this would require that the plant be shut down for six months.

Several other alternatives were considered, but the Tetra Tech Evaluation concluded that the Fine Mesh Screens and Mechanical Draft Wet Cooling Towers alternatives were the only two that warranted further consideration. Other options considered include:

- The Tetra Tech Evaluation's assessment was that Aquatic Microfiltration Barriers cannot be viewed, at this time, as a proven and realistic means of reducing entrainment at the DCPP.
- The Tetra Tech Evaluation did not evaluate dry or hybrid wet/dry cooling systems as a viable alternative because of the limited land area at the DCPP site and the resulting excessive duct lengths needed to connect the steam turbine exhaust to the air-cooled condenser.
- The Tetra Tech Evaluation did not evaluate cooling systems using fresh makeup water because there is no adequate source of fresh water within 25 miles of the facility and because of the costs and logistical difficulties of piping such a quantity of freshwater, or even treated wastewater, to the plant.
- The possibility of producing fresh water from sea water to use as makeup water was not given serious consideration because of issues of high cost, limited land availability, and disposal concerns for the concentrated brine wastes.
- The Tetra Tech Evaluation did develop a capital cost estimate for a natural draft wet cooling system. However, no further analysis was presented because this alternative did not appear to be viable due to estimated capital costs that were about twice the costs of the mechanical draft system, among other reasons.

The Tetra Tech Evaluation estimated costs for the Fine Mesh Screens and Mechanical Draft Wet Cooling Towers alternatives in four categories.

1) The capital cost of the new equipment required.
2) The additional operations and maintenance (O&M) costs associated with the new equipment and systems.
3) The "energy penalty" due to reduced output during future operation of the alternative systems.
4) The "lost revenue due to shutdown during retrofit", essentially the same as an energy penalty for the lost output of the entire plant during some parts of the construction period of the alternative systems.

The Tetra Tech Evaluation characterizes its cost results as "approximate cost estimates for conceptual cooling system alternatives for the DCPP, to enable the Board to consider feasibility and determine if additional analysis of alternatives is warranted."

The Tetra Tech Evaluation uses a 20 year project life for both alternatives, with the capital cost apparently occurring before operation and being amortized over 20 years, the cost of the construction-related outage occurring during the first year, and the O&M costs occurring the first year and each of the remaining 19 years.

For the Fine Mesh Screens alternative, the Tetra Tech Evaluation's "revenue loss" is due to an estimated 13 month construction outage that results in a net 364 days of lost output from the entire plant. This actually would be a cost rather than a revenue loss, because PG&E would have to purchase electricity from somewhere else rather than lose revenue from payments for DCPP's generation, but this detail does not affect the point. For the Mechanical Draft Wet Cooling Towers alternative the loss is due to a six month construction outage. In either case the lost output is valued at $34 per MWH.

For the Mechanical Draft Wet Cooling Towers alternative the estimated energy penalty is based on lost output of 46 MW. It is assumed to apply 350 days per year. The lost output is valued at $34 per MWH. The Tetra Tech Evaluation estimates that the energy penalty is zero for the Fine Mesh Screens alternative.

The Tetra Tech Evaluation calculated the present worth of the annual costs in each of these categories over an assumed twenty year life. The Tetra Tech Evaluation summarized its cost results in its Table 2, recreated below. The results also appear in Table 3 further below, where we compare them to revised values based on our analysis. In Table 3 the Tetra Tech Evaluation Fine Mesh Screens alternative is Case 1A and the Mechanical Draft Wet Cooling Towers alternative is Case 1B.

Table 2 – Summary of (Tetra Tech Evaluation) Cost Estimates for Cooling System Alternatives at the DCPP - $MM (Millions)

	Fine Mesh Screens With Fish Handling and Return Systems	Mechanical Draft, Wet Cooling System Using Seawater Makeup
Capital Cost	23	822
Annual O&M	1	1.7
Total Annual Energy Penalty	Not Applicable	13
Lost Revenue During Construction	660	330
Net Present Value – Assumes a 20 Year Project Life	-650	-1,320
Annualized Cost – Assumes Capital Costs Amortized Over 20 Years	663 (first year) 3.2 – 3.9 (thereafter)	422.5 (first year) 92.6 – 94.2 (thereafter)

5 Fine Mesh Screens Alternative

5.1 *Conclusions*

- It is highly uncertain whether fine mesh traveling screens would produce a net biological benefit at DCPP. First, it is unclear what level of entrainment reduction could be achieved through installation of fine mesh screens. Further, organisms not entrained will be impinged, and each step in the process of trapping organisms on the screens, lifting them out of the water for a limited period of time, washing them from the screens into a sluiceway, and returning them to the ocean beyond the intake cove could cause substantial mortality.
- The technology has not been demonstrated as a retrofit on a plant similar to DCPP in size and site conditions. Fine mesh screens have not been used before in an exposed coastal location such as exists at DCPP.
- The Tetra Tech Evaluation does not demonstrate the feasibility of the Fine Mesh Screens alternative.
- There are significant operation and maintenance issues with fine mesh screens because of the potential for fouling, invertebrate colonization, increased resistance to flow, screen wear and tear and damage due to storm surge, and the marine environment generally.
- Multiple levels of environmental reviews and approvals by a number of federal, state, and local agencies would be required for this project. This process would take years to complete, the necessary approvals might not be given, and years of litigation could follow any decisions that are reached as a result of the CEQA process.
- The costs to PG&E's customers of this alternative are uncertain but clearly are very high. The Tetra Tech Evaluation estimated the discounted total cost to be $650 million, equivalent to (our estimates based on Tetra Tech Evaluation data) $730 million undiscounted and level annual costs of $66 million. We believe that the actual costs will be higher. The discounted total cost is likely to be more in the range of $770 million ($848 million undiscounted), equivalent to level annual costs of $100 million.

5.2 *Biological and Environmental Issues*

With the existing once-through cooling system, virtually all organisms not large enough to move away from the 3/8- inch mesh screens pass through them and are entrained. Fine mesh screens reduce this entrainment by capturing (impinging) on a finer mesh screen many of the organisms that the existing system entrains, then washing them off and returning them to the ocean.

Those that are impinged would potentially be harmed by the process of being trapped against the screens, kept out of water for a limited period of time, washed from the screen and into a gravity sluiceway, and transferred through the sluiceways to the ocean.

The net benefit of the Fine Mesh Screens alternative depends on the factors affecting this overall process. If the Fine Mesh Screens alternative does not increase the overall survivability of the organisms that now come in contact with the cooling system, then it does not create any net environmental benefit and is not a feasible alternative.

Reduced Entrainment

The effectiveness of the screens in capturing (impinging) organisms that otherwise would be entrained is fundamental – entrainment is reduced only to the extent that this happens.

The Tetra Tech Evaluation refers to examples of other power plants with fine mesh screens and states, "Although the limited experiences described above suggest that 80% reduction in entrainment could potentially be achieved at the DCPP, through the use of fine mesh screens, any further consideration of such technology would require pilot studies to take into account site specific variables, including local species of concern and the potential for screen fouling with kelp and algae."

However, it must be noted that during sampling for PG&E's 316(b) study, Tenera originally used 0.5 mm mesh plankton nets, but changed to 0.3 mm mesh following observation of extrusion of larval cabezon through the 0.5 mm mesh. Appendix A concludes that " … even traveling screens with a small mesh size of 0.5 mm would result in entrainment of the early life stages of many of the fishes collected in entrainment samples at DCPP." (See Appendix A.)

Thus it is unclear that 80% reduction in entrainment could be achieved with 0.5 mm mesh traveling screens.

Mortality of Impinged Organisms

To whatever degree entrainment is reduced, any benefits of the Fine Mesh Screens alternative are reduced or eliminated by the mortality associated with impingement. The Tetra Tech Evaluation offers very limited data to support any estimate of the survival rate of impinged species. It does not provide estimates of mortality but does provide statistics on the survival rates of impinged fish eggs and larvae ranging from 65% to 93%.

Appendices A and B provide much more information on this issue. Appendix A concludes that "These results indicate the high level of uncertainty associated with any potential biological benefits from installing fine mesh traveling screens at DCPP. Finer mesh screening would convert entrainment to impingement for animals larger than the mesh size, but it is not clear whether impingement mortality of eggs and larvae would be more or less than the mortality currently attributed to entrainment. … the actual effectiveness of the screens at reducing mortality due to impingement or entrainment would require site-specific studies."

The Diablo Canyon Power Plant Final 316(b) Demonstration Report (TENERA Environmental Services, March 1, 2000) provides additional information on the extremely wide range of impingement survivability. As an example, under laboratory conditions, survival has ranged from 1 percent for striped bass to 96% for smallmouth bass and bluegill. Studies performed at other power plants such as Brayton Point and Big Bend also show species-dependent survival ranging from 0 – 90%.

Appendix B provides a report written by ASA Consultants that also discusses survival rates associated with fine mesh screens. It states that fine mesh screens at DCPP " … would offer relatively little fish protection benefit, while introducing an uncertain, and potentially high, level of impact on the operational reliability of the DCPP cooling water system."

In December 1999 the Electric Power Research Institute produced report number TR-114013, entitled "Fish Protection at Cooling Water Intakes". On pages 3 and 4 of this report's Section 3 the document states the following:

"With fine-mesh collection screens, the survival of each species/life stage to be protected must be weighed against the survival that would result if that organism were allowed to pass through coarse mesh screens and the circulating water system. For some species/life stages, impingement on fine-mesh screens can result in higher mortality than if the organism were allowed to be entrained through the circulating water system. Therefore, for these species/life stages, impacts will actually increase if fine-mesh screens are used to replace, or used instead of, coarse-mesh screens."

Thus it is not at all clear that fine mesh screens would improve survivability of the species that otherwise would be entrained.

5.3 *Engineering Issues*

Technology is Not Demonstrated at Relevant Conditions

The Tetra Tech Evaluation provides examples of the use of fine mesh traveling screens at other power plants. However, none of the examples were of applications as retrofits on plants as large as DCPP in an exposed coastal location, and Nexant is not aware of any such installations. There is no indication that the technology has been demonstrated as a retrofit on a plant similar to DCPP in size and site conditions.

Plant Design is Undefined

The Tetra Tech Evaluation does not provide a description of the design of the fine mesh screens system to be used at DCPP. It provides some information on fine mesh screens at other power plants, but does not describe the design proposed for DCPP, other than noting that the screen surface area at the plant would be doubled. It is not clear if the design contemplates a major expansion of the existing intake structure, or if it is technically feasible without such an expansion. There is no description of the following items, among others, that would affect the feasibility of the alternative.

- The design in general.
- The possibly major expansion of the existing intake structure to accommodate the doubled screen surface area, if the design contemplates such an expansion, or information demonstrating that it is technically feasible without such an expansion, if none is proposed.
- The pump wells.
- The screens themselves and their location and orientation.
- Whether there are fish buckets on the screens, what they would look like, and how they would operate.
- The systems necessary to wash or otherwise remove the impinged organisms from the screens.

- The systems necessary to wash or otherwise remove other debris from the screens.
- The systems used to collect the washed-off organisms and return them to the ocean.
- The operation of any of these systems.
- The maintenance of any of these systems.
- The impact of the new systems on the water flow through the cooling system.
- The impact of the new systems on auxiliary power demands.

Nexant believes that doubling the screen area will require expanding the intake structure itself, not just adding screens within the existing structure. This means it will be necessary to install a cofferdam in the intake cove, dewater the existing structure, expand the structure, and then install the screens. The Tetra Tech Evaluation states that the plant will have to be shut down for 13 months in the process of installing the new system, which seems consistent with the major activities mentioned above. However, it is not clear that the Tetra Tech Evaluation's cost estimate is adequate.

It is impossible to judge the feasibility of the alternative without addressing these issues. For example, the undefined systems to wash the impinged organisms off the screens or the systems to return the organisms to the ocean could destroy the organisms that survived the impingement itself, resulting in no net environmental benefit. It will be necessary to deliver the organisms to the ocean beyond the breakwaters to limit the chance of their returning to the intake structure.

Limited Experience with Fine Mesh Screens

Fine mesh screens have not been installed on a plant as large as DCPP, or in a location similar to its exposed coastal location. The power plants with fine mesh screens identified in the Tetra Tech Evaluation are located in estuarine environments and have vastly different types of debris loading concerns, as well as limited (if any) exposure to significant wave action. The Tetra Tech Evaluation states "The potential for fouling by kelp and algae at the DCPP would be significant, and intensive maintenance should be anticipated to avoid biofouling. … The example facilities, discussed above, do not have cooling water requirements near that of the DCPP. Tetra Tech Inc. acknowledges that these examples demonstrate limited full-scale use of the technology and have resulted in limited performance data."

System Maintenance

With mesh much finer than the existing traveling screens, debris that now is entrained and passes through the circulating water system would be impinged. "The fine mesh would entrap added amounts of fine scale matter including algae, shells, sediments, and degraded gelatinous organisms (e.g., marine snow) would likely become built up, wedged in, and difficult to extract from the fine mesh." (Draft Evaluation of Alternative Intake Technologies, PG&E, December 10, 1999)

Fouling would affect the fine mesh screens much more often than the existing screens. Debris loading will have a greater impact on the fine mesh screens than the existing screens during normal operation and especially during storm swell conditions.

The head differential across the fine mesh screens would be higher than the existing screens. The fine mesh will not be as sturdy as the existing mesh and will be more subject to tearing.

Appendix B provides information on Big Bend's fine mesh screen installation. Although Big Bend has light debris loading, Appendix B notes "A rigorous maintenance regime was put in place at Big Bend to keep screens operating reliably, and screens operate at up to 28 ft/min to keep head differential down (Brueggemeyer et al 1987). Also, coarse-mesh dual flow screens were installed behind the fine mesh screens to protect the pumps from any debris that enters in the event that emergency slide gates open (they open if fine-mesh screens clog and head differential rises)."

Heavy debris loading during storm conditions can outpace the handling capacity of the existing heavy-duty traveling screens. This (and storm swell) can create conditions that damage the screens and circulating water pumps. To address this problem PG&E has implemented an operational policy designed to eliminate unit trips due to problems with the screens. When wave energy measurements indicate significant storm activity, operators ramp the units down to 20% power. It is reasonable to expect that the units would need to be ramped down to 20% load much more often with the greater debris capture capability of the fine mesh screens.

Another maintenance consideration is the likelihood that barnacles, mussels, hydroid, and bryozoan communities would take up residence on the screens. These types of sessile invertebrate communities are limited in the fresh and brackish water environments where fine mesh screens have been installed and thus have not become a problem in these locations. However, these organisms are common at Diablo Canyon and would be expected to colonize the screens and reduce water flow. This poses a threat to the reliable operation of the cooling system and the removal of these types of communities would likely provide another significant operational challenge. (Draft Evaluation of Alternative Intake Technologies, PG&E, December 10, 1999)

With twice as many screens, presumably operating nearly continuously, there would be additional auxiliary power demands. The added head differential through the fine mesh screens would also slightly reduce circulating water pump flow.

As applied to DCPP, the increased auxiliary power demand and added shutdowns and other reduced power events would reduce annual energy production. Thus they and the high level of maintenance are cost items that would increase annual costs.

5.4 *Schedule and Cost Issues*

Schedule

With regard to the Mechanical Draft Wet Cooling Towers alternative, the Tetra Tech Evaluation acknowledges that "... the DCPP is located within the Coastal Zone, and any project, such as (this) cooling alternative would require approval by the California Coastal Commission. Tetra Tech, Inc. recognizes that such a land use approval process can be timely (sic) and expensive."

Nexant believes that a major activity such as doubling the size of the intake structure for the Fine Mesh Screens alternative would also require obtaining Coastal Development and other permits or licenses that will take years in addition to the construction itself. Apart from the above-noted comment about Coastal Commission approval for the Mechanical Draft Wet Cooling Towers alternative, the Tetra Tech Evaluation does not address the issue of the time required for these activities. Nevertheless, the time required for permitting, licensing, and environmental reviews would be significant. Judicial challenges to permitting decisions would also be a distinct possibility.

The term of the existing NRC license for Unit 1 ends in the year 2021 and the term of Unit 2's license ends in 2025. For the discussion below we average these values and use 2023 as the last year of plant life. It is now 2003. Given the scope of the work required to accomplish either project, Nexant believes that the permitting process would take a minimum of five years for either alternative. For the Fine Mesh Screens alternative the Tetra Tech Evaluation states that a 13 month total plant shutdown would be required for construction. Allowing another 11 months for pre- and post-construction activities produces a two year period from the time when the last permit is obtained and when operation of the new system begins. Thus construction could be complete by the end of the year 2009 if the project were started now. The new system could operate for 14 years, from and including the years 2010 through 2023.

Capital and O&M Cost Estimates

The Tetra Tech Evaluation's estimated capital costs were $21.4 million for the screens and $1.6 million for the auxiliary salt water system, for a total of $23 million. This appears to be low, given the length of the construction outage and the magnitude of the work. TENERA's Final 316(b) Demonstration, March 1, 2000 (the TENERA Demonstration) provided cost estimates for three separate components of a fine mesh screen system totaling $70 million:

- The estimate for a larger intake structure designed to halve through-screen velocities by doubling screen area was $51 million.
- The estimate for a gravity sluiceway fish return and a low-pressure spraywash system was $12 million.
- The estimate for fine mesh screens and associated equipment was $7 million.

The Tetra Tech Evaluation's estimated O&M costs also appear to be low. There will be a much larger structure, twice as many screens and motors, more screen wash pumps operating, and more chance of screen tears. Extra pumps and motors would create additional auxiliary (parasitic) loads. The Tetra Tech Evaluation estimated that the added O&M costs, over and above the current level, due to replacing the exiting screens with fine mesh screens would be $870,000 per year, plus 3% per year inflation. We assume that the added O&M costs are proportional to the capital cost. Increasing the Tetra Tech Evaluation's added annual O&M costs according to the increase in capital cost gives an annual added O&M value of (70 / 23) * $870,000 = $2.65 million per year, to which we add the same 3% per year escalation used in the Tetra Tech Evaluation.

Financial Parameters and Approach

The Tetra Tech Evaluation amortizes the capital costs over 20 years at an unspecified discount rate that appears to be about 7% to 8%. However, this approach does not correspond to the way PG&E would incur capital-related costs associated with the investment. DCPP is now subject to cost of service-based ratemaking. A capital investment is funded by common stock, debt, and preferred stock. PG&E's weighted average cost of capital is 9.12%. The return on the common stock is subject to income tax, and the investment at DCPP would be subject to property tax as well. The capital-related costs decrease each year, as depreciation reduces the net capital investment.

Cost of service-based ratemaking at one time was almost universal in the electric utility industry and is still common. The basic principle is that PG&E's profits are controlled and it must operate its business prudently, but in exchange its customers must pay all costs reasonably incurred by PG&E, including a reasonable level of profit. Thus all costs of a cooling system alternative, including capital-related costs such as all those noted above, would be charged to customers if it were built. If PG&E were required to build an expensive new cooling system, the burden of the costs ultimately would fall on its customers.

For each of the alternatives, we calculated a yearly cost stream that results from incorporating the factors above that affect costs:

- The appropriate data on PG&E's cost of capital, income taxes, property taxes, and project life.
- The revised capital and/or O&M costs described above.

Appendix C shows the annual values and calculations of discounted and undiscounted totals, and level annual costs. Table 3 compares these results to those of the Tetra Tech Evaluation. Table 3 includes results for the Mechanical Draft Wet Cooling Towers alternative, which the next section of this report discusses.

The net present value is the sum of the yearly cost figures, discounted to the start of year one of 20 for the Tetra Tech Evaluation cases (Cases 1A and 1B) and to the start of the first year of operation for the revised cases. The Tetra Tech Evaluation does not state the discount rate they used, but Nexant estimated it from the data that the Tetra Tech Evaluation did provide.

The undiscounted sum of costs is simply the sum of the annual costs, with no discounting. The Tetra Tech Evaluation does not provide this parameter, but Nexant estimated it from the data that the Tetra Tech Evaluation did provide.

The level annual cost is the equal annual cost in each year that has the same net present value as the net present value of the varying yearly costs. The Tetra Tech Evaluation does not provide this parameter, but Nexant estimated it from the data that the Tetra Tech Evaluation did provide.

The annual and total costs to PG&E and consequently to its customers are substantially higher when the revised data for financial parameters, project life, and basic cost assumptions are incorporated (Case 1A from the Tetra Tech Evaluation vs. Case 2A using revised data). This reflects the higher cost of capital, shorter life, income taxes, property taxes, and higher basic cost assumptions. The discounted totals increase from $650 million in the Tetra Tech Evaluation to $770 million using the revised values we think are more appropriate, with undiscounted totals rising from $730 million to $848 million. The level annual costs increase by 50%, from $66 million for Case 1A to $100 million for Case 2A.

Table 3 – Cost Results

	Fine Mesh Screens Alternative		Mechanical Draft Wet Cooling Towers Alternative	
	Case 1A	Case 2A	Case 1B	Case 2B
Basis for cost data	Tetra Tech Evaluation	Revised Data	Tetra Tech Evaluation	Revised Data
Discount rate, %	7% - 8% (Note 1)	9.12%	7% - 8% (Note 1)	9.12%
Project life, years	20	14	20	11
Capital cost, $ million	23	70	822	822
Annual added O&M, $ million	0.87	2.65	1.70	9.20
Total annual energy penalty, $ million	N/A	N/A	13	23
Lost revenue during construction, $ million	660	660	330	607
Annual costs, $ million				
First year (Note 2)	663	660	422	607
Later years	3.2 - 3.9	17.3 to 9.6	92.6 - 94.2	220.6 - 120.5
Net present value, $ million	650 (Note 3)	770	1,320 (Note 3)	1,819
Undiscounted sum of costs, $ million	730 (Note 1)	848	2,188 (Note 1)	2,483
Level annual cost, $ million	65.7 (Note 1)	100	124.6 (Note 1)	269

Note 1: Estimated by PG&E

Note 2: The Tetra Tech Evaluation apparently includes the lost revenue during construction in the first year costs, and calculates the present worth referred to the start of the first year. The revised cases treat that cost as occuring at the end of construction, the year before operation starts. The revised cases calculate the present value referred to the start of the first year of operation.

Note 3: Expressed as -650 or -1,320 in Tetra Tech Evaluation

6 Mechanical Draft Wet Cooling Towers

Many of the points made in this section are from the report "Feasibility of Retrofitting Cooling Towers at Diablo Canyon Power Plant Units 1 & 2", Burns Engineering Services Inc., April 11, 2003 (the Burns Report).

6.1 *Conclusions*

- The Tetra Tech Evaluation states that this alternative will reduce entrainment by 80 – 94%. However, there will be many other negative environmental impacts that partly or entirely offset this improvement, including:
  - The construction impacts of a massive project.
  - The high salinity blowdown water discharge.
  - Land use issues with such a large project.
  - Air quality and terrestrial impact issues due to salt drift.
  - Ground fog at times, a water vapor plume rising thousands of feet in the air and visible for miles at other times.
  - Noise due to cooling tower fans and falling water.
  - Visual impacts of the towers themselves and the plume.
- The technology has not been demonstrated as a retrofit on a plant similar to DCPP in size and site conditions. The magnitude of a cooling tower retrofit at DCPP would be of an unprecedented scale and complexity.
- The Tetra Tech Evaluation does not demonstrate the feasibility of the Mechanical Draft Wet Cooling Towers alternative.
- It is highly uncertain whether available land is adequate to build the cooling towers and related systems at the DCPP site.
- Multiple levels of environmental reviews and approvals by a number of federal, state, and local agencies would be required for this project. This process would take years to complete, the necessary approvals might not be given, and years of litigation could follow any decisions that are reached as a result of the CEQA process.
- The costs to PG&E's customers of this alternative are uncertain but clearly are very high. The Tetra Tech Evaluation estimated the discounted total cost to be $1,320 million, equivalent to (our estimates based on Tetra Tech Evaluation data) $2,188 million undiscounted and level annual costs of $125 million. We believe that the actual costs will be higher. The discounted total cost is likely to be more in the range of $1,819 million ($2,483 million undiscounted), equivalent to level annual costs of $269 million.

6.2 *Biological and Environmental Issues*

Entrainment would be reduced in proportion to the reduction in flow, from 1,670,000 GPM to 100,000 GPM. It is likely that mortality of entrained organisms will approach 100% because the cooling tower water is hotter and saltier than in the existing system, and the organisms will pass through the cooling towers several times.

However, the Mechanical Draft Wet Cooling Towers alternative has other environmental impacts, none of which the Tetra Tech Evaluation addresses. If any of these issues prevent the approvals necessary before construction can begin, this alternative will be infeasible. The impacts include:

- Construction impacts: The impacts will result from the construction activities associated with an $822 million project. This will include building 132 structures each roughly equivalent to a five-story building, massive earth moving to level the site for the cooling towers, constructing a retaining wall 1,800 feet long by 100 feet high, driving piles to provide foundations for the towers, and relocating (if possible) roads, buildings, and parking areas.
- Water quality: The blowdown discharge will be 1.5 times as salty as ocean water, and warmer. The closed cycle system will use chemicals to prevent buildup of biological or scale formation in the towers, probably requiring a waste treatment facility and leaving residual chemicals in the water. Although the flow rate will be far lower than the existing system, the high salinity and possible presence of chemicals present entirely new environmental and permitting issues.
- Land use: The towers and supporting systems cover an area many times larger than the existing turbine building, containment structures, and auxiliary building combined. The road, parking areas, DCPP septic system, and many other facilities displaced by the towers would have to be relocated. The Tetra Tech Evaluation's proposed scenario would require significant modification to the existing road to the raw water reservoir, substation, and future dry cask storage area. Whether the various facilities and roads can be relocated on the site is very doubtful. If they could be relocated, the access of employees to the site would be impaired.
- Air quality: The towers would produce seven million pounds per year of salt drift (the salt remaining from the evaporated salty water that provides the cooling, which is transported by the air flowing through the towers). This level of airborne salt is much greater than the natural airborne salt concentrations in that area that result in an estimated 86 pounds per acre-year of salt deposition. Hundreds of acres will be blanketed with salt at five or more times natural deposition rates, and hundreds more at lesser rates still well above 86 pounds per acre-year. Structures near the towers likely will be permanently coated with salt and other mineral deposits. This will have a negative impact on the local terrestrial ecosystems at the plant site itself and the neighboring agricultural and other areas to the south, east, and north. The salt drift will also negatively affect the operation and maintenance of the plant. (Burns Report)
- Noise: Each of the 132 tower cells would have a 250 horsepower fan and water flows of about 13,000 gallons per minute falling through the tower. Although there are no nearby houses or other non-plant facilities, the continual outdoor noise level at the administration building will be in the vicinity of 74 dBa, equivalent to loud street noise. This will affect plant personnel and local fauna. (Burns Report)
- Plume: The massive tower installation would produce a substantial water vapor plume during cool, damp weather periods. With the proposed Tetra Tech Evaluation design, all access roads, buildings, and parking lots could be blanketed with a ground level plume ("ground level fogging") during atmospheric conditions that occur frequently. This would be a hazard to plant safety and security. In addition, during cold, clear days with

light winds the plume would rise many thousands of feet into the air and be visible for tens of miles. (Burns Report)

- Visual impact: The towers cover an area many times larger than the existing turbine building, containment structures, and auxiliary building combined. The towers will produce visible plumes that could rise thousands of feet into the air.

6.3 *Engineering Issues*

Technology is Not Demonstrated at Relevant Conditions

Only a few existing plants throughout the United States have been retrofitted with closed cycle cooling towers. The retrofits were for small power plants or sites that had some accommodating physical features, such as the Palisades Nuclear Plant in Michigan. The magnitude of a cooling tower retrofit at DCPP would be of an unprecedented scale and complexity. The proposed DCPP cooling tower project would be the largest closed cycle saltwater mechanical draft cooling tower installation in the United States, retrofit or not. (Burns Report)

Plant Design is Not Completely Defined

Although the Tetra Tech Evaluation provides much more detail on the design of this alternative than on the Fine Mesh Screens alternative, the design is not complete.

The proposed cooling tower location will require relocation of several buildings, parking areas, an engineered road, and the plant septic system. Other facilities are located underground in the proposed area. Rather than locate a suitable area for the cooling tower retrofit, the Tetra Tech Evaluation simply displaces facilities for which there is no apparent alternative location within the plant boundary. The net effect is that the Tetra Tech Evaluation does not adequately address the lack of available land for the project.

For example, the 98,000 square foot warehouse proposed to be relocated is currently within the secure or protected area. The building has many requirements (seismic, air quality, etc.) due to the safety function of some of the components it stores. There is no land available within the industrially zoned area to relocate this building. Additionally, if it is relocated outside the protected area, significant security-related modifications would be required at the entrance to the protected area to accommodate inspection of the materials delivered from the warehouse.

Retrofit Construction of Cooling Water System Will Require Longer Plant Shutdown

To provide cooling water to and from the cooling towers, it will be necessary to dig new tunnels and tie into the existing cooling water tunnels. The area in front of the turbine building where these connections likely would be made has been heavily utilized with a labyrinth of service connections laid in underground layers that reach 50 feet below the surface. Forty-six discrete electrical and plumbing systems converge in that area, including safety-related systems. Construction will be painstakingly difficult.

The Burns Report estimates that plant shutdown to complete construction of the tie in to the existing system will require a plant shutdown of 12 months, not the six months estimated by the Tetra Tech Evaluation.

Cooling Tower Performance

The Tetra Tech Evaluation uses a cooling tower approach temperature of 9^0 F and does not consider re-circulation (warm air from the exhaust of a cooling tower being drawn back into tower inlets). Re-circulation increases the inlet wet bulb temperature above the ambient condition and impairs tower performance. The Burns Report estimates that the cooling tower approach would be 16^0 F and there would be 4^0 F of re-circulation, in effect providing an approach of 20^0 F. This reduces turbine efficiency and generator output. At the 61^0 F design point the electrical output would be 55.9 MW less than the existing once-through system, compared to 21 MW less estimated by the Tetra Tech Evaluation.

Combined with the 25 MW of additional auxiliary power requirements, The Burns Report estimates total energy loss for both units of 81 MW vs. 46 MW in the Tetra Tech Evaluation.

Blowdown Water Temperature

With the existing once-through cooling system, at full load the temperature of a unit's discharge water is about 20^0 F above the temperature of the intake water. Thus the discharge is normally 20^0 F above the temperature of the ocean water into which it flows. With a cooling tower, the temperature of the discharge water depends on the wet bulb temperature, which is not directly related to the temperature of the ocean water.

Thus, for example, using the design wet bulb temperature of 61^0 F and the Burns Report's 20^0 F approach, the water in the cooling tower basin would be 81^0 F regardless of ocean water temperature. TERA Corporation's 1982 report "Diablo Canyon Power Plant Assessment of Alternatives to the Existing Cooling Water System" noted an ocean water temperature range at DCPP of 48^0 F to 63^0 F. If the cooling tower basin water were used as the source for blowdown, it would be from 18^0 F to 33^0 F above the temperature of the ocean water, depending on the ocean water temperature at the time when the wet bulb temperature was 61^0 F. At lower wet bulb temperatures the increase above ocean water temperature would be less.

Operation and Maintenance

The salt drift will corrode unprotected structures and lead to electrical arcing incidents in the substation and in the 500 kV transmission lines running through the site.

Construction of the cooling towers would effectively surround the plant with construction, both for the installation of the towers and for routing of the circulating water tunnels and lines. A safe and controllable means of access will have to be devised.

The movement of people and equipment during the construction period would affect the normal operations of DCPP. After construction is completed, the relocation of the parking areas will continue to impede access of DCPP's 1,300 workers to their work areas.

Nuclear Safety, Security, and Licensing Issues

The Tetra Tech Evaluation's proposed design is not adequately detailed to perform a thorough nuclear safety and security review. However, this is a critical step in determining feasibility. The proposed 316(b) rule for existing power plants includes a provision that allows existing technology to be "best technology available" if alternative technologies would affect nuclear-related safety systems. The proposed design may have detrimental impacts on such safety related systems. Further, issues such as relocation of the warehouse could affect security concerns as well. Ground fog events would be a hazard to plant safety and security. In any case, license amendments, if permitted, would be necessary to account for many of the proposed changes. This potentially affects schedule, cost, and feasibility.

6.4 *Schedule and Cost Issues*

Many of the schedule and cost issues are similar or identical for both alternatives. Where they are, the discussion given in Section 5 will not be repeated here.

Schedule

Section 5 discusses schedule issues and concludes that the permitting process would take a minimum of five years for the Mechanical Draft Wet Cooling Towers alternative as well as the Fine Mesh Screens alternative.

The Tetra Tech Evaluation estimates a capital cost of $822 million for the Mechanical Draft Wet Cooling Towers alternative, signifying a huge project. The TERA Corporation's 1982 report "Diablo Canyon Power Plant Assessment of Alternatives to the Existing Cooling Water System" estimated a construction period of 61 months. This seems reasonable and our analysis below allows five years for procurement and construction, for a total of ten years for permitting and construction. The construction could be complete by the end of 2012 if it started now. The new system could operate from 2013 through and including 2023, a total of 11 years.

The Tetra Tech Evaluation's estimated O&M costs appear to be low. There will over a hundred fans and motors, corrosive drift, and in general maintenance of a much more complicated and expensive system than the existing system including frequent inspections, instruments and control, electrical and mechanical repairs, replacements, maintenance of the water treatment facilities, chemicals, and blowdown and makeup system upkeep. The EPRI document Cooling System Retrofit Analysis concludes that additional maintenance costs in the range 1% to 3% of system capital costs annually result from cooling system retrofits. Allowing 2% of the initial capital cost for O&M produces an annual cost of $16.44 million per year. Subtracting the $1 million per year of O&M for the existing system gives a net added O&M of $15.44 million. The Burns Report estimates an annual cost of six times the Tetra Tech Evaluation's estimate of $1.7 million per year, or $10.2 million per year. In our calculations below we will use the Burns Report value of $10.2 million less the $1 million for the existing system, or $9.2 million per year.

For this alternative the "revenue loss" from the Tetra Tech Evaluation is due to a six month construction outage that results in a net 182 days of lost output from the entire plant. The lost output is valued at $34 per MWH, for a total of $330 million. In our calculations below we will use a 12-month outage based on the estimate in the Burns Report. We assume that a one-month refueling outage would have occurred during this period, reducing the period of lost output from 12 to 11 months. This is similar to what was assumed for the Fine Mesh Screens alternative, where the refueling outage reduced the amount of lost output from 13 to 12 months. The total revenue loss is thus 365 * (11/12) * 24 * 2222 * 34 = $607 million.

The Tetra Tech Evaluation bases its calculation of the energy penalty on lost output of 46 MW. The Burns Report estimates the lost output to be 81 MW, which we use in our analysis. The penalty applies 350 days per year and is valued at $34 per MWH. Thus the penalty amounts to 81 * 350 * 24 * 34 = $23 million per year.

Similar comments regarding financing costs and plant life that were made for the Fine Mesh Screens Alternative apply to this alternative as well.

Appendix C shows the annual values and calculations of discounted and undiscounted totals, and level annual costs. Table 3 summarizes results from incorporating these factors and compares them to the Tetra Tech Evaluation's results.

The annual and total costs to PG&E and consequently to its customers are substantially higher when the revised data for financial parameters, project life, and basic cost assumptions are incorporated (Case 1B from the Tetra Tech Evaluation vs. Case 2B using revised data). This reflects the higher cost of capital, shorter life, income taxes, property taxes, and higher basic cost assumptions. The discounted totals increase from $1,320 million in the Tetra Tech Evaluation to $1,819 million using the revised values we think are more appropriate, with undiscounted totals rising from $2,188 million to $2,483 million. The level annual costs more than double, from $125 million for Case 1B to $269 million for Case 2B.

Appendix A

TENERA Report - Potential Use of Fine Mesh Screens for the Cooling Water Intake Structure at Diablo Canyon Power Plant

Potential Use of Fine Mesh Screens for the Cooling Water Intake Structure at Diablo Canyon Power Plant

Prepared by
TENERA Environmental
225 Prado Rd., Suite D
San Luis Obispo, CA 93401

Introduction

Tetra Tech (Tetra Tech 2002) recently completed an evaluation of cooling water system alternatives for the Diablo Canyon Power Plant (DCPP). One of the alternatives evaluated in the study was the installation of fine mesh screens of 5 mm or less on the existing traveling screen frames. Based on performance at other facilities the study indicated that an 80 percent reduction in entrainment could be achieved at DCPP through the use of fine mesh screens. The study did indicate that the example facilities did not have the cooling water flow requirements of DCPP and that there was the potential for fouling by kelp and algae. A review of screen system alternatives to manage debris loading at the DCPP intake was also completed by PG&E (PG&E 1996). This study determined that while fine mesh screens would enhance screening capabilities for debris removal, there were significant cost and engineering problems with them. Retrofitting the existing DCPP through-flow screens with fine mesh would increase the flow resistance and raise the potential for screen failure under high debris loading. Additionally, the traveling screens frames and intake would have to be redesigned or retrofitted to allow for fish buckets, gravity sluiceways, or other mechanical features designed to return impinged animals unharmed to the source water. The finer mesh screens would result in increased impingement of fish and invertebrate eggs and larvae, and there is no available information on impingement mortality for the suite of larval fishes entrained at DCPP. Most of the studies on fine mesh screens have been conducted on the east coast.

Fine-mesh screening has been investigated in laboratory and field studies to determine its potential to minimize entrainment at several east and gulf coast power plants (Magliente et al. 1978; Tomljanovich et al. 1978; Taft et al. 1981; LMS 1987; Brueggemeyer et al. 1988; Davis et al. 1988). Tomljanovich et al. (1978) show that traveling screens equipped with 1.0 mm (0.04 in) screen mesh substantially reduce entrainment of fish eggs and larvae, and that entrainment of larval fish and macroinvertebrates could be virtually eliminated by use of 0.5 mm (0.02 in) intake screen mesh. However, Cada et al. (1979) report that traveling screens with fine mesh do not offer any major biological advantages over conventional or modified vertical traveling screens, especially when considering that any decrease in entrainment mortality is replaced by increased impingement.

Site-specific studies at DCPP would be necessary to evaluate the survival of previously entrained fish eggs and larvae that would be impinged on fine-mesh screens. Two types of mortality can be expected when animals are impinged in cooling water systems: 'initial' mortality that occurs immediately upon contact with the screens, collection baskets, or screen wash system and 'latent' mortality that occurs at some interval beyond the initial impingement. Furthermore, mortality of the fish eggs and larvae that would be impinged, instead of entrained, is species and life-stage specific (Taft et al. 1981; Brueggemeyer et al. 1988) and can depend on secondary design features of the traveling screens such as collection baskets (PG&E 1996; Tenera 2000). Fine mesh traveling screens were not recommended at DCPP given the uncertain biological benefits of installing this type of screening combined with the potential for extensive maintenance requirements due to frequent, heavy kelp and algal loading and the cost of retrofitting the intake structure (Tenera 2000).

Examples of Biological Data on Fine Mesh Screens

Several power plants have installed or considered installing fine mesh screens in the attempt to reduce entrainment mortality. The Tampa Electric Company (TECO) Big Bend Station on Tampa Bay, Florida and the Brayton Point Station in Somerset, Massachusetts have both installed fine mesh screens and studied their effects on entrainment and impingement mortality. Fine mesh screens were also evaluated for the Contra Costa and Pittsburg Power Plants in San Francisco Bay to reduce striped bass losses in their cooling water systems. While these sites and the examples presented in the Tetra Tech report (Tetra Tech 2002) have installed or tested fine mesh screens, the cooling water system flows, intake designs, and species potentially affected are all different from DCPP.

Fine mesh (0.5 mm) no-well screens were installed at the TECO Big Bend Station on Tampa Bay, Florida (Taft et al. 1981; Brueggemeyer et al. 1988); studies of their biological effectiveness were conducted in 1985. Invertebrates had mortality rates ranging from 10–35 percent. Engraulididae (primarily bay anchovy) had initial mortality rates ranging from 42–84 percent and latent mortality rates ranging from 32–35 percent. Bay anchovy, Atlantic tomcod, and Atlantic silverside eggs showed a total mortality of 72.4 percent. Yolk-sac larvae of mummichog, Atlantic silverside, Atlantic tomcod, white perch, and winter flounder mortality ranged from 62–100 percent with the exception of winter flounder, which had a projected mortality range of 11–62 percent. Mortality for post-yolk-sac larvae was assumed to be slightly less but still ranged from 36–100 percent for all species in this life stage. The effectiveness of the fine mesh screens to reduce impingement mortality was very species specific with no examples for the species that would be entrained at DCPP.

At Brayton Point Station Unit 4, biological evaluations were conducted to determine the number, species, and initial and latent survival of fish impinged on the modified intake screens (LMS 1987; Davis et al. 1988). These fine-mesh, angled screens were installed at a new Unit 4 intake to divert larger, motile life stages and gently collect and recover early life stages. The lowest survival was calculated for bay anchovy and the highest was for tautog. Initial and extended survival varied by species. A group of numerically dominant taxa was classified by the authors as "fragile" (primarily, bay anchovy and Atlantic silverside) and had estimated survivorship below 25 percent while a "hardy" group, dominated by winter flounder and northern pipefish, had survival values greater than 65 percent. These studies also show that impingement survival with fine mesh screens was species specific.

The organism most often used to examine entrainment and impingement mortality is the striped bass *Morone saxatilis* (e.g., Polgar 1977; Schubel et al. 1977; King et al. 1978;

Tera Corporation 1982; Cowan et al. 1993). The Electric Power Research Institute (EPRI) conducted a review of entrainment studies from 1970-2000 and found that average entrainment survival of striped bass larvae was 60 percent (EPRI 2000). By comparison, impingement survival for striped bass at Contra Costa and Pittsburg Power Plants was on the order of 55 percent 96 hours after initial impingement when employing 3/8" square mesh traveling screens and continuous wash down rotation; this represents the best case scenario from these studies (Tera Corporation 1982). The traveling screens and mesh size at Contra Costa and Pittsburg Power Plants are similar to the system used at DCPP. It is important to note that the animals impinged in the above study would be substantially larger than those impinged against fine mesh screens. When fine mesh screens were tested under laboratory conditions, long term impingement survivorship dropped dramatically to less than 10 percent for striped bass larvae impinged for durations greater than eight minutes (Tomljanovich et al. 1978). In these latter two studies, impingement mortality was directly proportional to duration of impingement with dramatic increases after eight minute durations; mortality remained species and life-stage dependent (see also Taft et al. 1981; LMS 1987; Brueggemeyer et al. 1988; Davis et al. 1988). While other studies have shown that the effectiveness of the fine mesh screens to reduce impingement mortality was species specific, these studies show that their effectiveness is also life-stage and age specific.

The most abundant fishes in entrainment samples at DCPP were small nearshore species and rockfishes that have not been studied at other power plants and in most cases do not even occur on the east coast were many of these studies of impingement and entrainment survival have been conducted. Larval survivorship can be reduced in a variety of ways by mechanical stressors (e.g. wave action, entrainment, impingement). However, little is know about how mechanical stress affects mortality of the fishes entrained at DCPP. Therefore, it is difficult to categorize the larvae of specific groups of these fishes as "fragile" or "hardy," although studies on northern anchovy larvae have shown increased natural mortality following storm events at sea (Lasker 1975, Lasker 1981, Peterman and Bradford 1987, Smith et al. 1981). Fishes such as northern anchovy, Pacific sardine and white croaker that produce pelagic eggs and small, undeveloped larvae have high larvae mortality during these early larval stages (Lasker 1981, Lo 1986, Butler 1991, Love et al.

1984, Murdoch et al. 1989). These fishes could be contrasted with the rockfishes that release well-developed larvae that may be less vulnerable to mechanical disturbance. Fishes such as sculpins (cabezon, smoothhead and snubnose sculpins), pricklebacks (monkeyface prickleback), gobies and painted greenlings lay demersal egg masses that hatch in shallow nearshore areas that experience extreme waves and surge; their larvae may be better adapted to mechanical disturbance. This is consistent with results presented by EPRI (2000) that showed that gobies as a group had the highest entrainment survival in the data they reviewed.

Relationship of Larval Size to Mesh Opening Size

Field studies conducted at DCPP for the 316(b) Demonstration (Tenera 2000) showed that plankton nets with a mesh size of 0.5 mm were not sufficient to eliminate extrusion and potential loss of some larvae through the nets. Entrainment samples for the 316(b) study at DCPP were initially collected using 0.5 mm (505 μm) mesh plankton nets. However, during an early survey larval cabezon (*Scorpaenichthys marmoratus*) were observed partially extruded through the net mesh. Their body depth (BD) ranges from ca. 1 mm for yolk sac larvae up to ca. 4 mm for transformation stage specimens (derived from Matarese et al. 1989). Larval northern anchovy, clinid kelpfishes, white croaker, and several other species would have smaller cross-sectional diameters than cabezon larvae at similar sizes (yolk-sac to transformation BD of 0.2–4 mm and 0.7–3 mm, respectively [derived from Moser 1996]) and an even greater likelihood of extrusion at smaller sizes. Consequently, plankton nets of 0.3 mm (335 μm) mesh were used for the remainder of the surveys to reduce the chance of extrusion through the mesh openings. These observations indicate that even traveling screens with a small mesh size of 0.5 mm would result in entrainment of the early life stages of many of the fishes collected in entrainment samples at DCPP. Entrainment through the traveling screens may even occur for larvae with larger cross-sectional areas because the cooling water flow may pull these larvae through the screens. The actual levels of entrainment and impingement mortality would be species, and life-stage specific.

Conclusions

These results indicate the high level of uncertainty associated with any potential biological benefits from installing fine mesh traveling screens at DCPP. Finer mesh screening would convert entrainment to impingement for animals larger than the mesh size, but it is not clear whether impingement mortality of eggs and larvae would be more or less than the mortality currently attributed to entrainment. Entrainment and impingement mortality are dependent on a variety of factors. Entrainment mortality is species and life-stage dependent, but is also directly proportional to increases in temperature and through plant mechanical stressors experienced by a larva. Impingement mortality is also species and life-stage dependent while being directly proportional to the approach velocity and duration of impingement. Secondary to these initial impingement stressors, methods of retention (e.g., watertight fish boxes at the bottom of each screen panel) and return to the source water (e.g., gravity sluiceways) can significantly modify impingement mortality rates. The studies reviewed above indicate that impingement survival can be relatively low when employing fine mesh screens; lower in some cases than entrainment mortality, but these studies were conducted on striped bass that does not occur at DCPP and is known to be a fairly hardy animal at all life stages. While fine mesh screen studies have been conducted at other facilities, none have taken place under the unique environment and conditions present at the DCPP intake structure. Our entrainment studies indicate that many of the larval fishes will still be entrained at some age and size classes, and while some of the larvae may survive impingement on the screens the actual effectiveness of the screens at reducing mortality due to impingement or entrainment would require site-specific studies. In all likelihood, high retrofit costs combined with intensive maintenance demands placed on fine mesh screens subject to frequent, heavy algal loading common to DCPP would be disproportionate to the uncertain biological and ecological benefits.

Literature Cited

Brueggemeyer, V. D., D. Cowdrick, and K. Durell. 1988. Full-scale operational demonstration of fine-mesh screens at power plant intakes. *I*n: Fish Protection at Steam and Hydroelectric Power Plants, San Francisco, October 28-31, 1987. Sponsored by EPRI. CS/EA/AP-5663-SR.

Butler, J.L. 1991. Mortality and recruitment of Pacific sardine, *Sardinops sagax caerulea*, larvae in the California Current. Can. J. Fish. Aquat. Sci. 48:1713-1723.

Cada, G. F., J. B. Cannon, and D. W. Lee. 1979. Alternative screening devices at Indian Point Units 2 and 3, Bowline Point, and Roseton generating stations. Testimony prepared for Hudson River NPDES case before the U.S. Environmental Protection Agency, Region II. EPA Docket No. C/II-WP-77- 01.

Cowan, Jr., J.H., K.A. Rose, E.S. Rutherford, and E.D. Houde. 1993. Individual-based model of young-of-the-year striped bass population dynamics. II. Factors affecting recruitment in the Potomac River. Transactions of AFS. 122:439-458.

Davis, R. W., J. A. Matousek, M. J. Skelly,, and M. R. Anderson. 1988. Biological evaluation of Brayton Point Station Unit 4 angled screen intake. *I*n: Proceedings: Fish Protection at Steam and Hydroelectric Power Plants, San Francisco October 28-31, 1987. Sponsored by EPRI. CS/EA/AP-5663-SR.

Electric Power Research Institute (EPRI). 2000. Review of entrainment studies: 1970-2000. Technical Report 1000757, Electric Power Research Institute, Palo Alto, CA. *In*: Cowan, J.H. 2002. Entrainment mortality and the Morro Bay Power Plant modernization project: Technical comments and ecological context. Prepared for Duke Energy North America 9 April, 2002. 63 pp.

King, L.R., J.B. Hutchison, Jr., and T.G. Huggins. 1978. Impingement survival studies on white perch, striped bass, and Atlantic tomcod at three Hudson River Power Plants. Fourth National Workshop on Entrainment and Impingement. Impingement Survival at Hudson River Power Plants, pgs. 217-233.

Lasker, R. 1975. Field criteria for survival of anchovy larvae: the relation between inshore chlorophyll maximum layers and successful first feeding. U.S. Fish. Bull. 73:453-462.

Lasker, R.(ed.). 1981. Marine Fish Larvae. Morphology, Ecology, and Relation to Fisheries. Washington Sea Grant, University of Washington Press. 131 pp.

Lawler, Matusky & Skelly Engineers (LMS). 1987. Brayton Point Station Unit No. 4 angled screen intake biological evaluation program. Prepared for New England Power Company.

Lo, N.C.H. 1986. Modeling life-stage-specific instantaneous mortality rates, an application to northern anchovy, *Engraulis mordax*, eggs and larvae. Fish. Bull. 84(2):395-408.

Love, M. S., G. E. McGowen, W. Westphal, R. J. Lavenberg, and L. Martin. 1984. Aspects of the life history and fishery of the white croaker, *Genyonemus lineatus* (Sciaenidae), off California. Fishery Bulletin 82(1):179-198.

Matarese, A. C., A. W. Kendall Jr., D. M. Blood, and B. M. Vintner. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. NOAA Technical Report NMFS 80, 652 pp.

Moser, H. G. (ed.). 1996. The Early Stages of Fishes in the California Current Region. California Cooperative Oceanic Fisheries Investigations, Atlas No. 33, National Marine Fisheries Service, La Jolla, California. 1505 pp.

Murdoch, W. W., R. C. Fay, and B. J. Mechalas. 1989. Final Report of the Marine Review Committee to the California Coastal Commission, Marine Review Committee Doc. No. 89-02, 346 pp.

Pacific Gas and Electric Company (PG&E). 1996. Solutions for Managing Heavy Ocean Debris Loads at the DCPP Intake. Prepared by PG&E.

Polgar, T.T. 1977. Striped bass ichthyoplankton abundance, mortality, and production estimation for the Potomac River population. *In*: Population Dynamics of Ichthyoplankton, pgs. 110-125.

Schubel, J.R., C.F. Smith, and T.S.Y. Koo. 1977. Thermal effects of power plant entrainment on survival of larval fishes: A laboratory assessment. Chesapeake Science 18(3):290-298.

Smith, P.E., L.E. Eber, and J.R. Zweifel. 1981. Large-scale environmental events associated with changes in the mortality rate of the larval northern anchovy. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 178:200.

Taft, E. P., R. H. Berger, J. Larsen, J. G, Holsapple, and L. Eberley. 1981. Laboratory evaluation of larval fish impingement and diversion systems. *In*: Proceeding of the Workshop of Advanced Intake Technology, San Diego, April 22-24, 1981.

Tenera. 2000. Diablo Canyon Power Plant: 316(b) Demonstration Report. Prepared for Pacific Gas and Electric Company, March 1, 2000. Doc. No. E9-055.0.

Tetra Tech, Inc. 2002. Evaluation of cooling system alternatives: Diablo Canyon Power Plant. Prepared for the Regional Water Quality Control Board, Central Coast Region, November 2002.

Tomljanovich, D. A., J. H. Heuer, and C. W. Voigtlander. 1978. Investigations on the protection of fish larvae at water intakes using fine-mesh screening. Pages.125-139. *In:* Sharma, R.K and J.B. Palmer (eds.). Larval exclusion systems for power coolant cooling water intakes. Proceedings of the workshop held at Shelter Island Inn, San Diego, California, February 7-8, 1978. NUREG/CP-002, ANL/ES-66. Argonne National Laboratory, Argonne, Ill.

Tera Corporation. 1982. Assessment of alternatives to reduce the losses of striped bass: Contra Costa and Pittsburg Power Plants. Prepared for Pacific Gas and Electric Company, June 9, 1982. Appendix A. An evaluation of the possible effectiveness of small-mesh intake screens and other intake screen modifications in reducing total losses of striped bass at the Pittsburg and Contra Costa Power Plants.

Appendix B

ASA Report – Factors Influencing the Effectiveness and Reliability of Fine Mesh Screens as a Technology Alternative for DCPP

Factors Influencing the Effectiveness and Reliability of Fine Mesh Screens as a Technology Alternative for DCPP

The process of selecting viable fish protection alternatives for cooling water intake systems requires an evaluation of the engineering feasibility, operational reliability, potential biological benefits, and costs associated with implementing each alternative at the specific site in question. An initial screening-level review of the use of fine mesh panels on the existing traveling screens at DCPP suggests that implementation of this alternative would offer relatively little fish protection benefit, while introducing an uncertain, and potentially high, level of impact on the operational reliability of the DCPP cooling water system.

Mesh openings substantially smaller than the standard (i.e. 3/8 inch) mesh are considered to be "fine mesh". Fine mesh screens present a barrier to the passage of young fish that would normally be entrained through the standard mesh, thereby trading entrainment for impingement of those organisms. Therefore, the potential fish protection benefit of fine mesh traveling screens depends on screening efficiency for the species/life stages present at the intake and the impingement survival obtained. Unless the impingement survival of the focal species is substantially greater than survival of fish entrained through the cooling water system, there is little or no protection benefit from the installation of fine mesh screens. Survival of early stages of fish impinged on traveling screens is related to species and size of the organisms and through-screen water velocity (ARL/SWEC 1981, EA 1979)

Because the open area of the traveling screen panels decreases as the screen mesh becomes finer, fine mesh screens considered small enough to provide an effective entrainment barrier at most sites are more susceptible to fouling by biological growth and debris than are standard mesh screens. This may limit fine mesh screen reliability under high biofouling or debris-load conditions, as well as increase the impingement rate and mortality of impinged fish. Fouling of the screens can result in nonuniform screen flows and high through screen velocities in unclogged regions of the screen and buildup of head differential that can compromise screen integrity.

The use of fine-mesh screens as a fish protection alternative at DCPP is complicated by the fact that the larvae entrained at DCPP are generally very small—the median length of entrained larvae of most species is between about 2 to 5 mm (DCPP 316(b) Report). Very fine mesh would likely be required to effectively screen substantial portions the larvae currently being entrained at DCPP. Susceptibility to entrainment through a given size mesh is generally though to be related to the degree of streamlining, or ratio of length to body depth or width exhibited by the species. Therefore, the mesh size required to effectively screen life stages currently entrained at DCPP would be expected to vary among the species. However, available information suggests that a screen mesh of 0.5 mm or less would probably be required to effectively screen fish larvae entrained at DCPP. For example, Turnpenny (1981) quantified the relationship between body morphometry and square mesh size required to prevent entrainment using tests on 24 marine and freshwater species from Europe (Gowan et al 1999). Based on this relationship, and assuming a range of body length/depth ratios of 3 to 10 (which typically encompasses the streamlining of most larval fish species most species) DCPP would likely need a mesh size of between 0.4 and 1.1 mm to exclude larvae longer than 5 mm long, or a mesh size between 0.25

and 0.7 mm to exclude larvae more than 3 mm long. It should be noted that Turnpenny's studies were limited to larger mesh sizes (≥4 mm) and fish lengths (≥24mm), requiring extrapolation to the DCPP case. However, these estimates seem quite reasonable in light of the sampling gear mesh size (0.333 mm) used to assure reasonable collection efficiency of entrained life stages in the DCPP monitoring studies.

The operational reliability of a cooling water system as large as DCPP using 0.5 or smaller fine mesh screens has not been demonstrated, and is highly uncertain given the large flows, energetic environment, high kelp loadings and high potential for biofouling. Possibly owing to the reliability issues and questionable fish protection benefits of smaller-size fine mesh traveling screens, only three full scale installations of less than 1.0 mm mesh size exist—at the Big Bend Units 3 and 4, Barney Davis, and Prairie Island Stations (EPRI 1999). Two of these stations are located in saltwater environments. Big Bend has light debris loading, while Barney Davis has seasonally heavy loading of seagrasses. However, cooling water flow screened with fine mesh at these stations is considerably lower than for DCPP Units 1 and 2, ranging from about 1/5 to 1/3 of the DCPP flow. A rigorous maintenance regime was put in place at Big Bend to keep screens operating reliably, and screens operate at up to 28 ft/min to keep head differential down (Brueggemeyer et al 1987). Also, coarse-mesh dual flow screens were installed behind the fine mesh screens to protect the pumps from any debris that enters in the event that emergency slide gates open (they open if fine-mesh screens clog and head differential rises).

Even if DCPP could be reliably operated with mesh of sufficiently small size to exclude the larvae entrained at DCPP, site-specific factors make the potential for surviving impingement low. The few studies conducted to date on survival of early fish life stages impinged on fine mesh screens at other power plants indicate that survival of larvae is relatively low compared to that observed for juvenile and older fish. Studies conducted at the Big Bend station on a prototype 0.5 mm fine mesh screen in 1979-80 and on permanently installed fine-mesh screens in 1985 measured extended survivals (48 hr) of 0.3 to 10 percent for impinged larvae of bay anchovy, 0.5 percent for herrings, and 2 to 40 percent for seatrouts/weakfishes (Taft et. al. 1982, Brueggermeyer et. al. 1988). Initial survival was relatively high and it is unclear how much of the high mortality following impingement is due to impingement versus high natural mortality and holding effects on the larval stages. Impingement survival studies conducted on the 0.5mm mesh screens at the Prairie Island station from 1984-1987 indicated that survival of larval stages was substantially lower than that of juvenile stages for most species (Kuhl and Mueller 1988). Extended survival of the larval stages of most taxa, including gizzard shad, mooneye, carp, minnows, white bass, sunfish, sauger, crappie, perch, and freshwater drum ranged from about 0.1 to 23.7 percent. Extended survival of larvae was moderate (36 to 59 percent) only for two extremely hardy taxa, channel catfish and suckers.

No information on size of larvae was presented in the above reports. However, studies conducted at the Indian Point station on a through-flow screen retrofitted with 2.5-mm woven nylon mesh, fish buckets, capability for higher screen speeds (2.5 to 20 ft/min), and a low pressure wash system, indicate that larval size is an important determinant of impingement survival (EA 1979). Survival studies conducted in 1977 and 1978 indicated that the most sensitive early developmental stages (through early post yolk-sac larvae) were not able to survive collection on the screen system. No larvae of several species, including striped bass, white perch, river herring, bay anchovy and rainbow smelt, survived impingement on the screen when total larval length was less than about 15 mm. Impingement survival of striped bass on the fine mesh screen at Indian Point increased from 0 percent for early larvae to an estimated 60 percent for late post-yolk-sac larvae and to 77-100 percent for juveniles. Survival of white perch increased from 0 percent for larvae to 71 percent for juveniles. These same studies indicated that the length for selective retention (the point at which the number impinged exceeds the number entrained) of striped bass larvae on the 2.5 mm fine mesh screen was about 15 mm total length.

Given the early developmental stage and very small size of the majority of larvae entrained at DCPP, substantial impingement survival is unlikely. In addition, the high loadings of kelp at DCPP intake are likely to further reduce the potential for survival. For example, studies of impingement survival on the 0.5 mm screens at the Barney Davis station found that survival was lower during seasons when eel grass loadings on the screen were high (Murray and Jinnette 1978). Finally, the location of the DCPP intake within a protected cove would hamper the return of any surviving larvae to the waterbody, since return to the intake cove itself would result in reimpingement of the larvae. Returning impinged larvae to locations beyond the cove would require transit along a very long fish return sluice with the potential for additional mortality.

REFERENCES

Alden Research Laboratory and Stone and Webster Engineering Corporation (ARL/SWEC). 1981. Laboratory Evaluation of Fish Protection Devices at Intakes. Empire State Electric Energy Research Corporation.

Brueggermeyer, V., D. Cowdrick and K. Durrell. 1988. Full-Scale Operational Demonstration of Fine-Mesh Screens at Power Plant Intakes. In: Fish Protection at Steam and Hydroelectric Power Plants, San Francisco, CA, October 28-31, 1987.

Ecological Analysts (EA). 1979. Evaluation of the Effectiveness of a Continuously Operating Fine Mesh Traveling Screen for Reducing Ichthyoplankton Entrainment at the Indian Point Generating Station. Central Hudson Gas & Electric, Consolidated Edison Company of New York, Orange and Rockland Utilities, Power Authority of the State of New York.

Electric power research Institute (EPRI). 1999. Fish Protection at Cooling Water Intakes. Report No. TR-114013. Palo Alto, CA.

Gowan, C., G. Garman, and W. Shuart. 1999. Design Criteria for Fish Screens in Virginia: Recommendations Based on a Review of the Literature. Prepared for the Virginia Department of Game and Inland Fisheries, Richmond, VA.

Kuhl, G.M. and K.N. Mueller. 1988. Prairie Island Nuclear Generating Plant Environmental Monitoring Program 1988 Annual Report. Prepared for Northern States Power Company, Minneapolis, Minnesota.

Murray, L.S. and T.S. Jinnette. 1978. Survival of Dominant Estuarine Organisms Impinged on Fine Mesh Traveling Screens at the Barney M. Davis power Station. Central Power and Light Company.

Taft, Edward P., Thomas J. Horst, and John K. Downing. 1982. Biological Evaluation of a Fine-Mesh Travelling Screen for Protecting Organisms. In: Workshop on Advanced Intake Technology, San Diego, CA, April 22-24, 1981.

Appendix C

Supporting Information on Cost and Financial Results

Table C-1. Basic Data, Case 2A
Fine Mesh Screens, Revised Data

Basic data:	
Plant rating, MW	2222
Construction outage, months (net of refueling outage that otherwise would have occurred)	12
Net days of construction outage	364
Net energy loss during construction outage, MWH	19,411,392
Cost of lost output, $/MWH	34
Cost of lost output during constrution outage, millions	660
Energy loss during operation, MW	0
Days/year of energy loss	350
Annual MWH lost	0
Cost of lost output, $/MWH	34
Escalation on cost of lost output, %/yr	0.0%
Cost of lost output, millions/year	0
Capital investment, millions	70
Annual added O&M, millions (in proportion to capital)	2.65
O&M escalation rate, %/yr	3.0%
Life after construction, years	14
Discount rate = PG&E's cost of capital	9.12%

Table C Yearly Results Case A Fine Mesh Screens Revised Data

		ANNUAL COSTS MILLION												
	Year	Capital investment	Cost of construction outage lost output	BOY net capital investment	Depreciation	BOY net capital investment	Return	Income Tax	Property tax	Added O M	Lost energy	Total	Present value
				total doesn t include capital investmt which is recovered from									
Total post construction													
Total													
Level annual cost													

Table C-3. Basic Data, Case 2B
Mechanical Draft Wet Cooling Towers
Revised Data

Basic data:	
Plant rating, MW	2222
Construction outage, months (net of refueling outage that otherwise would have occurred)	11
Net days of construction outage	334.6
Net energy loss during construction outage, MWH	17,842,660
Cost of lost output, $/MWH	34
Cost of lost output during constrution outage, millions	607
Energy loss during operation, MW	81
Days/year of energy loss	350
Annual MWH lost	680,400
Cost of lost output, $/MWH	34
Escalation on cost of lost output, %/yr	0.0%
Cost of lost output, millions/year	23.1336
Capital investment, millions	822
Annual added O&M, millions	9.2
O&M escalation rate, %/yr	3.0%
Life after construction, years	11
Discount rate = PG&E's cost of capital	9.12%

Table C Yearly Results Case B
Mechanical Draft Wet Cooling Towers Revised Data

		ANNUAL COSTS MILLION											
	Year	Capital investment	Cost of construction outage lost output	BOY net capital investment	Depreciation	BOY net capital investment	Return	Income Tax	Property tax	Added O M	Lost energy	Total	Present value
				total doesn t include capital investmt which is recovered from									
Total post construction													
Total													
Level annual cost													

Appendix D

References

Appendix D – References

Preliminary Draft Evaluation of Cooling System Alternatives, Diablo Canyon Power Plant, Tetra Tech Inc., August 2002

Comments on Preliminary Draft Evaluation of Cooling System Alternatives, Diablo Canyon Power Plant, PG&E, September 24, 2002

Revised Draft Evaluation of Cooling System Alternatives, Diablo Canyon Power Plant, Tetra Tech Inc., November 2002

Diablo Canyon Power Plant Assessment of Alternatives to the Existing Cooling Water System, TERA Corporation, March 30, 1982

Draft Evaluation of Alternative Intake Technologies, PG&E, December 10, 1999

Diablo Canyon Power Plant Final 316(b) Demonstration Report, TENERA Environmental Services, March 1, 2000

Cooling System Retrofit Cost Analysis, EPRI, July 26, 2002

Solutions for Managing Heavy Ocean Debris Loads at the DCPP Intake Final Report, PG&E DCPP Debris Team, October 1996

Potential Use of Fine Mesh Screens for the Cooling Water Intake Structure at Diablo Canyon Power Plant, TENERA Environmental Services, 13 December 2002 (Appendix A of these PG&E Comments)

Fine Mesh Screens as a Fish Protection Alternative, ASA Analysis & Communication, Undated – received by PG&E February 2003 (Appendix B of these PG&E Comments)

Feasibility of Retrofitting Cooling Towers at Diablo Canyon Power Plant Units 1 & 2, Burns Engineering Services Inc., April 11, 2003

Nexant

101 Second Street, 11th Floor
San Francisco, CA 94105-3672

tel: +1 415 369 1000
fax: +1 415 369 9700
email: info@nexant.com

www.nexant.com

Attachment 4
Cooling Water System
Findings Regarding Clean Water Act Section 316(b)
Diablo Canyon Power Plant
NPDES Permit Order RB3-2003-0009

APPLICABLE LAW

Section 316(b) states:

> "Any standard established pursuant to section 1311 of this title or section 1316 of this title and applicable to a point source shall require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact."

There are no state or federal regulations interpreting section 316(b) that apply to DCPP. The United States Environmental Protection Agency (EPA) adopted regulations interpreting section 316(b) in 1976 but, they were invalidated on procedural grounds. EPA did not attempt to adopt regulations again until the 1990's. In December 2001, EPA issued final 316(b) regulations that apply only to new facilities (66 Fed. Reg. 65256, 40 C.F.R. Part 125, Subpart I.) These regulations do not apply to DCPP. In April 2002, EPA issued proposed regulations that would apply to existing facilities, including DCPP but EPA does not plan to issue final regulations until February 2004. (67 Fed. Reg. 17122.) Although the final and draft regulations do not apply to this proceeding, they represent EPA's most recent analysis of section 316(b). The Federal Register preambles to the final and draft regulations are also useful for the same reason.

EPA has directed:

> "Until the Agency promulgates final regulations based on today's proposal, Directors should continue to make section 316(b) determinations with respect to existing facilities, which may be more or less stringent than today's proposal on a case-by-case basis applying best professional judgment." (67 Fed. Reg. 17124 col. 3.)

EPA advised that an EPA 1977 draft guidance on section 316(b) still applies to existing facilities pending adoption of final regulations. (67 Fed. Reg. 17125, col. 1.) The draft guidance is entitled, *Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment; Section 316(b) (May 1, 1977) (1977 Draft Guidance).*

The legal standards applied here are based on assembling a mosaic of EPA administrative decisions, opinions, the 1977 draft guidance, federal court opinions and reference to the final 316(b) regulations for new facilities, the draft regulations for existing facilities and their preambles in the Federal Register.

There are four basic steps in a Best Technology Available (BTA) analysis:

1) whether the facility's cooling water intake structure may result in adverse environmental impact;

2) if so, what alternative technologies involving <u>location, design, construction and capacity</u> of the cooling water intake structure can minimize adverse environmental impact;

3) whether alternate technologies are available to minimize the adverse environmental impacts; and

4) whether the costs of available technologies are wholly disproportionate to the environmental benefits conferred by such measures.

The following legal principles were applied in the Board's 316(b) analysis:

- Adverse environmental impacts occur whenever there will be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure.

- Minimize does not mean to completely eliminate adverse impacts. New regulations define minimize to mean to reduce to the smallest amount, extent, or degree reasonably possible. EPA also views increases in fish and shellfish as an acceptable alternative to reduction in entrainment.

- Alternatives that must be considered are location, design, construction and capacity of a cooling water intake structures that minimize adverse environmental impacts.

- Although closed-cycle cooling systems are not cooling water intake structures they can be required indirectly by limiting the capacity of the intake by restricting the volume of water flow.

- A determination on whether a technology is "available" could be made on any number of grounds based on site-specific conditions. The 1977 Draft Guidance states,

  "It is accepted that closed cycle cooling is not necessarily the best technology available, despite the dramatic reduction in rates of water used. The appropriate technology is best determined after careful evaluation of the specific aspects at each site." (1977 Draft Guidance p. 12.)

- The standards for determining whether the costs of a technology are wholly disproportionate to the environmental benefited conferred by such measures are set forth in findings below.

SUMMARY OF CONCLUSIONS

- Because of sketchy legal authority interpreting Clean Water Act Section 316(b), which addresses entrainment and impingement impacts, the Board must exercise its best professional judgment to reach a reasonable conclusion based on site-specific conditions.

- Impingement of adult and juvenile fish on the traveling screens in front of a cooling water intake structure at DCPP amounts to only a few hundred fish per year. This impact is so minor that no alternative technologies are necessary to address impingement at DCPP, and the cost of any impingement reduction technology would be wholly disproportionate to the benefit to be gained.

- Entrainment of smaller organisms (like fish larvae) occurs in once-through cooling water systems. Entrainment losses at DCPP are significant for certain species, and represent an adverse impact. However, the technologies that may reduce entrainment at DCPP are either experimental (screens and filters) or are only conceptually available at this site (saltwater cooling towers). Therefore the Board cannot conclude that these systems are available at DCPP under the meaning of Section 316(b) of the Clean Water Act, which requires best technology "available." There are no demonstrated applications of these technologies at facilities similar to DCPP, and there are many significant problems associated with their potential use at DCPP.

- The costs associated with the potential technologies ranges from $650 million for fine mesh screens to $1.3 billion for saltwater cooling towers, based on independent estimates. Because of the experimental nature and/or uncertainty associated with the technologies the costs may be significantly higher than these estimates.

- This Net Present Value of entrainment losses as estimated by PG&E's consultant is $15,786 to $1,905,757. However, the Regional Board's independent scientists agree that this estimate is probably significantly underestimated because it does not include the majority of entrained organisms. The Regional Board's independent scientists believe that the actual value is likely to be in the ten million dollar range. This "value" range can be compared to the cost of saltwater cooling towers. Tetra Tech 2002 estimated the Net Present Value of saltwater cooling towers at $1.3 billion. Using these values, the cost of cooling towers is wholly disproportionate to benefit to be gained (regardless of whether the entrainment losses are valued in the million dollar or ten million dollar range). The same comparison can be made for fine mesh screens ($650 million), although fine mesh screens have not been demonstrated to be effective to minimize entrainment at DCPP. Assuming for the purpose of analysis that fine mesh screens are effective, the cost of fine mesh screens is also wholly disproportionate to the assumed benefit to be gained.

- The Regional Board's 316b analysis evaluates intake structure technologies (screens, filters) and closed cooling systems (cooling towers, dry cooling) and concludes that the potential technologies are either infeasible, experimental, or the costs are wholly disproportionate to the benefit to be gained for this facility. This conclusion is supported by independent evaluations (Tetra Tech, 2003; EPRI, 1999; SAIC, 1994, and other references discussed below). The existing cooling water intake structure is best technology available under Clean Water Act section 316(b) and no changes to the cooling water intake structure location, construction, design or capacity are required by this Order.

DETAILED ANALYSIS

Under the monitoring and reporting program amendments approved in February of 1995, the Regional Board required the Discharger to perform a comprehensive section 316(b) study. At the direction of the Regional Board, a technical workgroup was formed to oversee the 1995-1999 study. Workgroup members included the Regional Board's staff and independent scientists, the Discharger's staff and consultants, California Department of Fish and Game, USEPA, and the League for Coastal Protection (an environmental group). Currently, the Regional Board's independent scientists on this project are Dr. Greg Cailliet, Moss Landing Marine Laboratories, and Dr. Pete Raimondi, UC Santa Cruz. Note that during the technical workgroup process, Dr. Raimondi represented the League for Coastal Protection. Dr. Raimondi is now an independent consultant to the Regional Board. These scientists are independent from, and have never worked for, the Discharger. Dr. Cailliet and Dr. Raimondi have extensive experience as independent scientists on several power plant projects in California.

Dr. Cailliet is a professor of ichthyology, marine ecology, population biology, and fisheries biology, with main interests in community and population ecology, biological oceanography, marine plankton and nekton, and estuarine ecology.

Dr. Raimondi is a professor of ecology and evolutionary biology whose research emphasizes nearshore marine communities. He also has substantial experience on the design, evaluation and analysis of marine monitoring programs, with particular expertise on the evaluation of marine discharges. Dr. Raimondi is currently directing the largest intertidal monitoring program in the world (through the Partnership for Interdisciplinary Studies of Coastal Oceans, or PISCO).

The Regional Board also hired Dr. Alan Stewart-Oaten and Dr. Roger Nisbet from UC Santa Barbara as independent scientists on the technical workgroup. Dr. Stewart-Oaten and Dr. Nisbet are leading scientists in ecological modeling and statistical analysis. The workgroup reviewed and approved each phase of the study, as well as the final report. Phases of the study included review and assessment of target organisms, sampling locations, sampling methods, gear testing, data analysis and presentation. The technical workgroup reviewed all aspects of the study, including sampling equipment, sampling periods, target species selection, larval identification, and analyses of the results via a process that continued for almost five years.

Entrainment and Impingement

The Discharger submitted its *Diablo Canyon Power Plant 316(b) Demonstration Report,* in March 2000 (hereafter 316b Demonstration). The 316b Demonstration includes an overview of the report process, a description of the results, and an evaluation of alternative technologies to minimize entrainment and impingement. The entrainment and impingement study results are also discussed in Regional Board staff's testimony for this Order.

The purpose of the 316(b) Demonstration study at DCPP was to 1) estimate the number of larvae lost due to the power plant, 2) convert the larval loss to adult fish, and 3) estimate the proportion of larvae lost relative to the amount of larvae available in species-specific source water bodies, and 4) estimate impingement losses.

Entrainment

Entrainment Studies at Diablo Canyon began in October 1996, and continued through June 1999 (about 2 ½ years of sampling in front of the intake structure). In addition to entrainment sampling in front of the intake structure, the study included an offshore sampling program. The offshore sampling area consisted of a grid approximately 17.4 kilometers long and 3 kilometers miles wide, centered on the power plant. The offshore grid sampling began in June 1997, and continued through June 1999 (approximately two years of sampling).

The study used three methods to analyze the data: 1) Empirical Transport Model, or ETM; 2) Fecundity hindcasting, or FH; and 3) Adult Equivalent Loss, or AEL. Each of these methods has advantages and disadvantages as described in the 316(b) Demonstration report.

The ETM approach estimates the proportion of larvae lost relative to the amount of larvae available in a given source water body. <u>Source water bodies are different for each species.</u> The size of the source water body for a given species is based on the age of entrained larvae and current speed. For <u>nearshore</u> species, the size of the source water body is expressed as length of coastline. For example, if the average age of an entrained larval species is 5 days, and the net current speed of coastal waters is 10 kilometers per day, then the size of the source water body from which the larvae may have come is 5 days x 10 kilometers/day = 50 kilometers of coastline. The size of the source water bodies for nearshore species ranges from tens to hundreds of kilometers.

For <u>offshore</u> species, the source water body is expressed as ocean area, using the same parameters (larval age when entrained and ocean current speed). For offshore species, the sizes of the source water bodies typically range from hundreds to thousands of square kilometers, with larger areas for some species.

The FH and AEL approaches convert larvae to adults using life history information for each species. The major limiting factor with each of these approaches, and most fishery impact assessments, is our lack of knowledge about species life histories (such as larval stage duration, longevity, fecundity, mortality at various larval stages, etc.). The lack of available life history information for most species requires us to make assumptions to fill in the gaps. The results from the FH and AEL approaches have very large statistical errors, so there is a great deal of uncertainty associated with these methods. The assumptions used for the FH, AEL, and ETM approaches were based on the best professional judgement of the technical workgroup members. The consensus of the technical workgroup members was that the ETM approach was the most rigorous, robust, and defensible of the three methods.

The entrainment sampling program identified and enumerated all species collected. The target species (fish and crabs) were selected by the technical workgroup after reviewing the entrainment data. Species were selected based on a list of criteria, such as abundance in samples, threatened or endangered status, etc., as described in the 316(b) Demonstration final report (page 4-1).

The results of the analyses (amounts entrained and equivalent adults lost) are shown in Table 1. The last column lists the size of the source water bodies for each sampling period and species for the ETM method. The ETM method calculates the percentage of larvae taken from these source water bodies for each of the two sampling periods (labeled S1 for year one and S2 for year two). Larval losses are shown for two scenarios, mean larval age and maximum larval age of the species entrained. The age of entrained larvae is critical to the analysis because it determines the duration of exposure and the size of the source water body. Larvae with longer larval duration are at greater risk of entrainment because they are exposed to entrainment for a longer period of time. Longer larval duration also increases the time that larvae are traveling with the ocean current, and thus the size of their source water body. There is debate over whether the mean or maximum larval age should be used in the ETM approach. Both values were used in this evaluation, and results based on mean and maximum larval duration are presented.

The results show that proportional larval losses for offshore (deeper water) species, including sport and commercial species, are relatively low (with the exception of halibut, which had relatively high proportional losses in S1 (year one) and very low proportional losses during S2 (year two). Halibut were included in the analysis because they are an important commercial species, even though the total number of larvae collected was very low relative to other species (378 total larvae collected). Although the ETM approach indicates potentially high proportional entrainment for halibut, the number of larvae entrained only represents 9 and 18 adult fish for the two sampling periods. The FH estimates for halibut were a rough approximation because there is no larval survival data for this species. Nevertheless, since so few larvae were entrained, the FH, AEL, and ETM results for halibut have little no meaning. The other offshore species include sand dabs, rockfish, white croaker, Pacific sardine, and northern anchovy. The relatively low entrainment numbers for offshore taxa make sense because the intake structure is located at the shoreline.

Larvae from near-shore (relatively shallow water) species are entrained in significantly higher numbers. The nearshore species include smoothhead sculpin, monkeyface prickleback, clinid kelpfishes, snubnose sculpin, and blackeye goby. Again, this makes sense because of the location of the intake structure.

<u>The proportional larval loss values (ETM values) in Table 1 cannot be interpreted without the context provided by the source water body size.</u> For example, the loss of 5% of the larval fish in a source water body that is 1000 km of coastline in size is likely to be a greater loss (in abundance) than a proportional larval loss of 20% from a source water body of that is 50 km of coastline is size. The proportional larval loss estimates below must therefore be considered with the corresponding source water body sizes. In the Table, each value of proportional loss corresponds directly to a specific source water body size. For painted greenling, the proportional larval loss in sampling period one, or

S1, is listed as 0.9% for mean larval duration and 1% for maximum larval duration. These are percent larval losses from source water bodies of 360 and 830 kilometers (length of coastline), respectively. The largest proportional larval losses occur with clinid kelpfish, up to 41% from a source water body of 127 kilometers (length of coastline).

Table 1: Estimated losses due to entrainment at Diablo Canyon.
PG&E's 316(b) Demonstration Report, Pages 7-23 and 7-24, 2000.

	FH Method (adults lost)	**AEL Method (adults lost)**	**ETM[1] (proportion of larva entrained from source water body) S1= 1st sampling year S2= 2nd sampling year**		**Source Water Body size expressed as length of coastline for Coastal Taxa**	
NEARSHORE TAXA			ETM Based on Mean Larval Duration	ETM Based on Maximum Larval Duration	Length Based on Mean Larval Duration	Length Based on Maximum Larval Duration
Painted greenling	No calculation[3]	No calculation	S1: 0.9% S2: 1%	S1: 1% S2: 0.4%	S1: 360 km S2: 180 km	S1: 830 km S2: 1112 km
Smoothhead sculpin	No calculation	No calculation	S1: 10% S2: 15%	S1: 15% S2: 20%	S1: 49 km S2: 52 km	S1: 127km S2: 143 km
Snubnose sculpin	No calculation	No calculation	S1: 4% S2: 12%	S1: 2% S2: 2%	S1: 122 km S2: 45 km	S1: 684 km S2: 971 km
Cabezon	No calculation	No calculation	S1: 0.7% S2: 0.8%	S1: 0.6% S2: 0.9%	S1: 158 km S2: 42 km	S1: 379 km S2: 77 km
Monkeyface prickleback	No calculation	No calculation	S1: 16% S2: 11%	S2: 23% S2: 11%	S1: 52 km S2: 42 km	S1: 120 km S2: 139 km
Clinid Kelpfishes	No calculation	No calculation	S1: 32% S2: 29%	S1: 41% S2: 39%	S1: 54 km S2: 47 km	S1: 127 km S2: 108 km
Blackeye goby	No calculation	No calculation	S1: 19% S2: 17%	S1: 23% S2: 22%	S1: 35 km S2: 23 km	S1: 150 km S3: 43 km

Table 1 Continued…

	FH Method (adults lost)	AEL Method (adults lost)	ETM[1] (proportion of larva entrained from source water body) S1= 1st sampling year S2= 2nd sampling year		Source Water Body Size Expressed as Area of Marine Habitat for Offshore Taxa	
OFFSHORE TAXA			ETM Based on Mean Larval Duration	ETM Based on Maximum Larval Duration	Area Based on Mean Larval Duration	Area Based on Maximum Larval Duration
Pacific sardine	3,170–8,460/yr	2,600–7,000/yr	S1: 0.03% S2: No calculation[2]	S1: 0.007%	S1: 2,469 km^2 S2: no calculation	S1: 56,272 km^2
Northern anchovy	16,000–45,000/yr	43,000–120,000/yr	S1: 0.06% S2: 0.2%	S1: 0.008% S2: 0.02%	S1: 861 km^2 S2: 397 km^2	S1: 35,652 km^2 S2: 23,700 km^2
Blue Rockfish	20 – 43/yr	164 – 353/yr	S1: 0.09% S2: 2%	S1: 0.04% S2: 0.3%	S1: 485 km^2 S2: 240 km^2	S1: 2,198 km^2 S2: 3,132 km^2
KGB Rockfishes	497/yr – 617/yr	905 – 1,120/yr	S1: 1.5% S2: 2%	S1: 1% S2: 0.5%	S1: 376 km^2 S2: 230 km^2	S1: 1,540 km^2 S2: 2,813 km^2
Sand dabs	92 – 426/yr	511 – 1,450/yr	S1: 0.5% S1: 5%	S1: 0.4% S2: 1%	S1: 610 km^2 S2: 141 km^2	S1: 1,170 km^2 S2: 966 km^2
CA Halibut	No calculation	No calculation	S1: 0.08% S2: 12%	S1: 0.08% S2: 5%	S1: 465 km^2 S2: 182 km^2	S1: 1,874 km^2 S2: 51,712 km^2
CRABS			**ETM[1] (proportion of larva entrained from source water body) S1= 1st sampling year S2= 2nd sampling year Larval duration base on literature for crabs**		**Source Water Body Size Expressed as Area of Marine Habitat for Crabs Taxa**	
Brown rock crab	91,000–117,000/yr	182,000-234,000/yr	S1: 0.00186% S2: 0.0146%		S1: 135,200 km^2 S2: 21,767 km^2	
Slender crab	8,950–27,300/yr	17,900– 54,600/yr	S1: 1% S2: 0.08%		S1: 12,366 km^2 S2: 5,950 km^2	

[1]Percent ranges are based on mean larval age and maximum larval age, which determines the duration of exposure to entrainment and source water body size. The older the larvae, the longer their exposure to entrainment, the greater the risk of being entrained, and the larger the source water body.
[2] ETM Calculations not possible due to large variation in sampling abundance.
[3]FH and AEL calculations not possible for species with little or no life history information.

The conversion of larvae to equivalent adult fish could not be calculated (using the Fecundity Hindcasting and Adult Equivalent Loss methods) for several species due to the lack of life history information (as noted above, results using the FH and AEL methods have large statistical errors). These results show that the number of equivalent adults lost due to entrainment of fish larvae for offshore species is relatively small. Northern anchovies were the highest (up to 120,000 adults lost per year). However, this represents a small fraction of the commercial landing for this species. The number of equivalent anchovy adults lost equates to about two metric tons, with a value of approximately $576/yr. The value of Pacific sardines lost to the commercial fishery is about $700/yr. The commercial loss to the rockfish fishery (blue and KGB rockfish complexes combined) is approximately $21,000/year. The dollar values of the other harvested species in terms of commercial landings are generally small. The dollar values given above do not represent ecological value and are provided for reference only. From an ecological perspective, the workgroup considered these losses to be of minor importance, even considering the large statistical errors associated with the AEL and FH methods.

However, the results also show that the amount of larvae lost for nearshore species is relatively high. The larval losses for nearshore taxa cannot be converted into equivalent adults because very little is known about these species. Also, these non-harvested near shore species have no direct dollar value in terms of commercial fisheries, but do have ecological value. For several nearshore species (sculpins, kelpfish, blackeye goby, monkeyface prickleback), the amount of larvae taken by the power plant is large relative to the amount of larvae available in the source water body (large proportional losses).

As shown in Table 1 above, the source water bodies (measured as length of shoreline) were specific to each species. Data to determine the source water bodies were collected as part of each larval sampling survey. For each sample survey period, larval duration periods were determined for each species. Then, using current data collected prior to the sampling survey period, the range of up coast and down coast movement was calculated. This was done by taking the maximum up coast and down coast current vectors measured during each survey period and adding them together to obtain an estimate of the total along shore movement.

As shown in Table 1 above, the average proportional larval loss for nearshore taxa is 12 to 14%. There are no additional data that can be used to determine if this larval loss affects nearshore fish populations or communities. Local population trend data for some species are discussed in the 316(b) Demonstration report, however, there are no data from before the power plant came on-line, and no data from control stations. Therefore, there is no way to determine if any trend is natural or caused by some other factor.

PG&E conducted plankton tows in front of the intake structure from 1990 to 1998 (separately from the required entrainment study work). These data show a potential decline in the amount of snubnose sculpin and clinid kelpfish larvae near the intake structure for the sampling period. The potential trend in larval density could also be due to natural variation. No data are available from before the power plant came on-line, and no control station sampling was done, so the data are inconclusive.

Data from the south control station for the thermal effects monitoring program also indicate a possible decline in clinid kelpfish. The number of adult clinid kelpfish counted at the south control station during fish surveys declined between 1976 and the late 1990's. This sampling method does not provide good estimates of small, cryptic fishes, such as clinid kelpfishes. The data for these species are highly variable and their abundance is commonly recorded as zero even though they are most likely always present. However, there are no controls for this data and therefore no way of knowing if the potential decline is natural. These data are inconclusive.

In conclusion, the available data cannot be used to indicate any population declines due to entrainment. However, the relatively large proportional larval losses for nearshore taxa represent an adverse impact because the larval loss itself, regardless of any resulting population or community level affect, is a loss of resources.

PG&E disagrees with the Regional Board's position. PG&E concludes that given the low entrainment estimates for offshore species, the conservative nature of the higher nearshore estimates, and the limited nature of the population trend data, the entrainment data do not indicate any adverse environmental impact.

There are uncertainties in this entrainment study (and all other entrainment studies) because several assumptions are made in the data analysis, and the sampling results are highly variable. The major assumptions include:

1. That adequate sampling was done to estimate larval densities in the field.
2. That simple ocean current measurements can be used to estimate the size of source water bodies.
3. That 100% of the entrained larvae are killed.

Although there are uncertainties, and the entrainment results should be considered within the context of the uncertainties, the results are the best estimates of the technical workgroup, and are accepted by this Regional Board.

Impingement

In addition to entrainment of larvae by the intake system, adult and juvenile fish are impinged on travelling screens in front of the intake structure. The travelling screens are designed to remove debris before it enters the cooling water system. Adult fish can become trapped, or impinged, in the debris. PG&E conducted an impingement study during 1985 and 1986. The results of that study show that very few adult fish are actually impinged on the travelling screens. This is due to the low velocity of the water as it passes through the traveling screens. The water velocity is slow enough (1 ft/sec) so that fish inhabit the intake structure and swim onto and off of the travelling screens. The study showed that the DCPP intake structure impinged a total of about 400 fish (about 60 pounds) and 1,300 crabs during the sampling period (April 1985 through March 1986).

For comparison, the Huntington Beach Power Plant, with flow volumes about one fourth the flow volumes of DCPP, and with an offshore intake structure, impinges up to 21 tons of fish per year. The El Segundo Power Plant, also with flow values about one fourth DCPP flows and using an offshore intake, impinges about 15 tons of fish per year. Both of the offshore intakes noted above are about 2000 feet offshore in about 35 feet of water. The amount of fish impinged at DCPP (about 60 pounds during the sampling period) is a tiny fraction of the amount impinged at these other power plants. The minor impingement losses at DCPP are so insignificant that they do not justify implementation of alternatives to the cooling water intake structure to further reduce the losses (the losses are already minimized).

Alternative Technologies

Since impingement losses are insignificant at DCPP, only technologies that may reduce entrainment are relevant to this analysis. There are two potential ways of addressing entrainment losses:

1. Intake Structure Technologies
   a. Screening or filtering systems
   b. Changing the intake location
2. Reduced Cooling Water Volume Withdrawal
   a. Variable speed pumps
   b. Seasonal flow limitations
   c. Closed cooling systems (cooling towers, dry cooling)

The Administrative Record includes several references for this evaluation of alternative technologies, including:

a. PG&E's Assessment of Alternatives to the Existing Cooling Water System, 1982, by Tera Corporation.
b. PG&E's *316(b) Demonstration Report,* March 2000 (hereafter 316(b) Demonstration).
c. Tetra Tech's independent report to the Regional Board, *Evaluation of Cooling System Alternatives, Diablo Canyon Power Plant,* November 2002 (hereafter Tetra Tech 2002).
d. PG&E 's comments on Tetra Tech 2002, dated September 2002.
e. USEPA information for the new and proposed 316(b) regulations, including USEPA's Phase II Technical Development Document and supporting references.
f. *Preliminary Regulatory Development, Section 316(b) of the Clean Water Act, Background Paper Number 3: Cooling Water Intake Technologies,* 1994 (hereafter Background Paper No. 3).
g. *Fish Protection at Cooling Water System Intakes: Status Report,* EPRI, 1999 (hereafter EPRI 1999).
h. *Feasibility of Retrofitting Cooling Towers at Diablo Canyon Power Plant Units 1 and 2,* Burns Engineering, April 2003 (hereafter Burns 2003).
i. PG&E's *Estimation Of Potential Economic Benefits Of Cooling Tower Installation At The Diablo Canyon Power Plant,* April 2003, ASA Analysis & Communication, Inc (hereafter ASA 2003).
j. Review of the ASA 2003 report by Stratus Consulting, an independent Consultant to the Regional Board (hereafter Stratus 2003).
k. Review of the ASA 2003 report by Dr. Raimondi (hereafter Raimondi 2003).
l. Other power plant case studies and reports in the record.

Intake Structure Technologies (Screens, Filters)

Intake structure technologies are evaluated in detail in Background Paper No. 3. This report was prepared by Science Applications International Corporation (SAIC), an <u>independent consultant</u> to the EPA. The EPA suggests that agencies use Background Paper No. 3 when implementing section 316(b) of the Clean Water Act. Background Paper No. 3 describes all potential intake structure technologies, including ten types of intake screens and five types of passive intake systems.

Background Paper No. 3 includes a description of each technology and corresponding Fact Sheets that describe where the technology is being used (if it is being used), advantages and disadvantages, research findings, and design considerations. The conclusions of Background Paper No. 3 are summarized below.

Regarding intake screen systems Background Paper No. 3 states: "The main finding with regard to intake screen systems is that they are limited in their ability to minimize adverse aquatic impacts." The report also states that "there has also been an interest in the use of fine-mesh mounted on traveling screens for the minimization of entrainment. However, the use of fine-mesh mounted on traveling screens has not been demonstrated as an effective technology for reducing mortality of entrainment losses." This is an important issue. Both once-through cooling and screening technologies cause mortality of organisms. The net benefit of a screening technology must be measured as a reduction in overall mortality. If the screening technology prevents entrainment of larvae and eggs, but simply replaces entrainment mortality with screening induced mortality, there is no benefit. The screening technologies are currently experimental. Site-specific and species specific research must be done to determine their potential effectiveness at a particular power plant.

With respect to passive screens, Background Paper No. 3 concludes: "The main findings for passive intake systems are that available technologies that effectively reduce fish eggs and larvae entrainment are extremely limited." Radial wells and wedgewire screens are the only alternatives considered to have potential for reducing entrainment mortality, but they are not used on large scale systems such as DCPP. Radial wells are literally ground water wells, and are used on small-scale applications, not on facilities like DCPP Units 1 and 2, which require a total cooling capacity of 2,500 million gallons per day (mgd). Wedgewire screens are also limited in their application, as discussed later in this report.

A comprehensive review of intake technologies is also provided in EPRI 1999. EPRI is the Electric Power Research Institute, Inc., of Palo Alto, California. Utility companies fund EPRI, which in turn sponsors research on utility industry issues. The conclusions of EPRI 1999 are similar to the conclusions of Background paper No. 3, that is, more research is needed on the various intake structure technologies before their applicability can be determined.

Tetra Tech 2002 illustrates that fine mesh screens have been used at other facilities with varying degrees of success (see also 316(b) Demonstration, EPRI 1999, and Background Paper No. 3). However, fine mesh screens have not been used at a facility similar to DCPP.

The Board concurs with the conclusions of Background Paper No. 3. The data collected on intake technologies to date are limited, highly variable, site-specific, and species-specific. The only technologies that may apply to DCPP for the purpose of reducing entrainment mortality are certain screening technologies, such as fine mesh screens, but they are considered experimental. A major problem with fine mesh screens is biofouling and mortality of larvae that are impinged on the screen. It is also difficult to determine the survivability of larvae that are impinged and then washed of the screens. Tetra Tech reports that survival rates for impinged larvae varies greatly based on studies at other facilities. The 316(b) demonstration report also provides highly variable survivability (or mortality) results from studies done at other facilities. The only way to determine the effectiveness of a screening technology at DCPP is to conduct site-specific research, with independent scientific experts overseeing all aspects of the work. Such research would likely take years to complete, and the total costs are unknown. Therefore, fine mesh screens are not a demonstrated "available" technology for DCPP. Tetra Tech estimates the total cost of installing fine mesh screens at Diablo Canyon at $650 million. The major component of this cost is the Power Plant downtime necessary to install the screens.

Filter Technology: Tetra Tech 2002 concludes that an aquatic filter-barrier is not feasible at Diablo Canyon due to the massive size of the filter that would be needed, the ocean conditions at the site, and the experimental nature of the technology. A filter area of approximately 160,000 square feet would be needed, which would be 8,000 long by 20 feet deep. Such a system could not be installed in a highly dynamic ocean environment, and has never been used in a setting like that at DCPP or for a facility of this size. The aquatic filter barrier is therefore not available for Diablo Canyon.

Screening and filtering technologies are experimental at this time, and there are no known applications of these technologies at facility similar to DCPP.

Intake Structure Location

Changing the vertical location of the intake structure in the water column is not possible at Diablo Canyon. The intake structure is located in Intake Cove, a relatively shallow (about 35 feet) cove constructed to protect the intake structure from wave and debris. The size of the intake opening takes up most of the vertical depth of the cove.

The potential benefit of moving the location of the intake structure offshore would be to decrease the larval losses for nearshore species. The disadvantage would be greater impingement and entrainment of offshore species, including groundfish species, whose populations are in decline along the west coast. The DCPP intake structure currently impinges an insignificant number of fish per year (a few hundred fish per a year). For comparison, as noted above, the Huntington Beach Power Plant, with flow volumes about one fourth the flow volumes of DCPP, and with an offshore intake structure, impinges up to 21 tons of fish per year. The El Segundo Power Plant, also with flow volumes about one fourth DCPP flows and using an offshore intake, impinges about 15 tons of fish per year. Both of the offshore intakes noted above are about 2000 feet offshore in about 35 feet of water. This information is from Documents filed with the Energy Commission by the utility companies. It should be noted that fish return systems are available, such as the system used at the San Onofre Nuclear Generating Station (SONGS). The overall efficiency of the SONGS fish return system is about 68%, making that offshore intake structure more favorable.

However, entrainment of larvae cannot be reduced in an offshore intake system. Some of the offshore taxa that would be impinged and entrained in an offshore intake at Diablo Canyon are currently heavily impacted to the point of near collapse. The National Marine Fisheries Service and California Department of Fish and Game recently implemented emergency "no-take" measures for certain species of groundfish, which may apply to an offshore intake structure. Therefore, an offshore intake would simply move the impacts offshore. In addition, the physical construction of an offshore intake system would cause major impacts on a significant amount of marine habitat, including an area of one-hundred feet wide by thousands of feet in length, through intertidal zone and subtidal kelp beds (Tetra Tech 2002).

Tetra Tech, the Regional Board's independent consultant regarding alternatives at DCPP, estimates the cost of an offshore intake system at $300 to $455 million, which does not include preparing the ocean floor for construction or other contingencies that could only be determined by a comprehensive assessment of this alternative (Tetra Tech, 2002). Further, an offshore intake structure may not be possible at DCPP due to the steep offshore slope and rocky subtidal habitat. The Board has no information indicating there are any offshore intake structures in an environment such as that found at DCPP, although Board staff searched for such information. Offshore intakes (or discharges) are typically found where there is a gentle offshore slope in a sandy bottom environment.

In conclusion, an offshore intake structure would not provide an environmental benefit, is not a demonstrated available alternative for a facility like DCPP, and would cost a minimum of $300 to $455 million. Therefore, this alternative cannot be considered available, feasible, or beneficial at DCPP.

Reduced Cooling Water Volume Withdrawal

Variable Speed Pumps: In theory, variable speed pumps may reduce entrainment rates in some cases by decreasing cooling water flows relative to fixed speed pumps. DCPP is a nuclear power plant and is designed to operate as a base load facility with minimal changes in power output over long periods of time (316(b) Demonstration). Accordingly, variable speed pumps are not applicable to DCPP, and independent cost estimates are not available. PG&E's 316(b) Demonstration estimates that the maximum possible benefit of variable speed pumps would be to reduce cooling water flows by 2 to 10%, and estimates the cost of installing variable speed pumps at $6.7 million. However, this cost estimate does not include the cost of power plant shut down time, which would be in the hundreds of millions of dollars. The existing pumps are embedded in the concrete of the intake structure, so replacement of the pumps would be a major construction project (as with fine mesh screen installation). This alternative would offer little or no benefit, and the costs due to power plant down time are very high. Therefore this alternative is not reasonable at DCPP.

Seasonal Flow Limitations: Seasonal flow limitations are applicable in cases where one or more particularly important species (such as endangered or threatened species) are being entrained during specific times of the year. This is not the case at DCPP, where no threatened or endangered species were identified in the entrainment sampling program (316(b) Demonstration). At DCPP, larvae are available and entrained throughout different seasons, and seasonal flow limits would require choosing some species over others for protection. This alternative is not recommended at DCPP as there is no practical way to choose certain taxa as being more important than others unless there are threatened or endangered species present. The cost (lost revenue) of seasonal flow restrictions depends on the duration and magnitude of the seasonal limitation and energy prices. The costs could range into the hundreds of millions per year depending on these factors.

Tetra Tech 2002 included total revenue estimates for DCPP. Based on an estimated revenue of $900,000 per Unit per day, annual revenue is estimated at $657 million at DCPP. Therefore, any significant reduction in cooling water flows (such as 20% annual reduction) will result in a cost in the hundred million-dollar per year range. As noted above, there is no biological argument for seasonal flow limitations based on the species entrained. Therefore, this alternative is not reasonable at DCPP.

Closed Cooling Systems

Closed cooling systems are of two main types: wet and dry. Wet cooling systems recirculate fresh or saltwater through towers. Make-up water is needed to replace losses due to evaporation. Dry cooling systems recirculate fresh water in a truly closed system (like the radiator in an automobile); no evaporation occurs and therefore no makeup water is needed. These systems follow the general hierarchy below:

Closed Cooling Systems
- I. Wet Cooling (saltwater or freshwater)
  - a. Mechanical Draft Cooling Towers
  - b. Natural Draft Cooling Towers
- II. Dry Cooling
  - a. Air Condensers
- III. Hybrid Cooling (saltwater or freshwater)
  - a. Mechanical Draft Towers and Air Condensers Combined

Availability of Wet Cooling Systems

In a mechanical draft system, heated water from the power plant is pumped to the top of cooling towers where it is then sprayed downward inside the tower. Air is forced upward through the tower by large fans (this makes them "mechanical draft"). The forced air transmits heat from the water to the atmosphere. The cooled water collects at the bottom of the tower where it is recirculated back to the power plant. Some water is lost to evaporation, and "make-up" water is needed to keep the volume constant. Mechanical draft cooling towers can be designed to handle all or part of the cooling load. Mechanical draft towers using <u>freshwater</u> are the most common cooling systems, and are being installed on the majority of new non-nuclear power plants in California (California Energy Commission 2002). All of the newly constructed and planned power plants in California use natural gas to generate electricity. No nuclear power plants are planned.

Mechanical draft towers using <u>freshwater</u> could theoretically reduce cooling water withdrawal from the Pacific Ocean to zero. However, fresh water cooling towers at Diablo Canyon would require approximately 50,000 gallons per minute, or 72 million gallons per day of fresh water to replace the water evaporated in the cooling towers (make-up water). This quantity of fresh water is not available at Diablo Canyon or anywhere in the vicinity. Conceptually, a desalination system could be constructed to provide the necessary fresh water supply. However, sufficient Ocean water or brackish ground water would have to be withdrawn in a volume sufficient to provide 72 million gallons per day of fresh water after desalinization. Additionally, the cost of cooling towers alone, without a massive desalination system, is in the billion dollar range (see estimate below for saltwater cooling towers). Finally, it is unlikely that there is enough space available at DCPP to build both a very large desalination facility and the very large mechanical draft cooling system (Tetra Tech 2002). The surrounding land is in the Coastal Zone and is zoned for agricultural use. Burns 2003 maintains that there is not enough available space around DCPP, to build the mechanical draft cooling towers alone, without the desalination facility.

Mechanical draft towers that use saltwater could reduce cooling water withdrawals by up to about 95%. Tetra Tech estimates 132 towers would be required @ 60 ft wide x 60 ft long x 65 ft high. Tetra Tech estimates the total net present value of costs for this system to be $1.3 billion. This cost includes revenue losses for a shut down period of six months (which could be significantly longer). Burns 2003 states that the minimum downtime for DCPP would be one year, which would result in significantly higher costs than estimated by Tetra Tech 2002. There are significant issues associated with retrofitting DCPP with cooling towers, including available space, relocation of existing structures and utilities to another location (which may not be possible), rezoning, and permitting by other agencies. The cooling towers would have to be located where the parking lot, service road, and large warehouse (475 ft x 207 ft) are currently located. There does not appear to be adequate space within the industrial zoned area to relocate these facilities, thus requiring rezoning of nearby land and approval by various permitting agencies. In addition, no facility of this size has ever been retrofitted with a closed cooling system. The cost estimate of $1.3 billion should be considered within the context of the project, which is conceptual, unprecedented, and highly complex. The costs could therefore be significantly higher than the estimate presented by Tetra Tech, and the retrofit may not be physically possible. Accordingly, retrofitting DCPP with salt water cooling towers is a conceptual option only, with unknown actual costs.

Tetra Tech also considered natural draft cooling towers. This system would require 10 towers, 200 feet in diameter by 450 feet in height. The total cost would be over $2 billion when lost revenue due to down time is considered. Further, the performance of a natural-draft cooling tower is dependent on relative humidity. In the vicinity of the DCPP, the relative humidity falls below 68 percent about 10 percent of the time (when the wet bulb temperature is 61°F). When this occurs, tower performance will be reduced and plant efficiency will be further impacted. The visual impacts of ten 450-foot high towers would also be significant. Further, the seismic zoning at DCPP precludes the construction of such tall structures (Tetra Tech, 2002). Accordingly, natural draft cooling towers are not available at DCPP.

Availability of Dry Cooling Systems

Dry cooling technology is similar to the cooling system in an automobile. Heated water is pumped from the power plant to a large external "'radiator" or condenser. Large fans force air over the condensers and heat is thereby transferred from the condenser to the atmosphere. Dry cooling systems can be totally closed, requiring no make-up water. USEPA has found that dry cooling is not "best technology available" for new power plants on a national basis but might be feasible in limited cases based on site-specific circumstances (66 Fed. Reg. p. 65305, col. 3; USEPA has tentatively made the same determination for existing power plants 67 Fed. Reg. p. 17168). In California and elsewhere, dry cooling is used where fresh water supplies are very limited. No nuclear power plants have been retrofitted with dry cooling systems.

Tetra Tech concluded that dry cooling is not an available alternative at Diablo Canyon. Tetra Tech determined that eight air-cooled condensing systems would be required, each occupying an area of 316 feet by 197 feet with an overall height of 119 feet. Each condenser would use forty, 150 hp fans; and the resulting turbine back pressure would be in the range of 3.5 to 4 inches HgA, considerably higher than the Power Plant's design value of 1.5 inches HgA. GEA Energy Technology Division, a leading designer of dry cooling systems, maintains that the length of duct from a power plant to an air-cooled condenser should be limited to a distance less than or equal to 200 feet. It is not physically possible to place eight very large dry cooling units within 200 feet of the Power Plant. At Diablo Canyon, duct lengths of 500 to 1000 feet would be required. Since these specifications for dry cooling cannot be met at Diablo Canyon, Tetra Tech did not provide costs estimates for this system. However, the USEPA estimates that dry cooling systems cost approximately three times more than wet cooling systems, which would result in a cost of several billion dollars at Diablo Canyon. Dry cooling is not an available alternative at Diablo Canyon.

Availability of Hybrid Systems
Hybrid systems are simply a combination of dry and wet cooling technologies. The proportion of cooling assigned to each technology depends on site-specific conditions, such as the amount of make-up water available. A hybrid system that uses both dry cooling and fresh water mechanical draft towers would reduce cooling water withdrawals to zero. A hybrid system that uses dry cooling and saltwater mechanical draft towers could reduce cooling water flows by 95% or greater. However, hybrid systems use the same technologies discussed above (wet and dry systems), and therefore are not currently available at DCPP for the reasons noted above. The same issues apply to a hybrid system: lack of available space, unproven applicability at a site like Diablo Canyon, lack of fresh water, and extreme costs.

Other Cooling Technology

Cooling Ponds: There are two types of cooling ponds: "passive" and "spray." These systems are not available at Diablo Canyon because of the massive size needed. The ponds would have to be thousands of acres in size to provide the cooling capacity needed at DCPP (PG&E's 316(b) Demonstration Report, 2000).

Wholly Disproportionate Cost Test

Legal Background
EPA interpretations of section 316(b) have consistently implemented a "wholly disproportionate" cost test as established in a 1977 Decision of the Administrator. (*Public Service Company of New Hampshire, et al. Seabrook Station, Units 1 and 2*, (June 10, 1977 Decision of the Administrator) Case No. 76-7, 1977 WL 22370 (E.P.A.) "*Seabrook I.*") In *Seabrook I*, the EPA Administrator ruled that EPA was not required to perform a cost/benefit analyses when applying section 316(b) on a case-by-case basis. However, the Administrator reasoned that cost must be considered otherwise "the effect would be to require cooling towers at every plant that could afford to install them, regardless of whether or not any significant degree of entrainment or entrapment was anticipated." (*Id.* pp. 6-7.) The Administrator ruled "I do not believe it is reasonable to interpret Section 316(b) as requiring use of technology whose cost is wholly disproportionate to the environmental benefit to be gained." The "wholly disproportionate" test was affirmed by the federal First Circuit Court of Appeals in *Seacoast Anti-Pollution League v. Costle* (1st Cir. 1979) 597 F.2d 306.)1

---

1. *Seabrook I* was appealed and remanded based on some procedural issues. (*Seacoast Anti-Polution League* v. *Costle*, 572 F.2d 872.) On remand, the Administrator cured the procedural flaws and readopted all the findings in *Seabrook I*. (*Public Service Co. of New Hampshire, et al.* v. *Seabrook Station Units 1 and 2* (August 4, 1978 Decision of Administrator.) The Court of Appeal in *Seacoast Anti-Pollution League* v. *Costle*, 597 F.2d 306, cited in text above, affirmed the Administrator's decision on remand.

The First Circuit Court clarified the "wholly disproportionate test" was one of incremental cost. The Court stated: "[t]he Administrator decided that moving the intake further offshore might further minimize the entrainment of some plankton, but only slightly, and that the costs would be 'wholly disproportionate to any environmental benefit'." (*Id.* at 311.) The wholly disproportionate test has continued to be used by EPA when applying section 316(b) since the *Seabrook I* decision. It does not appear in the 1977 Draft Guidance because that document was issued in May 1977 before the *Seabrook I* ruling.

While EPA has continued to use the wholly disproportionate test, there does not seem to be any consistency in how the test is used. In *Seabrook I,* the Administrator considered various construction/design alternatives and the alternative to locate the intake offshore. Concluding that these alternatives would provide minimal environmental benefit, the Administrator rejected them. The First Circuit Court of Appeals affirmed that the cost of the offshore outfall location was wholly disproportionate to this minor additional minimization of entrainment.

When EPA drafted the New Plant Final Rule, it determined that closed-cycle cooling was best technology available for all new facilities but provided for site-based alternatives justified by use of alternative technologies and restoration projects. (66 Fed. Reg. 65314, cols. 2-3; 65315 cols. 1-2.). Nonetheless, the New Plant Final Rule preserves a form of the wholly disproportionate test. It provides that if the discharger demonstrates that facility-specific data shows the cost of compliance would be wholly disproportionate with costs considered by EPA when establishing a compliance requirement, a less costly alternative may be permitted. (40 C.F.R. § 125.85(a).)

Application of the Wholly Disproportionate Test to DCPP
A wholly disproportionate cost test compares the cost of technology alternatives to the benefit to be gained by implementing alternatives. The EPA provides information on entrainment valuation methods in their supporting documentation for the proposed 316(b) rule for existing facilities. The valuation methods basically attempt to put a dollar value on entrainment losses. EPA acknowledges that this is a difficult process because there are few actual values, such as commercial fishing values, associated with entrained larvae. Assumptions must therefore be made about larval losses with no associated economic value.

PG&E submitted a report titled *Estimation Of Potential Economic Benefits Of Cooling Tower Installation At The Diablo Canyon Power Plant,* April 2003, ASA Analysis & Communication, Inc (hereafter ASA 2003). The report discusses four categories of benefits: market benefits, nonmarket direct use benefits, indirect use benefits, and nonuse benefits. Benefits were estimated according to methods used by the EPA in its benefits case studies for the proposed Phase II rulemaking under § 316(b) of the Clean Water Act (see Chapters A5, A9, and A10 of Part A of the Case Study Document available at: http://www.epa.gov/waterscience/316b/casestudy/).

ASA 2003 estimates that the total annual benefit expected due to implementing cooling towers at DCPP would range from $1,755 to $110,647 per year. To estimate the Net Present Value of the series of annual benefits ASA 2003 assumed that the cooling towers would not be in operation until 2008 (due to design, permitting, construction, and tie-in). ASA 2003 assumed the use of cooling towers would end in 2023, the mean year of license expiration for the two DCPP units. For purposes of bounding the expected benefits, discount rates of 2 percent (applied to upper bound values) and 7 percent (applied to lower bound values) were used.

Under these assumptions, ASA 2003 estimated the Net Present Value of expected benefits to the target species from implementing closed cycle cooling at DCPP would range from $11,045 to $1,334,030. Since the target species represent approximately 70 percent of the total entrainment of fish larvae, ASA 2003 assumed that the overall economic benefits could be estimated by dividing by 0.7 and, thus, range from $15,786 to $1,905,757.

The Regional Board's independent consultant regarding entrainment valuation, Stratus Consulting Inc., reviewed the ASA 2003 report and concluded that in general, ASA 2003 may significantly underestimate the actual value of entrainment losses because most of the entrained taxa are not accounted for in the analysis (Stratus 2003). The Regional Board's independent scientists agree. Dr. Raimondi's review of ASA 2003 indicates that the larval losses could be valued in the ten million dollar range, depending on the assumptions made. Stratus 2003 also states that the Habitat Recovery Cost (HRC) method could also be used to estimate the entrainment value losses, which would result in a much higher valuation for the losses. The HRC method estimates the cost of creating or restoring habitat that would produce the losses caused by entrainment. Stratus notes the HRC approach is not true benefit "valuation" method, and therefore cannot be taken as a measure of economic benefits. However, Stratus states that the HRC method can be used in a policy context or in permit negotiations as a point of reference for evaluating technology costs. The Regional Board acknowledges this potential approach, but notes that no habitat restoration work appears to be viable for the DCPP area.

This Net Present Value of entrainment losses as estimated by ASA 2003 ($15,786 to $1,905,757) or the higher estimate by Raimondi 2003 (ten million dollar range) can be compared to the cost of salt water cooling towers. Tetra Tech 2002 estimated the Net Present Value of saltwater cooling towers at $1.3 billion. Using these values, the cost of cooling towers is wholly disproportionate to benefit to be gained.

The only other potential technology for reducing entrainment at DCPP is fine mesh screening. If for the purpose of analysis fine mesh screens are assumed to be as effective as cooling towers at reducing entrainment, which is highly unlikely based on the limited data available from the references noted in this Order, then the same economic benefit as above can assumed. That is, a Net Present Value of $15,786 to $1,905,757, or up to the ten million dollar range, for the resulting benefits of fine mesh screens can be compared to the Net Present Value of the cost of the screens, which is $650 million based on Tetra Tech 2002. Using these values, the minimum cost of this experimental technology is wholly disproportionate to the benefit to be gained.

The Regional Board realizes that the estimated value of reduced entrainment (the benefit) is subject to qualitative evaluation and there are uncertainties involved in the methodology. However, even if the higher Net Present Value of the benefits is used (the ten million dollar range) the costs of technologies would still be wholly disproportionate to the benefits to be gained.

AIR POLLUTION CONTROL DISTRICT
COUNTY OF SAN LUIS OBISPO

STATE OF CALIFORNIA WATER QUALITY CONTROL
RWQCB RECEIVED
MAR 08 2004
Region 3 Office

March 4, 2004

Michael Thomas
Regional Water Quality Control Board
895 Aerovista Place, Suite 101
San Luis Obispo, CA 93401-7906:

Re: Saltwater Cooling Tower Issues Related to Air Quality – Duke Morro Bay Power Plant Modernization Project

Dear Mr. Thomas:

The use of saltwater cooling towers as the primary cooling method for the Morro Power Plant Modernization Project conflicts with two air quality requirements: Best Available Control Technology (BACT) and offsets.

BACT is required for any emission source greater than 25 lb/day. Particulate matter emissions from saltwater cooling towers would exceed that level. The currently proposed once through cooling has negligible particulate emissions. If it were not allowed, BACT would almost certainly be considered dry cooling towers over saltwater cooling towers.

Offsets, which are emission reductions equivalent to an emissions increase, are required for Duke's proposed project. Offsets of this magnitude have not yet been identified and are not readily available. In addition, if the offsets were available, there is an issue with expending a scarce commodity (offsets) on a project that could otherwise avoid the emissions.

Based upon these findings, it is unlikely that an Air Pollution Control District permit for salt water cooling towers could be issued for the Duke Modernization project.

If you have any questions, please to contact me at (805) 781-5937 or by email at gwilley_apcd@co.slo.ca.us.

Sincerely,

Gary E. Willey
Air Pollution Control Engineer

H:\ENGINEER\GARY\WP51\CPERMITS\DUKE\Saltwatercooling_RWCQB.doc

3433 Roberto Court • San Luis Obispo, CA 93401 • 805-781-5912 • FAX: 805-781-1002
info@slocleanair.org ❖ www.slocleanair.org

Proposed I																			
Unit Identifi	ER 94 ESPAR1	2002 Operating Data		Calculated Ratios	Other Informati														
Owner	Plant	Unit	Status	In-Service Year	Dependable Capacity (MW)	Output (MWh)	Fuel Use (MMBtu)	NOx Emitted (pounds)	NOx Rate (lb/MMBtu)	Heat Rate (Btu/kWh)	Capacity Factor	RMR	ISO list or MUNI3	Air Basin4	Once Through Cooled5	Site Redvlmnt Plan6	SCR Installed7	County
16	Mirant	Contra Costa 6	Operating	1964	340	876534	8635012	395697	0.0458	9851	0.294			SF	YES	NO	NOa	Contra Costa
1	Mirant	Contra Costa 7	Operating	1964	340	1148685	11231342	103704	0.0092	9778	0.386	RMR		SF	YES	NO	YES	Contra Costa
39	Duke	Morro Bay Power Plant 1	Retired	1956	163	30826	343384	20521	0.0598	11140	0.022			SCC	YES	NO	NOd	San Luis Obispo
18	Duke	Morro Bay Power Plant 2	Retired	1955	163	80218	852057	51193	0.0601	10622	0.056			SCC	YES	NO	NOd	San Luis Obispo
21	Duke	Morro Bay Power Plant 3	Operating	1962	338	503361	4776954	159684	0.0334	9490	0.17		ISO	SCC	YES	NO	NOd	San Luis Obispo
12	Duke	Morro Bay Power Plant 4	Operating	1963	338	1000637	9545492	336051	0.0352	9539	0.338		ISO	SCC	YES	NO	NOd	San Luis Obispo
50	Duke	Moss Landing Power Pla 6	Operating	1967	739	2276079	20879237	182344	0.0087	9173	0.352		ISO	NCC	YES	NO	YES	Monterey
29	Duke	Moss Landing Power Pla 7	Operating	1968	739	1730249	16032235	281251	0.0175	9266	0.267		ISO	NCC	YES	NO	YES	Monterey
31	Mirant	Pittsburg Power 5	Operating	1960	325	547082	5652989	132775	0.0235	10333	0.192	RMR		SF	YES	NO	YES	Contra Costa
28	Mirant	Pittsburg Power 6	Operating	1961	325	703877	7523108	88369	0.0117	10688	0.247	RMR		SF	YES	NO	YES	Contra Costa
40	Mirant	Pittsburg Power 7	Operating	1972	720	2760981	27536340	1113654	0.0404	9973	0.438			SF	YES	NO	NOa	Contra Costa
17	Mirant	Potrero Power 3	Operating	1965	207	570643	5927227	325825	0.055	10387	0.315	RMR		SF	YES	NO	NOa	San Francisco
24	Dynegy/NRG	Encina 1	Operating	1954	107	152068	1671418	34264	0.0205	10991	0.162	RMR		SD	YES	NO	YES	San Diego
19	Dynegy/NRG	Encina 2	Operating	1956	104	191628	2142231	43916	0.0205	11179	0.21	RMR		SD	YES	NO	YES	San Diego
25	Dynegy/NRG	Encina 3	Operating	1958	110	195769	2143917	43950	0.0205	10951	0.203	RMR		SD	YES	NO	YES	San Diego
33	Dynegy/NRG	Encina 4	Operating	1973	293	933529	10730897	219983	0.0205	11495	0.364	RMR		SD	YES	NO	YES	San Diego
34	Dynegy/NRG	Encina 5	Operating	1978	315	1051716	10982456	225140	0.0205	10442	0.381	RMR		SD	YES	NO	YES	San Diego
43	Port of San Dieg	South Bay Power Plant 1	Operating	1960	147	459135	4654531	60028	0.0129	10138	0.357	RMR		SD	YES	YES	YES	San Diego
9	Port of San Dieg	South Bay Power Plant 2	Operating	1962	150	466098	4400057	52738	0.012	9440	0.355	RMR		SD	YES	YES	YES	San Diego
36	Port of San Dieg	South Bay Power Plant 3	Operating	1964	171	319847	3312646	42271	0.0128	10357	0.214	RMR		SD	YES	YES	YES	San Diego
41	Port of San Dieg	South Bay Power Plant 4	Operating	1971	222	84940	1023633	42206	0.0412	12051	0.044	RMR		SD	YES	YES	YES	San Diego
20	AES	AES Alamitos LLC 1	Operating	1956	175	142973	1809301	56448	0.0312	12655	0.093			SC	YES	NO	YES	Los Angeles
47	AES	AES Alamitos LLC 2	Operating	1957	175	167808	2164441	52874	0.0244	12898	0.109			SC	YES	NO	YES	Los Angeles
8	AES	AES Alamitos LLC 3	Operating	1961	320	1043989	11092851	206735	0.0186	10625	0.372	RMR		SC	YES	NO	YES	Los Angeles
37	AES	AES Alamitos LLC 4	Operating	1962	320	710764	7777048	122890	0.0158	10942	0.254			SC	YES	NO	YES	Los Angeles
45	AES	AES Alamitos LLC 5	Operating	1969	480	1433863	14778258	92473	0.0063	10307	0.341			SC	YES	NO	YES	Los Angeles
10	AES	AES Alamitos LLC 6	Operating	1966	480	619790	6626709	104371	0.0158	10692	0.147			SC	YES	NO	YES	Los Angeles
27	Reliant	Coolwater 1	Operating	1961	65	86692	920494	45130	0.049	10618	0.152		ISO	SDT	NO	NO	NOe	San Bernardino
13	Reliant	Coolwater 2	Operating	1964	81	108811	1122952	100371	0.0894	10320	0.153		ISO	SDT	NO	NO	NOe	San Bernardino
22	Reliant	Coolwater 3	Operating	1978	241	924133	8879376	934507	0.1052	9608	0.438			SDT	NO	NO	NOe	San Bernardino
2	Reliant	Coolwater 4	Operating	1978	241	781626	7657460	819318	0.107	9797	0.37			SDT	NO	NO	NOe	San Bernardino
32	Dynegy/NRG	El Segundo Power 3	Operating	1964	335	1061387	10399010	58862	0.0057	9798	0.362			SC	YES	NO	YES	Los Angeles
30	Dynegy/NRG	El Segundo Power 4	Operating	1965	335	1340186	13301719	99620	0.0075	9925	0.457			SC	YES	NO	YES	Los Angeles
38	Reliant	Etiwanda Generating Sta 3	Operating	1963	320	543179	5969559	69468	0.0116	10990	0.194	RMR		SC	NO	NO	YES	San Bernardino
35	Reliant	Etiwanda Generating Sta 4	Operating	1963	320	258695	3019710	50263	0.0166	11673	0.092	RMR		SC	NO	NO	YES	San Bernardino
26	AES	AES Huntington Beach L 1	Operating	1958	215	647852	7405994	81300	0.011	11432	0.344	RMR		SC	YES	NO	YES	Orange
6	AES	AES Huntington Beach L 2	Operating	1958	215	699436	7633953	87194	0.0114	10914	0.371	RMR		SC	YES	NO	YES	Orange
23	Dynegy/NRG	Long Beach Generation 8	Operating	1976	303	81883	939891			11478	0.031		ISO	SC	YES	NO	NOf	Los Angeles
15	Dynegy/NRG	Long Beach Generation 9	Operating	1977	227	31254	362036			11584	0.016		ISO	SC	YES	NO	NOf	Los Angeles
44	Reliant	Mandalay 1	Operating	1959	215	499331	4710452	23304	0.0049	9434	0.265			SCC	YES	NO	YES	Ventura
48	Reliant	Mandalay 2	Operating	1959	215	564964	5144509	31252	0.0061	9106	0.3			SCC	YES	NO	YES	Ventura
46	Reliant	Ormond Beach 1	Operating	1971	750	1189349	12028916	93498	0.0078	10114	0.181		ISO	SCC	YES	NO	YES	Ventura
42	Reliant	Ormond Beach 2	Operating	1973	750	1210342	12059181	93552	0.0078	9963	0.184			SCC	YES	NO	YES	Ventura
14	AES	AES Redondo Beach LL 5	Operating	1954	175	83476	1127491	79601	0.0706	13507	0.054		ISO	SC	YES	YES	YES	Los Angeles
7	AES	AES Redondo Beach LL 6	Operating	1957	175	47302	670001	24897	0.0372	14164	0.031		ISO	SC	YES	YES	YES	Los Angeles
11	AES	AES Redondo Beach LL 7	Operating	1967	480	965701	9843859	130365	0.0132	10193	0.23		ISO	SC	YES	YES	YES	Los Angeles
49	AES	AES Redondo Beach LL 8	Operating	1967	480	984254	9695744	92965	0.0096	9851	0.234		ISO	SC	YES	YES	YES	Los Angeles
Total					14444	32,312,942	327,138,078	7,506,822										

CEEB Petition

ARNOLD SCHWARZENEGGER, GOVERNOR — OFFICE OF ADMINISTRATIVE LAW

California Regulatory Notice Register

REGISTER 2006, NO. 26-Z — PUBLISHED WEEKLY BY THE OFFICE OF ADMINISTRATIVE LAW — JUNE 30, 2006

PROPOSED ACTION ON REGULATIONS

(Continued on next page)

Time-Dated Material

GENERAL PUBLIC INTEREST

ACCEPTANCE OF PETITION TO REVIEW ALLEGED UNDERGROUND REGULATIONS

SUMMARY OF REGULATORY ACTIONS

The *California Regulatory Notice Register* is an official state publication of the Office of Administrative Law containing notices of proposed regulatory actions by state regulatory agencies to adopt, amend or repeal regulations contained in the California Code of Regulations. The effective period of a notice of proposed regulatory action by a state agency in the *California Regulatory Notice Register* shall not exceed one year [Government Code § 11346.4(b)]. It is suggested, therefore, that issues of the *California Regulatory Notice Register* be retained for a minimum of 18 months.

CALIFORNIA REGULATORY NOTICE REGISTER (USPS 002-931), (ISSN 1041-2654) is published weekly by the Office of Administrative Law, 300 Capitol Mall, Suite 1250, Sacramento, CA 95814-4339. The Register is printed by Thomson West and is offered by subscription for $202.00 (annual price). To order or make changes to current subscriptions, please call (800) 888-3600. "Periodicals Postage Paid in Saint Paul, MN." **POSTMASTER:** Send address changes to the: CALIFORNIA REGULATORY NOTICE REGISTER, Thomson-West/Barclays, P.O. Box 2006, San Francisco, CA 94126. The Register can also be accessed at **http://www.oal.ca.gov.**

OFFICE OF ENVIRONMENTAL HEALTH HAZARD ASSESSMENT

Final Report "Development of Health Criteria for School Site Risk Assessment Pursuant to Health and Safety Code Section 901(g): Child–Specific Reference Doses (chRDs) for School Site Risk Assessment: Manganese and Pentachlorophenol. [06/30/06]

The Office of Environmental Health Hazard Assessment (OEHHA) of the California Environmental Protection Agency announces the availability of the final Report "Development of Health Criteria for School Site Risk Assessment Pursuant to Health and Safety Code Section 901(g): CHILD–SPECIFIC REFERENCE DOSES (chRDs) FOR SCHOOL SITE RISK ASSESSMENT—Manganese and Pentachlorophenol." Health and Safety Code (HSC), Section 901(g) requires the Office of Environmental Health Hazard Assessment (OEHHA), in consultation with the appropriate entities within the California Environmental Protection Agency, to identify those chemical contaminants commonly found at school sites and determined by OEHHA to be of greatest concern based on child–specific physiological sensitivities. HSC 901(g) also requires OEHHA to annually evaluate and publish, as appropriate, numerical health guidance values or chRDs for those chemical contaminants until the contaminants identified have been exhausted.

In developing these chRDs, OEHHA has followed the requirements set forth in Health and Safety Code Section 57003 for receiving public input. The first draft document was posted on the OEHHA Website (www.oehha.ca.gov) in December 2004. A public workshop was held in January 2005 to discuss the scientific basis and recommendations in the draft report. After considering public comments and input from an external peer review panel assembled by the Office of the President, University of California, OEHHA revised the document for additional public review in April 2006. The release of the final document is a culmination of this public input process.

If you would like to receive further information on this announcement or have questions, please contact our office at (916) 324–2829 or the address below or go to the OEHHA Website at www.oehha.ca.gov:

Mr. Leon Surgeon
Integrated Risk Assessment Branch
Office of Environmental Health Hazard Assessment
P.O. Box 4010
1001 I Street, MS–12B
Sacramento, California 95812–4010
FAX: (916) 322–9705

ACCEPTANCE OF PETITION TO REVIEW ALLEGED UNDERGROUND REGULATIONS

STATE LANDS COMMISSION

Office of Administrative Law

Acceptance of Petition to Review Alleged Underground Regulation

The Office of Administrative Law has accepted the following petition for consideration. Please send your comments to:

Kathleen Eddy, Senior Counsel
Office of Administrative Law
300 Capitol Mall, Ste. 1250
Sacramento, CA 95814

You must also send a copy of your comment to the petitioner and the agency contact as identified in the petition. Please refer to CTU–06–0525–01.

May 25, 2006

William L. Gausewitz
Director of Administrative Law
Office of Administrative Law
300 Capitol Mall, Suite 1250
Sacramento, CA 95814–4339

Dear Director Gausewitz:

Enclosed please find a petition submitted pursuant to California Code of Regulations Title 1, Division 1, Chapter 2 regarding the recently adopted Resolution by The California State Lands Commission Regarding Once–Through Cooling in California Power Plants.

Respectfully,

/s/
VICTOR WEISSNER
President

Enclosures

cc: Mr. Paul D. Thayer, Executive Officer, State Lands Commission
Mr. Michael R. Valentine, Chief, Land Management Division, State Lands Commission

PETITION FOR DETERMINATION OF UNDERGROUND REGULATION ADOPTED BY THE STATE LANDS COMMISSION

Introduction

The Office of Administrative Law (OAL) has the authority to address a petition that alleges that a state agency has "issued, used, enforced, or attempted to enforce an underground regulation" pursuant to Title 1, California Code of Regulations Section 260. The California Council for Environmental and Economic Balance (CCEEB) submits this Petition for Determination of Underground Regulation (Petition) and respectfully request that the OAL find that the State Lands Commission (SLC) "Resolution by The California State Lands Commission Regarding Once–Through Cooling In California Power Plants" (Resolution) is an underground regulation and should be voided. CCEEB is an is a nonprofit, nonpartisan coalition of business, labor and public leaders that works to advance policies that protect public health and the environment while also allowing for continued economic growth. CCEEB's members include corporations, unions, and other members of the public. CCEEB is interested in assuring that state agencies create regulations that are well–considered, reasonable, and foster good energy policy. However, the Resolution creates an underground regulation without the benefit of public comments from CCEEB and other members of the public interested in the regulation of coastal power plants. In fact, CCEEB's members include the owners of all the coastal power plants that will be adversely impacted by the State Lands Commission Resolution. Those members include Southern California Edison Company (SCE), San Diego Gas and Electric Company, Cabrillo Power I LLC and El Segundo Power, LLC. Thus, CCEEB submits this Petition, which raises issues of considerable public importance, and requests prompt action by the Office of Administrative Law.

1. Identifying Information:
   California Council for Environmental and Economic Balance
   Victor Weisser, President
   100 Spear Street Suite 805
   San Francisco, CA 94105
2. State Agency Issuing Underground Regulation:
   State Lands Commission
3. Description of the Underground Regulation being Challenged:
   a. Background of SLC Resolution

The SLC has approved the Resolution based upon the SLC concerns with the claimed environmental impacts associated with once–through cooling water systems at power plants located along the California coast. The Resolution was proposed for adoption at the SLC meeting on February 9, 2006. The SLC deferred the vote on the Resolution at that meeting, and adopted the Resolution at its April 17, 2006 meeting. The text of the Resolution is Attachment 1 to this Petition.

   b. Summary of SLC Resolution

A full description of the Resolution is contained in the Staff Report regarding the Resolution that is Attachment 2 to this Petition. The SLC Resolution makes conclusions regarding the alleged impacts of once–through cooling on the marine environment. Many of the conclusions are unsupported by evidence regarding claimed environmental impacts. As a result of these alleged impacts, the Resolution imposes, in part, significant regulatory constraints on existing power plants or new plants that would be, under the jurisdiction of the Commission. For example, the Resolution provides that the SLC "shall not approve leases for new power facilities that include once–through cooling technologies . . ." The Resolution also creates a restriction on the SLC ability to issue new leases, or lease extensions or amendments, based upon how a power plant is complying with laws outside the SLC jurisdiction. Additionally, the Resolution requires that the SLC include a provision in extended leases that allows the SLC to re–open a lease under certain circumstances.

4. Description of the Agency Action

The SLC adopted the Resolution by a 3–0 vote at its April 17, 2006 meeting without complying with the California Administrative Procedure Act. (See April 17, 2006 Agenda Voting Record, which is Attachment 3 to this Petition.)

5. Legal Basis that the Resolution is an Underground Regulation
   a. Requirements for the Promulgation of Regulations.

The California Administrative Procedure Act (APA) was passed to "establish basic minimum procedural requirements for the adoption of administrative regulations." (Government Code Section 11346) The APA provides that no state agency shall "issue, utilize, enforce, or attempt to enforce any guideline, criterion, bulletin, manual, instruction, order, standard of general application, or other rule, which is a regulation as defined in Section 11342.600" unless the action has been adopted as a regulation under the APA. (Government Code Section 11340.5; *Morning Star Co. v. State Board of Equalization*, 2006 Lexis 3953, April 24, 2006 at pp. 15–16) The APA also gives the OAL the authority to determine if the action is a regulation that has not been properly adopted pursuant to the APA. (Government Code Section 11340 et seq.)

The OAL has recently issued regulations that establish a procedure for reviewing agency actions that are regulations that have not been through the required APA process. The OAL calls such actions "underground regulations". The OAL regulations at 1 CCR §250(a) define "underground regulation" as any

> guideline, criterion, bulletin, manual, instruction, order, standard of general application, or other rule that is a regulation as defined in Section 11342.600 of the Government Code, but has not been adopted as a regulation and filed with the Secretary of State pursuant to the APA and is not subject to an express statutory exemption from adoption pursuant to the APA.

Government Code Section 11342.600 defines a "regulation" as:

> every rule, regulation, order, or standard of general application or the amendment, supplement, or revision of any rule, regulation, order, or standard adopted by any state agency to implement, interpret, or make specific the law enforced or administered by it, or to govern its procedure.

Government Code Section 11346 is consistent with the broad definition of "regulation" in Section 11342.600; Section 11346 provides that the APA applies to the exercise of any quasi–legislative power conferred upon any agency by any statute.

b. SLC Resolution

The Resolution By The California State Lands Commission Regarding Once–Through Cooling In California Power Plants was adopted by the SLC at its April 17, 2006 meeting. The SLC did not subject the Resolution to the process required for regulations by the APA. The Resolution contains a rule, order, and standard of general application that is a regulation. Specifically, three of the "resolved" clauses in the SLC Resolution are underground regulations because of the requirements that they impose on the SLC and the effect that they will have on SLC leases to power plant operators. The three resolved clauses are as follows:

- "Resolved, that as of the date of this Resolution, the Commission shall not approve leases for new power facilities that include once–through cooling technologies; and be it further
- Resolved, that the Commission shall not approve new leases for power facilities, or leases for re–powering existing facilities, or extensions or amendments of existing leases for existing power facilities, whose operations, include once–through cooling, unless the power plant is in full compliance, or engaged in an agency–directed process to achieve full compliance, with requirements imposed to implement both Clean Water Act Section 316(b) and the California water quality law as determined by the appropriate agency, and with any additional requirements imposed by state and federal agencies for the purpose of minimizing the impacts of cooling systems on the environment, and be it further
- Resolved, that the Commission shall include in any extended lease that includes once–through cooling systems, a provision for noticing the intent of the Commission to consider re–opening the lease, if the appropriate agency has decided, in a permitting proceeding for the leased facility, that an alternative, environmentally superior technology exists that can be feasibly installed, and that allows for the stability of the electricity grid system, or if state and federal law or regulations otherwise require modification of the existing once–through cooling system, and be it further"

c. SLC Jurisdiction

The SLC is the state agency charged with regulating the use of state lands, including tide lands and public trust lands upon which are located once–through cooling water facilities. (See Division 6 of the Public Resources Code.) Public Resources Code Section 6501.1 provides that the SLC may lease lands owned by the state, and under the SLC's jurisdiction, for whatever purposes the SLC deems advisable, including for industrial purposes like the operation of a power plant. Public Resources Code Section 6502 provides that any person desiring to lease land from the state may apply to the SLC for such permission. The SLC has the right to reject that application. The SLC has previously promulgated a number of regulations that allow it to implement this authority. These regulations begin at Title 2 CCR §2000. For example, the Southern California Edison Company (SCE) and San Diego Gas & Electric Company (SDG&E) hold a 49 year lease from the SLC for the intake and discharge structures that constitute a critical piece of the once–through cooling water system for the San Onofre Nuclear Generating Station Units 2 and 3 (SONGS).[1] Attachment 2 lists ten power plants that operate subject to SLC leases. In fact, Attachment 2 shows that two power plants have leases that have expired and are operating in holdover status, and a third lease will expire in August 2006.

d. The SLC Resolution is a Regulation

The SLC Resolution is a regulation that precludes the SLC from issuing new leases for power plants that would have once–through cooling structures. The Resolution also precludes the issuance of lease extensions or amendments for other power plants depending upon how the power plant is complying with state water qual-

[1] SONGS is jointly owned by SCE, San Diego Gas & Electric Company, and the cities of Anaheim and Riverside. SCE is the operating agent for these other entities.

ity laws. Additionally, the Resolution requires that the SLC include a provision in extended leases that allows the SLC to re-open a lease under certain circumstances. The Resolution establishes a set of rules that is generally applicable to all current, or future, power plants that have once-through cooling systems. The California Supreme Court in *Tidewater Marine Western Inc. v. Victoria Bradshaw*, 14 Cal. 4th 557, 571 (1996), citing *Union of American Physicians & Dentists v. Kizer*, 223 Cal. App. 3d 490, 497 (1990), explained that a regulation subject to the APA has two principal identifying characteristics:

> First, the agency must intend its rule to apply generally, rather than in a specific case. The rule need not, however, apply universally; a rule applies generally so long as it declares how a certain class of cases will be decided. (*Roth v. Department of Veterans Affairs* (1980) 110 Cal. App. 3d 622, 630 [167 Cal. Rptr. 552].) Second, the rule must "implement, interpret, or make specific the law enforced or administered by [the agency], or . . . govern [the agency's] procedure." (Gov. Code, § 11342, subd. (g).) *See also, Morning Star Co. v. State Board of Equalization*, 2006 Lexis 3953, April 24, 2006 at pp. 18-19.

Moreover, the *Tidewater* court concluded that a "written statement of policy that an agency intends to apply generally, that is unrelated to a specific case, and that predicts how the agency will decide future cases is essentially legislative in nature even if it merely interprets applicable law." *Tidewater*, at p. 574-575. See also *Yamaha Corp. of America v. State Bd. of Equalization*, 19 Cal. 4th 1, 18 (1998).

The SLC Resolution applies to the general class of once-through cooling water structures located on state lands. The fourth "Whereas" clause in the resolution states that there are 21 power plants along the California Coast that use once-through cooling systems. Attachment 2 concludes that 10 of these power plants are subject to the SLC's jurisdiction. Thus, these 10 power plants would be subject to the SLC regulatory prohibitions established by the Resolution. The SLC's intent is to eliminate the perceived environmental impacts associated with these once-through cooling water systems. Thus, the Resolution meets the first prong of the *Tidewater* case — the Resolution is not limited to a specific case, but is applicable to all once-through cooling water facilities located on state lands within the SLC's jurisdiction.

Next, the Resolution meets the second prong of the *Tidewater* test. The Resolution emphatically directs the SLC as to how it shall implement the existing lease regulations when applications are filed for once-through cooling water systems. The Resolution is clear; the SLC "shall not approve leases for new power facilities that include once-through cooling technologies. . ." The other two resolved clauses listed above contain similar directives. For instance, the SCE lease from the SLC for the SONGS Units 2 and 3 intake and discharge structures will expire on February 28, 2023. The SLC would be unable to issue a lease extension to SCE to allow SCE to continue to operate the SONGS cooling water structures after February 28, 2023 without including the re-opener provision required by the third "resolved" clause. Therefore, the Resolution makes specific how the SLC will process lease applications and requests for extensions and amendments for once-through cooling water power plants, which meets the second prong of the two part test in *Tidewater*. As the Resolution meets the *Tidewater* test as a regulation, the Resolution is a regulation and must go through the APA.

e. The SLC Resolution Has Not Used the APA

The SLC did not follow the APA in implementing the Resolution. According to the California Supreme Court:

> The APA establishes the procedures by which state agencies may adopt regulations. The agency must give the public notice of its proposed regulatory action (Gov. Code, § 11346.4, 11346.5); issue a complete text of the proposed regulation with a statement of the reasons for it (Gov. Code, § 11346.2, subds. (a), (b)); give interested parties an opportunity to comment on the proposed regulation (Gov. Code, § 11346.8); respond in writing to public comments (Gov. Code, § 11346.8, subd. (a), 11346.9); and forward a file of all materials on which the agency relied in the regulatory process to the Office of Administrative Law (Gov. Code, § 11347.3, subd. (b)), which reviews the regulation for consistency with the law, clarity, and necessity (Gov. Code, § 11349.1, 11349.3). *Tidewater* at p. 568.

For example, the SLC did not submit a copy of the Resolution to the Office of Administrative Law for review. Nor has the SLC provided a statement of reasons for the Resolution that meets the requirements in Government Code Section 11346.2.

f. The SLC Resolution is Not Exempt From the APA

Petitioner is unaware of any statutory exemption from the APA that would allow the SLC to pass the Resolution without compliance with the APA.

6. The Public Importance of the Petition

a. Adverse Effects on the State Wide Energy System

In adopting the Resolution, the SLC took action to stop the issuance of new or extended leases for power facilities utilizing once–through cooling without sufficiently considering evidence as to how that action might negatively and severely affect statewide generation. All 21 plants operate with once–through cooling water systems and represent 24,000 megawatts of generation, which accounts for over 45% of the in–state power generation. The passage of this Resolution casts an immediate cloud over future capital expenditures at these facilities for such things as installation of upgrades, air pollution controls and repowers (significant reconstruction of critical power plant infrastructure with new, state of the art equipment).

The Resolution creates regulatory uncertainty that frustrates long–term electric reliability planning. The Resolution may have a chilling effect on capital investments and result in early, unanticipated plant retirements that will jeopardize electric reliability. Owners of affected facilities may be disinclined to invest in capital projects with long pay–back periods such as reliability upgrades or pollution control equipment. In such cases, electricity consumers may be forced to shoulder higher costs to maintain short–term reliability of critical power plants considered by the state to be "reliability must–run" facilities. Similarly, the Resolution may dissuade facility owners from repairing equipment that suffers a sudden, catastrophic failure. In the event of such a failure, the uncertainty resulting from the Resolution may cause a facility owner to shut down a plant long before the Resolution may have otherwise have forced it to close.

The electric power grid relies on a balance of generation, transmission and demand. The locations of the power plants targeted by the SLC Resolution were originally chosen both for the availability of cooling water and their proximity to high–population areas with high electric demand. The infeasibility of converting existing power plants to alternative cooling technologies may force the plants to close and require that they be replaced with new generation. However, a number of factors such as land use zoning, property costs, visual impacts, unavailability of emission reduction credits, and noise, may prohibit construction of replacement generation that does not use once–through cooling on the sites of existing power plants. If the existing power plants are replaced with new generation that is not similarly located, new transmission lines will be required to transport electricity to the areas of high electric demand. Transmission lines are not only expensive, but the significant losses of power resulting from increased transmission distances compound the negative environmental and economic effects resulting from less efficient electric generation using alternative cooling technologies. Moreover, the existing power plants provide important electric reliability services—such as voltage support, contingency reserves and regulating reserves—that cannot be provided by remotely located electric generation. The SLC did not consider the potential effects of the Resolution on electric reliability and costs to electric consumers.

No comprehensive study has been performed to determine if these coastal power plants could continue to operate other than with a once–through cooling system. To convert the plants to cooling towers using degraded groundwater, recycled water, or ocean water would undoubtedly cost millions of dollars per plant, if such a conversion were even feasible. Any conversion would have potential environmental impacts associated with the installation and operation of cooling towers, which have also not been studied.

b. State Wide Environmental Adverse Effects and Lack of Commensurate Benefits

The SLC Resolution is specific in the actions to eliminate the use of once–through cooling systems at power plants, but vague in the benefits that would result from that elimination. In adopting the Resolution, the SLC did not sufficiently evaluate the specific environmental and economic impacts that may occur as a result of that action. The SLC cites the impacts of only one power plant, San Onofre Nuclear Generating Station, and does so without providing any context for that citation, as evidence that once–through cooling as a technology is categorically unacceptable. Although the Resolution may affect any number of existing or future proposed power plants, the SLC did not evaluate how or if eliminating once–through cooling at every site would provide the environmental benefits the SLC relies on to justify their action.

The SLC Resolution wrongfully cites the availability and use of an alternative cooling technology at other locations in California and nation as evidence that such technologies are feasible for conversions at plants currently using once–through cooling systems. However, there is no supporting analysis by which the SLC shows on a site–by–site basis the practical and economic feasibility for such a conversion. Thus, the SLC can neither cite the specific benefits that would result from eliminating OTC nor can they cite the environmental and economic costs to achieve any perceived benefits.

Converting existing power plants that utilize once–through cooling to any other form of cooling will lower power plant efficiency. This means that more fuel will need to be burned just to maintain equivalent electrical generation. Increased fuel consumption will result in increased emissions of criteria pollutants such as nitrogen oxides, particulate matter, and carbon monoxide. Increased fuel consumption will also result in an increase in greenhouse gas emissions, specifically carbon dioxide. These increases in air pollutant emissions to provide some vague and un–quantified environmental benefit run contrary to ongoing state policies and actions to reduce emissions of criteria and greenhouse gas pollutants.

Dry cooling systems reduce a power plant's generating efficiency by nearly 9%. To compensate for this impact, additional electric generation must take place. This generation generally will be from natural gas–fired power plants and, assuming no ocean cooling, will result in an estimated 27 tons of additional particulate matter (PM 10) emissions for wet cooling towers and 483 tons for dry cooling systems.[2] Statewide, annual CO_2 emissions will increase 311, 491 metric tons for wet cooling towers and 1,914,837 metric tons for dry cooling systems. If potable water wet cooling towers were used to replace all of the once–through cooling systems, over 20 billion gallons of water would be consumed annually.[3] Preliminary estimates are that twelve of the 21 coastal power plants cannot switch to cooling tower systems because of space restraints or land use restrictions.

The United States Environmental Protection Agency has already addressed the environmental effects of Once Through Cooling and generation companies are working to be in compliance with these requirements. The implementation of the regulations will be through the State Water Resources Control Board (SWRCB). In June, the SWRCB will begin the process of developing guidance for the Regional Water Quality Control Boards for the implementation of the Clean Water Act section 316(b) requirements for Once Through Cooling. The Board staff has indicated they will use the SLC Resolution as the official state policy on once through cooling. Thus, the implementation of the 316(b) requirements will be driven by the State Lands Commission resolution.

7. Certification of Petition Submittal to the State Lands Commission

The undersigned, Victor Weisser, certify that I have submitted a copy of this Petition and all its attachments to:

[2] Dry or air cooling towers are much less efficient than wet cooling towers, accounting for the higher replacement power and emissions numbers.

[3] On June 19, 1975, the State Water Resources Control Board adopted its "Water Quality Control Policy on the Use and Disposal of **Inland** Waters Used for Powerplant Cooling." (emphasis added) The policy states in relevant part: "Where the Board has jurisdiction, use of fresh inland waters for powerplant cooling will be approved by the Board only when it is demonstrated that the use of other water supply sources or other methods of cooling would be environmentally undesirable or economically unsound." The Policy also states: "It is the Board's position that. . .the source of powerplant cooling water should come from the following sources in this order of priority. . .(1) wastewater being discharged to the ocean, (2) ocean, (3) brackish water from natural sources or irrigation return flow, (4) inland wastewaters of low TDS, and (5) other inland waters."

Mr. Paul Thayer
Executive Officer
State Lands Commission
100 Howe Avenue, Suite 100 South
Sacramento, California 95825–8202
Phone Number: (916) 574–1800

All of the above information is true and correct to the best of my knowledge.

By: ____________________ Date: 5/25/06

Victor Weisser
President
California Council for Economic and Environmental Balance

SUMMARY OF REGULATORY ACTIONS

REGULATIONS FILED WITH SECRETARY OF STATE

This Summary of Regulatory Actions lists regulations filed with the Secretary of State on the dates indicated. Copies of the regulations may be obtained by contacting the agency or from the Secretary of State, Archives, 1020 O Street, Sacramento, CA, 95814, (916) 653–7715. Please have the agency name and the date filed (see below) when making a request.

AIR RESOURCES BOARD
Reporting Requirements for Transit Agencies

This non–substantive change makes sense of Title 13 section 2023.4(e)(1)(C). As drafted and enacted, a particular report must be submitted a transit agency by January 31, 2009 analyzing the NOx fleet average reduction requirements. The report submitted by the agency due on January 31, 2009 the average NOx emission for the agency's fleet. If the average exceeds that required by the regulations, the report must include a schedule of actions planned to achieve compliance by December 31, 2007. This rulemaking changes the schedule deadline to achieve compliance to December 31, 2010, as it would be impossible to achieve compliance through any series of plans retroactively.

Title 13
California Code of Regulations
AMEND: 2023.4
Filed 06/16/06
Effective 07/16/06
Agency Contact: Alexa Malik (916) 322–4011

TRIANGLE ECONOMIC RESEARCH
A BBL Company

Benefits Valuation Study for Diablo Canyon Power Plant

Final Report

Prepared for:

Pacific Gas and Electric Company
77 Beale Street
San Francisco, CA 94105

Prepared by:

Matthew F. Bingham
Ateesha F. Mohamed
Jason C. Kinnell
Leigh A. Hostetter
William H. Desvousges

February 21, 2005

2775 Meridian Parkway
Durham, NC 27713

•

Phone: 919-544-2244
Fax: 919-544-3935
E-mail: info@ter.com

Item No. 15 Attachment 4
September 9, 2005 Meeting
PG&E Diablo Canyon Power Plant

Benefits Valuation Study for Diablo Canyon Power Plant

Final Report

Prepared for:

Pacific Gas and Electric Company
77 Beale Street
San Francisco, CA 94105

Prepared by:

Matthew F. Bingham
Ateesha F. Mohamed
Jason C. Kinnell
Leigh A. Hostetter
William H. Desvousges

Triangle Economic Research
2775 Meridian Parkway
Durham, NC 27713

February 21, 2005

Project No. 23205

TER
A BBL Company

Table of Contents

List of Figures and Tables

Figure **Page**

Table **Page**

1. OVERVIEW AND EXECUTIVE SUMMARY

Cooling water intake structures (CWIS) are regulated under Section 316(b) of the Clean Water Act. This statute directs the United States Environmental Protection Agency (EPA) to assure that the location, design, construction, and capacity of CWIS reflect the best technology available (BTA) for minimizing adverse environmental impact (AEI). EPA is developing national performance standards for CWIS in three phases. The Phase II Rule, which was promulgated in July 2004,[1] applies to existing electric generating plants with significant cooling water intake capacity and requires these plants to reduce impingement mortality and entrainment (I&E) of aquatic organisms according to national standards.[2] In developing the Phase II Rule, EPA included two conditions under which a facility may be allowed a site-specific determination of standards.[3] One such condition occurs when the costs of compliance are significantly greater than the associated economic benefits. The regulatory requirements for demonstrating this condition include the submission of three studies: the Cost Evaluation Study, the Benefits Valuation Study, and the Site-Specific Technology Plan.

Triangle Economic Research (TER) has prepared this Benefits Valuation Study (BVS) report for Pacific Gas and Electric Company's (PG&E's) Diablo Canyon Power Plant (DCPP or Plant). In preparing this report, we followed EPA's benefit valuation methodologies developed for the Phase II Rule, and incorporated site-specific I&E information developed by Tenera Environmental. We also include information from EPA's I&E reduction benefits studies for Northern California and for all California (EPA 2003; EPA 2004).

The major findings of the BVS include the following:

- The annual baseline losses for 16 representative indicator species (RIS) of fishes and shellfishes are in the range of $18,635 to $34,206, with a mean

[1] The Phase II Rule is being judicially challenged by environmental and industry groups. The appeal is currently pending in the U.S. Court of Appeals, Second Circuit. The Phase II Rule has not been stayed pending appeal, and therefore is currently effective.

[2] Impingement occurs when fish and aquatic species become trapped on equipment at the entrance of the cooling system. Entrainment occurs when aquatic organisms, eggs, and larvae are taken into the cooling system, through the heat exchangers, and discharged back into the waterbody.

[3] A site-specific determination implies less stringent reduction standards.

of $26,412. The RIS account for approximately 70 percent of the fishes and shellfishes that are entrained.

- The annual benefits of reducing impingement mortality by 80 to 95 percent and entrainment by 60 to 90 percent for the RIS range from $13,280 to $27,220, with a mean of $19,863.[4]
- The present value of economic benefits from compliance to 2023 for RIS species ranges from $167,661 to $343,655.[5,6]
- The present value of economic benefits from compliance to 2053 for RIS species ranges from $281,342 to $576,667.[6,7]
- The annual benefits of reducing impingement mortality by 80 to 95 percent and entrainment by 60 to 90 percent for all species (including the additional 30 percent of forage fish larvae not specifically evaluated during the 316(b) Demonstration Study) range from $18,971 to $38,886. The present value of economic benefits from compliance to 2023 for all species ranges from $239,516 to $490,936. The present value of economic benefits from compliance to 2053 ranges from $401,917 to $823,809.[6]
- The annual benefits of eliminating all I&E (including the additional 30 percent of forage fish larvae not specifically evaluated during the 316(b) Demonstration Study) range from $26,621 to $48,866. The present value of economic benefits from eliminating all I&E until 2023 ranges from $336,098 to $616,934. The present value of economic benefits from eliminating all I&E until 2053 ranges from $563,986 to $1,035,240.[6]
- The species with the highest economic impacts are California Halibut, Brown Rock Crab, and Kelpfish.
- Recreational fishing accounts for 56 percent of the total economic impacts.
- Impingement accounts for only about 2 percent of all economic impacts.
- Under EPA guidance, nonuse benefits should not be monetized in this case, and in any event are likely to be minimal.

The foregoing economic impact estimates are conservative because:

- We assume that aquatic populations do not biologically compensate for I&E impacts.
- We assume that no organisms survive entrainment.

[4] The Phase II Rule states that a facility must reduce impingement mortality by 80 to 95 percent and entrainment by 60 to 90 percent to be in 316(b) compliance.

[5] The NRC licenses for Units 1 and 2 at the DCPP expire in 2022 and 2024, respectively. We therefore assumed full operations of both units until 2023 to facilitate this analysis.

[6] We use a 3-percent discount rate for recreational and forage values, a 7-percent discount rate for commercial values, and assume immediate compliance with the Rule.

[7] A final decision has not been made to seek renewal of the NRC licenses. We have assumed for analytic and illustrative purposes only that the Plant will continue to operate until 2053.

- We assume that the availability of forage species limits populations of commercially and recreationally valuable species.
- We assume that 316(b) compliance is instantaneous.

2. BACKGROUND

Estimating the economic benefits of reducing I&E at existing CWIS requires quantifying all beneficial ecological outcomes and assigning appropriate monetary values. Estimating economic benefits in this context is challenging because it requires first linking reductions in I&E to ecosystem changes and then linking ecosystem changes to the resulting changes in quantities and values for the associated environmental goods and services that ultimately are linked to human welfare (EPA 69 *Fed. Reg.* 41,655, July 9 2004). This section provides background on the DCPP's potential ecological impacts and the ecological and economic methodologies used by EPA for assessing the benefits of I&E reductions in the Phase II Rule.

2.1 Ecological Endpoints

Tenera Environmental conducted the Plant's 316(b) entrainment study from October 1996 through June 1999 and submitted a final report in March 2000 (Tenera Environmental 2000). The entire study was conducted under the auspices of an Entrainment Technical Work Group (ETWG) that was assembled by the California Regional Water Quality Control Board, Central Coast Region (RWQCB), to assist their staff in assuring the adequacy of the study's design and implementation. The ETWG was composed of PG&E and their consultants, the RWQCB and their consultants, a consultant to the League for Coastal Protection, the California Department of Fish and Game, and the EPA.

The process of identifying organisms for assessment at DCPP included a consideration of guidelines presented in the original 316(b) directive developed by EPA's (1977) draft *Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500.* Based on this guidance, the following criteria were used to select the target organisms:

- Organisms that were representative, in terms of their biological requirements, of a balanced, indigenous community of fish, shellfish, and wildlife;
- Commercially or recreationally valuable species (e.g., among the top ten species landed – by dollar value);
- Threatened or endangered species;

- Species critical to the structure and function of the ecological system (i.e., habitat formers);
- Species potentially capable of becoming localized nuisance species;
- Species necessary in the food chain for the well-being of those species identified in the first four bullets above;
- Species meeting any of the foregoing criteria with potential susceptibility to impingement and/or entrainment.

In addition to those EPA standards, the ETWG included three additional criteria:

- Organisms capable of being identified to the species level;
- Organisms that are entrained in sufficient abundance to allow for a robust impact assessment;
- Organisms whose adult and larval populations can be demonstrated to be local (i.e., not a deep-water species whose larvae drifted ashore).

These additional criteria were important in contributing to the level of confidence in the estimates of entrainment effects. The most important criterion was abundance; therefore, the assessment was based only on the most abundant organisms. The organisms meeting the criteria included 14 species of larval fishes, 2 species of larval *Cancer* spp. crabs, and larval sea urchins. The ETWG determined the final list of species included in the assessment based mainly on data collected during this study and the criteria listed above. The 14 fishes accounted for the predominant species and for approximately 70 percent of the total number of larval fishes collected from the entrainment samples. The remaining 30 percent of the larval fishes were a mix of recreational, commercial, and forage species.[8]

The ETWG reviewed other potential target organism groups for possible inclusion in the assessment, but those groups were intentionally excluded from the Study. For example, the ETWG decided not to include phytoplankton, zooplankton, and algal spores in the assessment due to their large populations, and in the case of phytoplankton and zooplankton, their short generation times. EPA has previously expressed similar views with respect to phytoplankton and zooplankton (EPA 1998). In sum, it was readily apparent that the DCPP's intake would only have negligible, localized impacts on these organisms.

[8] The remaining 30 percent are valued in this analysis.

Fish eggs and larvae from several commercially important invertebrates such as clams and abalone were also excluded from the assessment by the ETWG, in part because they are small and difficult to identify to the species level. More importantly, there was a very low likelihood that any abalone larvae would be entrained, and there is no suitable substrate for the settlement of Pismo clams near the DCPP. Fish eggs were excluded because most of the fishes at issue have egg stages that are not likely to be entrained: i.e., either they are demersal/adhesive eggs or they are internally fertilized and extrude free-swimming larvae. EPA has previously expressed a similar view with respect to fish eggs (EPA 1998). Young squid were not analyzed because they are competent swimmers immediately after hatching, and therefore would have a low probability of entrainment.

In fact, as the ETWG itself found appropriate for the DCPP, most ecological assessment endpoints for 316(b) studies include only fish and shellfish species (EPA 1998). Indeed, the other organisms entrained have no measurable value other than potential nonuse value (see discussion below). Not surprisingly, EPA itself limited its Phase II benefits valuation to fish and shellfish.

Tenera Environmental developed the impingement data used in this BVS based on a study conducted from April 1985 to March 1986 (Tenera 1988). Their study indicated that impingement by the CWIS' traveling screens was so minor that detailed analysis was not necessary. Nevertheless, we include impingement estimates in this BVS.

2.2 Identifying Ecological and Economic Impacts

In theory, it should be possible to quantify ecosystem changes from I&E impacts through direct observation of ecosystem changes and statistical isolation of the influence of water withdrawal. In practice, however, efforts of this nature have failed to identify a significant relationship between the volume of cooling water withdrawn and the status of local fish populations (EPRI 2003). The problem with this approach lies in the large *natural* population fluctuations that are typical for aquatic organisms.

Faced with this situation, EPA expended considerable effort developing methodologies to quantify the impacts of I&E.[9] Over the course of developing its methodologies, EPA made substantial improvements in identifying theoretically appropriate methods for measuring benefits, and TER now believes that EPA has developed a reasonable approach for evaluating the ecological impacts of I&E.[10] In the final Phase II Rule, we believe EPA also identified a reasonable approach for evaluating the economic impacts of I&E on commercial and recreational species. Accordingly, the approach used for evaluating impacts from I&E to commercial and recreational species in this report generally follows that of EPA's most recent analysis.[11]

In that analysis, EPA estimated a national total of $83 million in annual benefits that could be achieved by reducing the I&E of commercial and recreational species. The EPA estimate does not include the value of impacts to forage species or organisms that are not directly recreationally or commercially valuable. This BVS, however, does value forage species impacts using the methodology described in EPA's final Phase II Rule (EPA 2004, Chapter A5: I&E Methods). In the assessment, we assume that populations of recreational and commercially valuable species are limited due to availability of forage populations.[12] Accordingly, lost forage species are valued in terms of the larger populations of recreational and commercial fish that they would have supported had the forage species not been impinged or entrained.

2.3 I&E, Fishing, and Population Growth

Evaluating the economic impacts of I&E requires understanding the potential ecological effects of I&E. To do so, we characterize a fishery using the growth and population model developed by Schaefer (1954, 1957). This model recognizes that most fish stocks follow a population-dependent growth pattern, as illustrated in Figure 1.

[9] TER has been substantially involved in the evaluation of the methods developed by EPA. See Bingham, Mohamed, and Desvousges (2003) and Desvousges, et al. (2002).

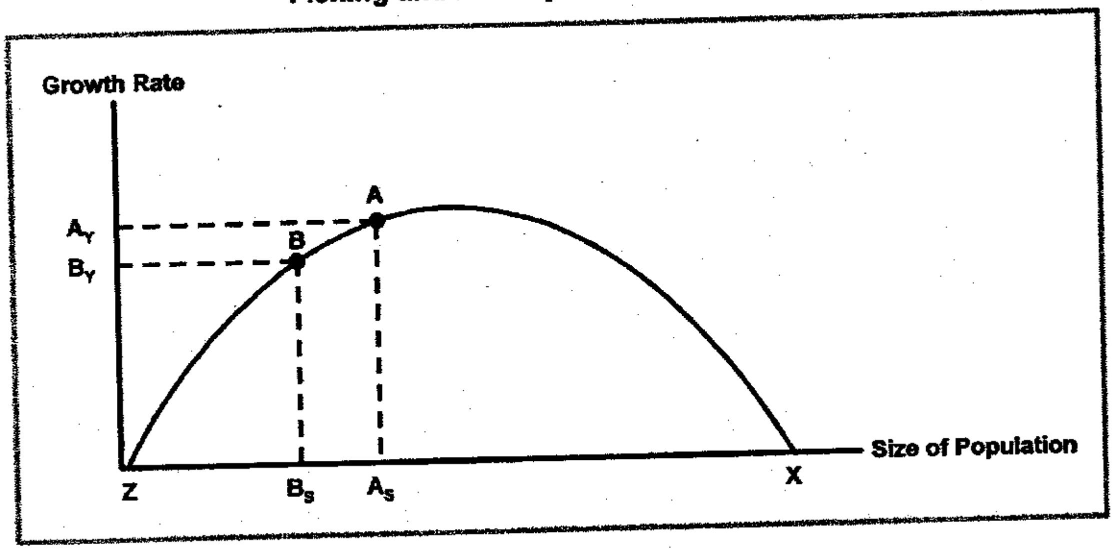
[10] There are shortcomings with EPA's approach, which likely tend to overstate benefits. For example, EPA has been criticized for not considering the ability of aquatic populations to offset I&E impacts through higher productive and survival rates.

[11] The only significant exception is in our analysis of commercial impacts, where we employ an approach that EPA has acknowledged is more theoretically appropriate and that returns higher economic impact estimates.

[12] If this is not the case, our assessment provides overestimates of economic losses.

Figure 1 depicts the relationship between the growth in fish stock on the vertical axis and the size of the fish population on the horizontal axis.[13] Point A is the starting population, which includes I&E and fishing impacts. It would be possible to sustain the population at A_s if the total impacts were equal to the growth in the fish population (A_y). For example, if the growth rate is 10 percent per year (A_y) and the starting population is 100 fish (A_s), then it would be possible to harvest 10 fish per year, starting at the end of the first year, without affecting the size of the population. Point B illustrates the results of overharvesting due to increased I&E and fishing impacts on the fish population. The lower population level (B_s) and corresponding lower growth rate (B_y) indicate that the number of harvested fish is now greater than the growth in the population. If overharvesting persists in this manner, the fish population will continue to decline.

Figure 1
Fishing and I&E Impacts on Population



In the Phase II Rule, EPA mentions that secondary effects of I&E include decreased recruitment, decreased fishing yields, and reduced ecosystem productivity (Chapter A1: Risk Assessment Framework). However, EPA does not account for these potential secondary effects in their national benefits analysis.

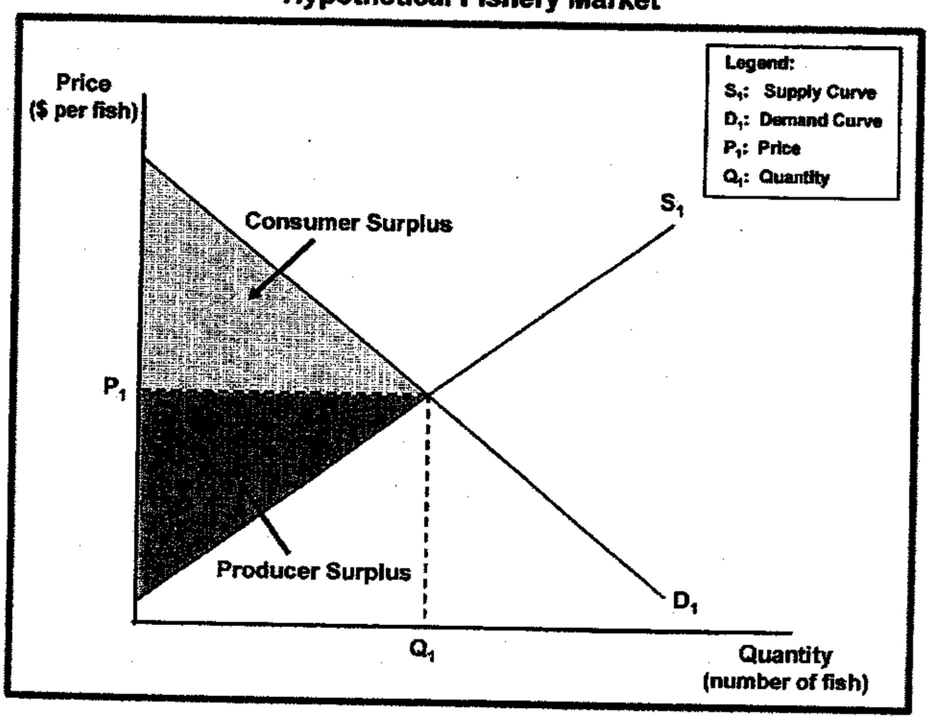
[13] X represents the carrying capacity of the fish population in a state of *natural or stable equilibrium*. The carrying capacity is the maximum fish population that can be sustained in the absence of the fishery and I&E. If the fish population exceeds X, natural mortality rates increase such that the fish population returns to the natural equilibrium. Z is the minimum viable population or the point of extinction.

2.4 Fishery Valuation Overview: Use Values

Unlike traditional physical and financial assets, natural resources such as fisheries are generally owned by the public. Although the values of publicly owned resources are not directly revealed in a marketplace, resource economists have well-established methodologies for measuring fishery value. Over a particular time period, the value of a fishery is equal to the difference between the cost of harvesting fish and the value of the fish harvested.

Figure 2 shows how a commercial fishery's value is determined in a hypothetical market for harvested fish.[14] In this figure, the price of fish is on the vertical axis and the quantity of fish harvested is on the horizontal axis. The supply curve (S_1) represents how many fish the producers are willing to supply at a given price. The demand curve (D_1) corresponds to the maximum cost per fish that consumers are willing to pay for different quantities of harvested fish. The demand curve slopes downward to indicate that the value of each fish drops as the quantity of fish in the market increases.

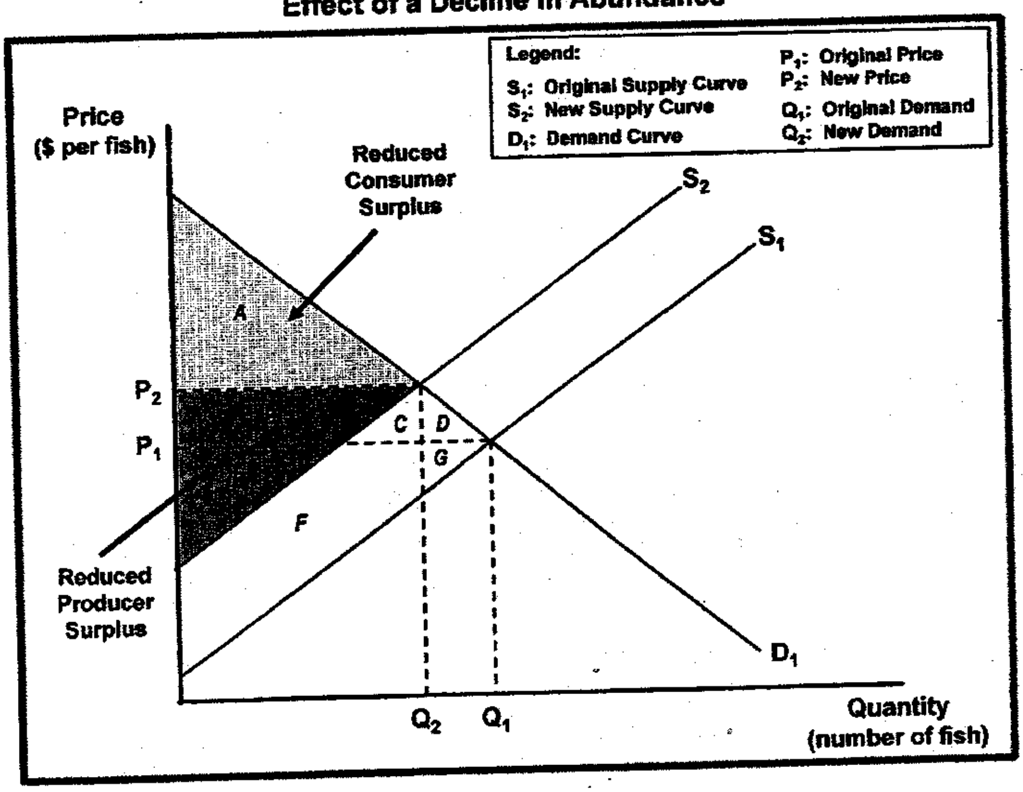
Figure 2
Hypothetical Fishery Market



[14]A value for recreational fisheries can be derived using a similar approach.

The value of this fishery is equal to the difference between the cost of harvest (area above the supply curve) and the value of the fish harvested (area below the demand curve). Graphically, this is shown in the shaded areas of Figure 2. Note that the value of the fishery is the sum of producer and consumer surplus. Producer surplus is the difference between the costs that fishermen incur to harvest the fish (as represented by the supply curve) and the market price (P_1). In Figure 2, producer surplus is the darker shaded area between the supply curve and the market price. Consumer surplus is the difference between the maximum price that consumers are willing to pay for harvested fish (as represented by the demand curve) and the market price (P_1). In Figure 2, consumer surplus is the lightly shaded area between the demand curve and the market price. This simple framework also provides the necessary background for evaluating how a change in abundance affects the value of a fishery, as seen in Figure 3.

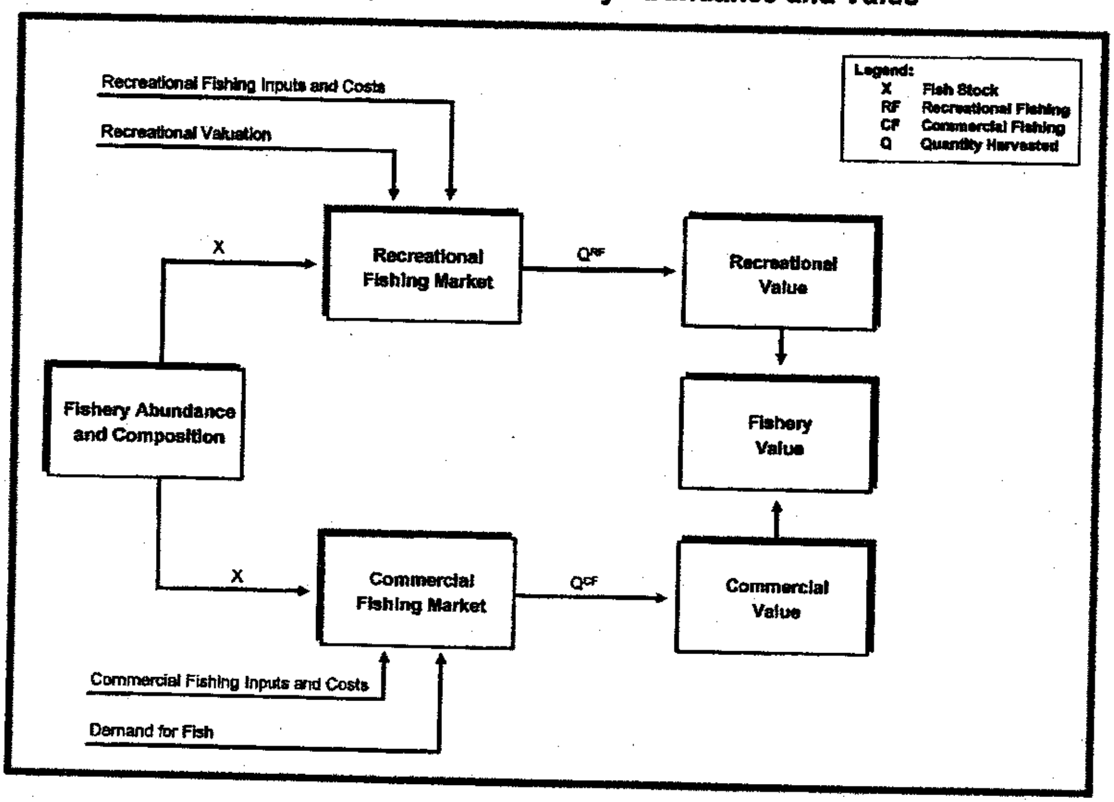
Figure 3
Effect of a Decline in Abundance



Other things equal, a decline in abundance will increase the cost of harvesting fish. In the supply and demand framework of Figure 3, increased costs are represented by an upward shift of the supply curve. The market determines the decline in the quantity of fish harvested (Q_1 to Q_2) by the intersection between the new supply curve (S_2) and the demand curve (D_1). The intersection also leads to an increase in price (P_1 to P_2). The respective change in price and quantity reduces the value of the fishery. The changes in price and quantity affect both the producers and the consumers. Because of the decrease in the abundance of the fishery, producer surplus decreases from the sum of Areas E, F, and G to the sum of Areas E and B. The reduced consumer surplus is the darker shaded consumer surplus or the value of the fishery as it declines from the sum of Areas A, B, C, and D to lightly shaded Area A.

Although Figures 2 and 3 depict the fishery as a single market, the overall value of the fishery actually depends on two markets: a commercial fishing market and a recreational fishing market. Figure 4 depicts the association between the abundance of a fish stock, commercial and recreational fishing markets, and the economic value of a fishery.

Figure 4
Relationship between Fishery Abundance and Value



Both the commercial and recreational fishing markets depend on the determinants of supply and demand to establish price and quantity. The abundance of fish within the fishery is an important factor for the value of these fishing markets. For example, in the commercial fishery, a decline in abundance means commercial fishermen will expect to catch fewer fish with the same amount of effort (i.e., commercial fishing inputs and costs). The higher cost of catching fish will result in smaller harvests for commercial fishermen. The reduction in harvested fish will reduce the value of the commercial fishery. In the recreational fishing market, decreased catch rates at some sites leads to less satisfaction with trips to those sites. In addition, some recreational anglers choose to fish elsewhere and take trips of lower value. Others substitute lower-valued activities.

2.5 Overview of EPA Case Studies for California and the ASA 2003 Study for the DCPP

This section summarizes the two EPA regional studies we use in our analysis—the Northern California and California studies—and ASA's prior study. EPA conducted the Northern California study for the Phase II Rule Notice of Data Availability (NODA) and the California study for the final Phase II Rule (Part B: California regional studies).

2.5.1 Northern California Regional Study

The Northern California Regional Study area is equivalent to the Northern California National Marine Fisheries Statistics (NMFS) region, which extends from Point Conception north to the Oregon border. According to EPA, of the eight power plants in this region, six withdraw water from estuaries and two withdraw cooling water from the Pacific Ocean. Fisheries in this area are managed by the Pacific Fishery Management Council (PFMC) and the California Department of Fish and Game (CDFG). The PFMC governs recreational and commercial fisheries in federal waters from 3 to 200 nautical miles off the coasts of Washington, Oregon, and California, while the CDFG manages fisheries within 3 nautical miles off the coast of California. In EPA's estimation, this region provided annual recreational benefits of $663,965 from I&E reductions and commercial benefits of $19,514 in 2002 dollars (assuming a 3-percent discount rate). In the NODA, EPA did not present nonuse estimates for the Northern California region. DCPP is included in this region.

2.5.2 California Regional Study

This regional study includes 20 facilities that are in-scope for the Phase II Rule. Of the 20 facilities, 8 are located in northern California and 12 are located in southern California. Eight of the 20 facilities withdraw cooling water from an estuary or tidal river and 12 withdraw water from the Pacific Ocean. DCPP is in northern California and withdraws cooling water from the Pacific Ocean. EPA lists DCPP's 2001 capacity at 2,300 MW and the 2001 net generation at 18,077,713 MWh. For all of California, EPA estimates commercial benefits from the Phase II Rule in 2002 dollars at a low estimate of $0 or a high estimate of $0.52 million and recreational benefits at $2.45 million (assuming a 3-percent discount rate). EPA does not estimate nonuse or forage impacts in this regional study.

2.5.3 ASA Consulting 2003 Benefit Valuation Study for DCPP

ASA Consulting performed a benefits valuation study for DCPP based on an 80-percent reduction in the entrainment estimates developed by Tenera Environmental (the same ones used in this BVS). ASA did not separately value the benefits of impingement reduction, as we did here, and based its analysis on EPA's then-existing guidance, some of which was later changed in the final Phase II Rule when promulgated in July 2004. For example, ASA used EPA's then-proposed rule of thumb for estimating nonuse values at 50 percent of the estimated recreational fishing value. In its forage species valuation, ASA used a range of trophic transfer efficiencies that EPA was then considering, but subsequently changed. Other differences from this study include the fact that ASA did not place a value on crabs and used a range of commercial fishing exploitation rates (10 to 40 percent) that is different from the rates assigned in this BVS. Table 1 shows ASA's estimated annual benefits of an 80-percent entrainment reduction for the 14 species of larval fishes.

Table 1
ASA's Estimate of Annual Benefits of an 80-Percent Entrainment Reduction

Category	Lower Bound (2001 $)	Upper Bound (2001 $)
Commercial Fishing	$0	$25,177
Recreational Fishing	$782	$33,322
Forage Species	$582	$35,487
Nonuse Value	$391	$16,661
Total	**$1,755**	**$110,647**

Assuming 2 percent (upper bound values) and 7 percent (lower bound values) discount rates and assuming that the cooling towers would be in operation beginning in 2008, ASA estimated the net present value (NPV) of the benefits to be $11,045 to $1,334,030 in 2001 dollars, assuming Plant closure in 2023. Assuming Plant closure in 2023, and "grossing up" the benefits by another 30 percent to conservatively account for the 30 percent of the fish species not evaluated in the 316(b) Demonstration Study, ASA estimated that the NPV ranges from $15,786 to $1,905,757 in 2001 dollars, of which $3,517 to $424,587 was nonuse. Assuming Plant closure in 2053, ASA estimated that the NPV ranges from $22,800 to $4,195,663 in 2001 dollars, of which $5,080 to $934,760 was nonuse.

3. BENEFITS VALUATION STUDY

The BVS requires that a facility use a comprehensive methodology to fully value the impacts of I&E at its site and the benefits of complying with the applicable performance standards. In addition, the Phase II Rule requires that the benefit study include (EPA 2004):

- Description of the valuation methodologies for commercial, recreational, and ecological benefits (including any nonuse benefits, if applicable).
- Documentation of the basis for any assumptions and quantitative estimates.
- An analysis of the effects of significant sources of uncertainty on the results of the study.
- If requested by the Director, a peer review of the items submitted in the BVS.
- Narrative description of any non-monetized benefits if the facility were to meet the applicable performance standards and a qualitative assessment of their magnitude and significance.

Each section below presents the details of the analysis.

3.1 Description of Valuation Methodologies

In this subsection, we present our valuation methodologies for estimating the benefits of I&E reduction at DCPP for commercial, recreational, and ecological benefits. We specifically followed the methodology of EPA's final Phase II Rule national 316(b) benefits analysis, except for the approach EPA used in estimating commercial impacts. For commercial impacts, we employed a methodology more conservative than EPA's.[15] The following sections provide an overview of the valuation methodologies and their application at DCPP.

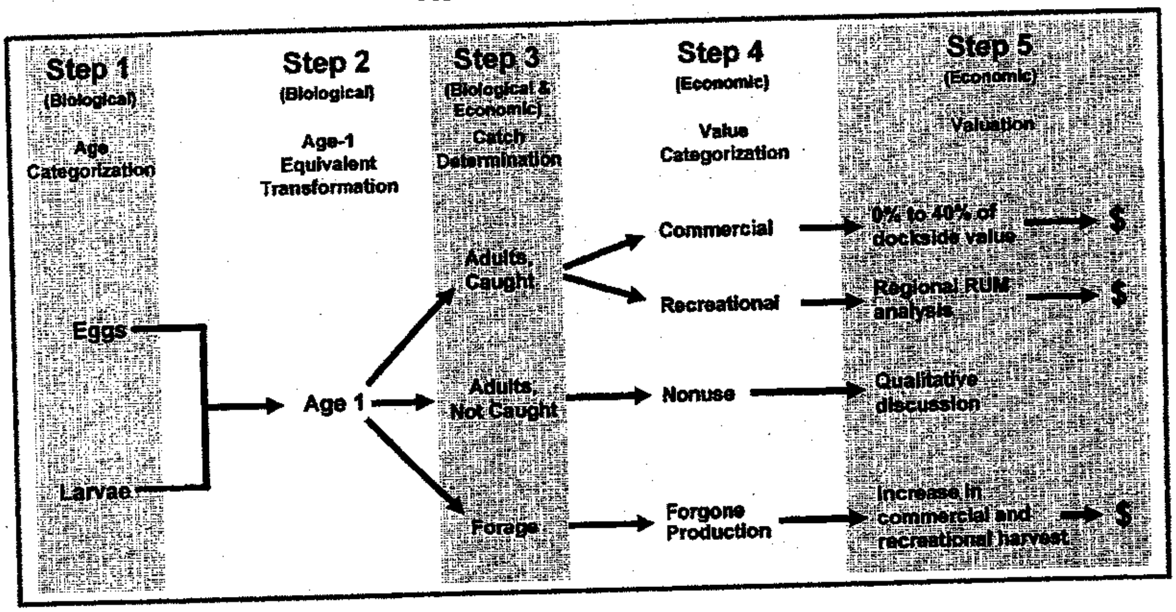
3.1.1 Overview of EPA's Phase II Rule Benefit-Estimate Methodology

Figure 5 depicts the approach used to evaluate the biological effects and economic benefits of reducing entrainment for commercial, recreational, and forage species. The sections following Figure 5 describe each step. The approach used to assess the biological effects and economic benefits of reducing impingement for commercial, recreational, and forage species is very similar; therefore, we did not

[15] This methodology is described below and results in higher estimates than EPA's method for estimating commercial impacts.

describe each step again with respect to impingement. The only difference between the entrainment analysis and the impingement analysis is that juvenile, Age 1, and Age 2 fish are impinged, whereas eggs and larvae are entrained.

Figure 5
Steps in EPA's Valuation Process for Determining the Economic Value of Reductions in Entrainment



Step 1: Categorize Entrained Fish

Step 1 categorizes entrained fish by life stage and species. Appropriate age categorization is an important factor in estimating biological effects and economic benefits appropriately. This is true because younger fish equate to fewer Age-1 equivalents than older fish and vice versa.

Step 2: Transform Entrained Fish into Age-1 Equivalents

In Step 2, we use cumulative survival rates from each age category (eggs and larvae) to Age 1 fish to determine the expected number of Age-1 equivalents associated with entrainment. We follow EPA's calculations for determining the cumulative survival rates as outlined in Chapter A5: I&E Methods (Part A: Evaluation Methods of the regional studies).

Step 3: Determine Number of Fish Caught

After converting entrained fish into Age-1 equivalents, we employ natural and fishing mortality parameters to determine the number of each harvested species that will be caught over the lifespan of the fish. Species that are not harvested recreationally or commercially are categorized as forage fish.

Step 4: Determine Value Categorization

In Step 4, we determine how many of the harvested fish will be caught recreationally and how many will be caught commercially. This determination is based on the recreational/commercial breakdowns employed in EPA's California and Northern California regional studies.

Step 5: Determine the Value of Fish that Would Be Produced through I&E Reductions

After completing Steps 1 through 4, we value the additional fish production that would be achieved through I&E reductions. TER values fish that are caught recreationally by transferring parameters from appropriate random utility models (RUMs) employed in EPA's analysis. A RUM uses anglers' site choices to evaluate the importance of factors that influence an angler to visit a site. When correctly applied, random utility analysis is the best method for valuing I&E reduction impacts on recreational fishing.[16] In our analysis, the transferred RUM parameters measure the marginal value of catching an additional fish.

In the Phase II Rule, EPA estimated commercial benefits as 0 to 40 percent of gross revenue (increased landings from I&E reductions multiplied by the dockside price). However, we do not follow EPA's commercial valuation procedure in this BVS. We determine commercial impacts by using the percent increase in commercial landings and the percent change in dockside value based on the assumption that the price elasticity of demand is –1.[17] For example, if the percent increase in commercial landings from reducing I&E is 10 percent and the price elasticity of demand is –1, then

[16] RUMs are recognized in the DOI regulations (43 *CFR* §11.83) as an appropriate method for quantifying recreation service losses in natural resource damage claims. Currently, the RUM is the most widely used model for quantifying and valuing natural resource services. RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1997), and electricity demand estimation (Cameron 1985), as well as more recently in environmental and resource economics.

[17] The price elasticity of demand measures the percent change in price for a 1-percent change in quantity.

the percent decrease in the dockside value is 10 percent. To estimate commercial impacts, the new dockside value ($/lb.) is multiplied by the increase in commercial landings (lbs.). TER's method for evaluating commercial impacts is economically sound and results in higher estimates than EPA's method. Thus, our commercial impacts are conservative compared to EPA's. For example, applying EPA methodology results in commercial impacts of $0 to $3,426 for entrainment and $0 to $17 for impingement, whereas TER estimation methods result in commercial impacts of $7,930 for entrainment and $52 for impingement at DCPP.

Forage species are valued in terms of forgone production of recreational and commercial species. Following EPA's methodology in the Phase II Rule as outlined in Chapter A5: I&E Methods (Part A: Evaluation Methods of the regional studies), we applied a net trophic transfer efficiency rate of 2.5 percent to lost biomass of all forage species. This approach uses two distinct estimates of trophic transfer efficiency rates within two kinds of food web pathways: (1) the portion of forage production with a high trophic transfer efficiency because it is directly consumed by harvested species and (2) the portion of forage production with a low trophic transfer efficiency rate that is not consumed directly by harvested species but reaches harvested species indirectly through other parts of the food web.

This approach monetizes all direct and indirect fishery losses.[18] Uncaught recreational and commercial fish do not have a traditional use value and are therefore categorized as having potential nonuse value. However, the number of fish not valued is small.[19] For example, in the NODA (p. 13,567), EPA stated that "Unharvested recreational and commercial fish represent 0.77 percent of the total age one equivalent impingement and entrainment losses." For this reason, nonuse impacts are minimal at DCPP.

[18] Direct losses reflect I&E of harvested species; indirect losses reflect I&E of forage species that support these recreationally and commercially desirable fish.

[19] The number of uncaught fish varies by species and depends upon pressure and expected lifespan.

3.1.2 *Applying EPA Benefit-Estimate Methodology to DCPP Using Site-Specific Information*

In this section we calculate the biological effects and economic benefits of I&E reductions at DCPP, employing the methodologies described above and site-specific information from several sources. The analysis incorporates information from:

(1) EPA's 2003 Northern California benefits study (recreational and commercial species classification and life history parameters as indicated in Appendix C of this report)

(2) EPA's 2004 California benefits study (RUM parameters, recreational and commercial species classification, and life history parameters as indicated in Appendix C of this report)

(3) Tenera's I&E study for the DCPP (Tenera Environmental 2000).

Table A.1 in the appendix provides the list of species that are potentially impinged, annual impingement estimates, and the potential biological and economic effects of this annual impingement for DCPP. Table A.2 reports the same information for entrained organisms. Table A.3 combines both types of information and reports I&E estimates for DCPP.

Step 1: Categorize Impinged and Entrained Organisms

Step 1 categorizes impinged and entrained organisms by life stage and species. We obtained annual I&E estimates from documents that DCPP submitted to EPA (Diablo_Input.xls in EPA NODA Docket #OW-2002-0049). We first grouped some of the species together to simplify the analysis. For example, we grouped all the rockfish species together.

To determine the percentage of Age 1 and Age 2 fish impinged we applied percentages by species from appropriate EPA case studies. In our analysis, we do not categorize any impinged fish as Age 0/juvenile because there were no juveniles or Age 0 fish impinged in the relevant EPA case studies. For example, we assumed that 68 percent of pipefish impinged at DCPP were Age 1 and the remaining 32 percent were Age 2 based on the impingement of northern pipefish at the Seabrook and Pilgrim facilities.

To determine the percentage of eggs and larvae entrained, we relied primarily on the DCPP 316(b) Demonstration Report (Tenera Environmental 2000), a memorandum from Chris Ehrler at Tenera Environmental, and consultations with John Steinbeck at Tenera Environmental. For many entrained species, we realized that only larvae can be entrained. For example, rockfish are live bearers and gobies have adhesive eggs. For all the other species (California halibut, Northern anchovy, Pacific sardine, sanddabs, and white croaker), if no information was available, we assumed that the ratio of eggs to larvae was 50:50, which increased the entrainment estimates for these five species by 100 percent.[20]

In order to estimate egg entrainment, we conservatively assumed a 1:1 eggs-to-larvae entrainment ratio. An example, for northern anchovy, showed less risk. We used instantaneous mortality (M) rates of 0.191 d^{-1} for eggs and 0.114 d^{-1} for larvae. Using an entrainment duration for eggs of 3.5 days and for larvae of 70 days, combined with natural mortality and exponential survival, we calculated that at the end of 3.5 days 1,000,000 eggs would become 512,000 larvae. Then using these two numbers as N_0, we calculate that the ratio of integrals of egg and larval distributions is the expected power plant entrainment fraction for eggs. The integral is computed as:

$$N = \int_0^t N_0 e^{-Mt}\,dt = \left.\frac{N_0 e^{-Mt}}{-M}\right|_0^t \quad (1)$$

Integration resulted in 2.55 million eggs and 4.49 million larvae, i.e., a 0.558:1 estimated entrainment ratio, thus showing a higher risk to larvae attributable to the prolonged susceptibility.

Step 2: Transform Impinged and Entrained Organisms into Age-1 Equivalents

To convert impinged and entrained organisms into Age-1 equivalents, we relied primarily on the life history parameters reported in EPA's Northern California and California regional studies. Appendix C lists all the life history parameters we incorporated and their sources. As can be seen there, all of the life history parameters

[20] John Steinbeck at Tenera Environmental consulted with TER on this assumption.

used were developed by EPA for use in its own benefits studies. For some species, we did not have a perfect match and we transferred the life history parameter from the most similar species based on consultations with John Steinbeck at Tenera Environmental. The fishes in this category consist of nearshore forage species.

To convert an Age-2 fish to Age-1 equivalents, we multiplied the number of Age 2 fish by the inverse of the survival rate from Age 1 to Age 2. We applied the cumulative survival rate from eggs to Age 1 to convert eggs to Age-1 equivalents and the cumulative survival rate from larvae to Age 1 to convert larvae to Age-1 equivalents. The following definitions are important in understanding these calculations.

Natural mortality (M): The instantaneous rate of natural (not fishing or I&E) death. Natural mortality (M) changes over an organism's lifetime and generally decreases with age. It is represented by species/life stage-specific parameters or equations.

Total mortality (Z): Mortality attributed to both fishing and natural causes. (Froese and Pauly 2004). It is the combined rate or sum of natural mortality and mortality attributable to commercial and recreational fishing pressure. Total mortality (Z) is defined as: Z = M + F, where M is the natural mortality rate and F is the rate of recreational and commercial fishing mortality.

Survival Rate (S): The fraction of an age class that will survive to enter the next age class stage. Survival rate (S) is defined as: S = exponent $^{(-z)}$, where Z is the total mortality rate (Ricker 1975).

Cumulative Survival Rate (CS): Cumulative Survival rate from age entrained to Age-1 Equivalent as detailed in the Phase II Rule (EPA 2004).

Step 3: Determine Number of Fish Caught

After converting impinged and entrained organisms into Age-1 equivalents, we employ the natural and fishing mortality parameters detailed in Appendix C to determine the number of each species that will be caught. Once again, EPA developed all of these parameters for use in its own benefits studies, including the Northern California Study and the California Regional Study. The remaining fish that are not categorized as either recreationally or commercially important species are categorized as forage species. For the California Regional Study, EPA estimated that harvested recreational and commercial species accounted for 4.8 percent of all Age-1 equivalents.

Step 4: Determine Value Categorization

In Step 4, we determine which of the caught fish will be caught recreationally and which will be caught commercially. To determine the recreational/commercial breakdown between species that are caught both recreationally and commercially at DCPP, we employ data from the 316(b) Demonstration Study, EPA's California and Northern California regional studies, and the California Department of Fish and Game website. For example, we estimated that 62 percent of all cabezon caught is commercial and the remaining 38 percent is recreational based on landings data reported by the California Department of Fish and Game.

Step 5: Determine the Value of Fish Produced as a Result of I&E Reductions

After completing Steps 1 through 4, we value the increased fish production that would result from I&E reductions. TER values fish that were caught recreationally at DCPP by transferring parameters from EPA's California Regional RUM Study. We determine commercial impacts by incorporating 20-year National Marine Fisheries Statistics (NMFS) landings data and most recent dockside prices with the method outlined in the previous section. We value forage species using EPA's production forgone method detailed in Chapter A5: I&E Methods (Part A: Evaluation Methods of the regional studies). Forage species account for 93.8 percent of total current I&E expressed as Age-1 equivalents at DCPP.

3.1.3 Detailed Description of Valuation Process Using Brown Rock Crab

This section provides a detailed description of the valuation process using brown rock crab as an example. The discussion provides information on the equations, parameters, and assumptions employed to estimate the recreational and commercial benefits from reducing brown rock crab entrainment. Brown rock crab was chosen for this example because the value of the losses due to DCPP entrainment was larger than any of the other organisms included in the assessment.

Step 1: Categorize Entrained Brown Rock Crabs

Brown rock crab is a type of cancer crab. According to the 316(b) Demonstration Study (p. 5-21), cancer crabs carry eggs in a mass under their abdominal flap. Therefore, no eggs are entrained. Brown rock crabs have six larval stages—zoea 1 through zoea 5 and megalops. In our analysis, the entrained brown rock crabs (average of 1997 and 1998 data) are classified as zoea 1 through zoea 5 and megalops. In addition, we incorporated information from the 316(b) Demonstration Study to determine the percent allocation by life stage for entrained brown rock crabs (Table 2).

Table 2
Percent Allocation by Life Stage for Entrained Brown Rock Crabs

Life Stage	Number Entrained (in millions)	Percent
Zoea 1	17,950.00	67.70%
Zoea 2	4,175.00	15.75%
Zoea 3	3,570.00	13.46%
Zoea 4	723.00	2.73%
Zoea 5	57.24	0.22%
Megalops	40.50	0.15%
Total	**26,515.74**	**100.00%**

Step 2: Transform Entrained Brown Rock Crabs into Age-1 Equivalents

To transform the entrained brown rock crabs into Age-1 equivalents, we estimate the cumulative survival rate from each of the six larval stages to Age 1 using the life history parameters in Table C.3 in Appendix C, the percent allocation by life stage for entrained brown rock crabs in Table 2, and Equations 2 to 4 presented below. This step results in 5.1 million Age-1 equivalents.[21]

$$Z = M + F \qquad (2)$$

[21]TER confirmed this estimate of Age-1 equivalents with John Steinbeck at Tenera Environmental. John Steinbeck also estimated 5.1 million Age-1 equivalents from the entrained brown rock crabs using the Adult Equivalent Loss (AEL) method.

where:

Z = the total instantaneous mortality rate
M = natural (nonfishing) instantaneous mortality rate
F = fishing instantaneous mortality rate

$$S = e^{(-Z)} \tag{3}$$

where:

S = the survival rate as a fraction

$$S_{j,1} = S_j^* \prod_{i=j+1}^{jmax} S_i \tag{4}$$

where:

$S_{j,1}$ = cumulative survival from stage j until Age 1
S_j = survival fraction from stage j to stage j + 1
S_j^* = $2S_j e^{-\log(1+S_j)}$ = adjusted S_j
j_{max} = the stage immediately prior to Age 1

Step 3: Determine Number of Brown Rock Crabs Caught

In this step, we convert the 5.1 million Age-1 equivalents into the number of caught crabs employing the natural and fishing mortality parameters in Table C.3 in Appendix C. We determined that brown rock crabs are first caught when they are Age 3 or Age 4. We estimate the cumulative survival rate from Age 1 to Ages 3 and 4 and estimate that approximately 6,343 brown rock crabs would be caught recreationally and commercially.

Step 4: Determine Value Categorization

According to the California Department of Fish and Game website, brown rock crab is caught commercially and recreationally. Based on the available commercial landings data and the recreational crabbing information, we assumed that 75 percent of the caught brown rock crabs would be caught commercially and the remaining 25 percent would be caught recreationally. This step results in an estimate of 1,586 brown rock crabs caught recreationally and 4,758 brown rock crabs caught commercially.

Step 5: Determine the Value of Brown Rock Crabs Produced as a Result of Entrainment Reductions

TER values fish that were caught recreationally at DCPP by transferring parameters from EPA's California Regional RUM Study. For brown rock crabs, we estimate a recreational value of $0.49 per crab. Thus, the recreational value of lost brown rock crabs is approximately $771. The recreational benefits of 316(b) compliance from entrainment reduction range from about $463 (60 percent of total value) to $694 (90 percent of total value). In our analysis, we estimate benefits from entrainment reduction using the 60 to 90 percent compliance range.[22]

We determine commercial impacts by using the percent increase in commercial landings and the percent change in dockside value based on the assumption that the price elasticity of demand is –1. For brown rock crabs, we looked at the 1981 to 2002 NMFS commercial landings data for crabs.[23] The commercial landings data are reported in pounds. To estimate the percent change in quantity due to entrainment reduction, we determine the lost commercial pounds. John Steinbeck (Tenera Environmental) stated that the average weight of an adult male brown rock crab is 0.45 kg and the average weight of an adult female brown rock crab is 0.34 kg. To convert to pounds the 4,758 brown rock crabs that would be caught commercially, we multiplied by the average weight of an adult male and female brown rock crab (0.395 kg or 0.871 lbs.). We estimate lost commercial yield from entrainment for brown rock crabs at 4,143 pounds. We estimate that the average commercial landings from 1981 to 2002 for California are 161,623 pounds. The average per-pound value for 2002 was $0.94. The expected increase in landings is 2.56 percent.[24] Given that the assumed price elasticity of demand is –1, the expected decrease in price from the increase in quantity is 2.56 percent. The per-pound price for brown rock crab adjusts to $0.91. We estimate the total commercial impacts for brown rock crab at $3,784. Thus, the

[22] Similarly, in our analysis, we estimate benefits from impingement reduction using the 80- to 95-percent compliance range.

[23] Source: http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html

[24] (4,143/161,623) * 100 = 2.56 percent.

commercial benefits of 316(b) compliance from entrainment reduction range from about $2,271 (60 percent of total value) to $3,406 (90 percent of total value).

3.2 Analysis of the Effects of Uncertainty

There are numerous sources of uncertainty that may lead to imprecision or bias in benefit estimates in this analysis as well as EPA's analysis. Using Finkel (1990), EPA classifies uncertainty into two general types (EPA 2002):

- The first is structural uncertainty, which reflects limited understanding of the appropriate model and relationships among model parameters. Structural uncertainty is an unresolved issue that is inherent in this assessment and all such evaluations that require simplifying complex natural processes.
- The second is parameter uncertainty, which reflects imprecision in the specific numeric values of model parameters.

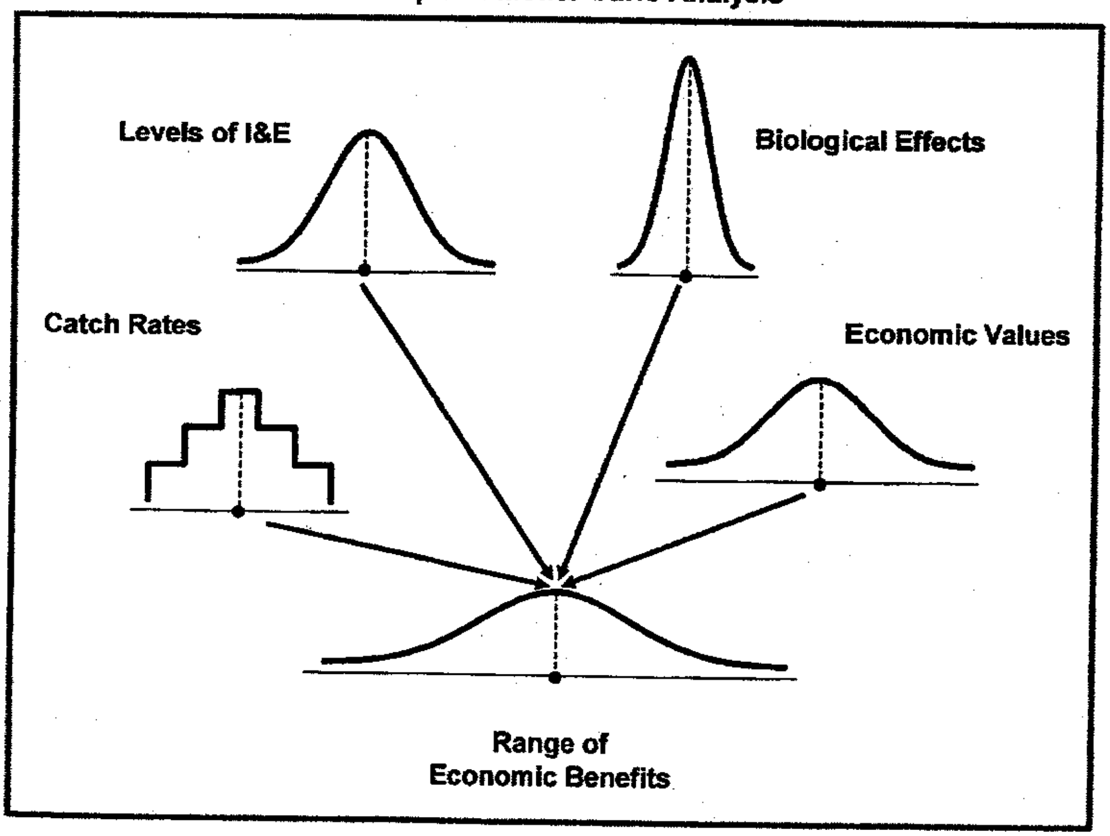
EPA believes that structural uncertainties will generally lead to inaccuracies, rather than imprecision, in economic and biological impact estimates (EPA 2004). EPA does not offer support for this contention. However, in practice, our ability to evaluate such uncertainties is limited. Accordingly, the uncertainty analysis conducted for this effort focuses primarily on parameter uncertainty.

We use a Monte Carlo analysis to quantify the effects of uncertainty on benefits, as recommended by EPA. The Monte Carlo analysis combines and calibrates the inputs from the known and unknown factors to account for the uncertainty of unknown factors in developing the range of 316(b) compliance benefits. The Monte Carlo analysis uses estimated ranges from each unknown factor, randomly selects a value from the range of each factor, and then combines the estimates within the framework of EPA benefit estimation methodologies and 316(b) compliance requirements. The resulting combination of the various inputs creates a range of compliance benefits.

The Monte Carlo analysis repeats this process of drawing from the various factor distributions 10,000 times, each time drawing randomly from the designated ranges of values for calculating biological impacts and economic benefits in a 316(b) framework. Each repetition produces a different estimate of compliance benefits. The resulting distribution of outcomes from the 10,000 draws produces the range of potential 316(b) compliance benefits.

Figure 6 provides an illustrative example. The example presents the process of determining the range of economic benefits associated with reducing I&E. Economic benefits are one component of the larger Monte Carlo analysis depicted in Figure 6. The figure shows that several different components determine the economic benefits associated with reductions in I&E: the current level of I&E, the biological effects associated with the current level of I&E (i.e., how many fish are lost because of the current I&E), the effect of reduced fish populations on catch rate, and the economic values associated with changes in catch rates. The illustration associated with each component shows that there is a range associated with each component and the ranges may have different properties. For example, the range on the levels of I&E may be a typical bell curve, whereas the range associated with catch rates may be more like a series of steps.

Figure 6
Example of Monte Carlo Analysis



As Figure 6 shows, the Monte Carlo analysis draws from each element influencing economic benefits to determine the range of economic benefits. For example, in one draw, the analysis may draw a low estimate from the range of current levels of I&E, but then draw a high estimate from the biological effect and catch rate and a mid-level estimate from economic benefits. Putting all four of these estimates together produces one estimate of economic benefits. The analysis then draws again. This time it may draw a mid-level estimate from each element. The process is repeated 10,000 times to produce the range of economic benefits.

Appendix B presents a detailed discussion of our Monte Carlo analysis and the specific uncertainty parameters we employ. In our uncertainty analysis, we attempted to account for parameter uncertainty as recommended by EPA. We incorporate uncertainty parameters to account for:

- Biological/Life History—natural mortality rates
- Stock characteristics—fishing mortality rates
- Ecological system—fish community composition and abundance
- Economic value of lost fish—recreational and commercial values
- Compliance levels—performance standard ranges.

Table 3 presents the results of our Monte Carlo analysis. The lower bound and upper bound values represent the 95-percent confidence interval. We provide uncertainty estimates for RIS I&E losses, all I&E losses (including the additional 30 percent of forage fish larvae not specifically evaluated during the 316(b) Demonstration Study), and the benefits of 316(b) compliance (80- to 95-percent impingement reduction and 60- to 90-percent entrainment reduction).[25] In addition, Table 3 lists the present value estimates in 2002 dollars for the benefits of 316(b) compliance until plant termination in 2023 and for an extension to the existing permit up to 2053.[26]

[25]To estimate all I&E losses, we "gross up" the RIS losses by multiplying by (100/70).

[26]We apply a 3-percent discount rate for recreational and forage values and a 7-percent discount rate for commercial values.

Table 3
Results of Uncertainty Analysis for Diablo Canyon Using Monte Carlo Simulation

Estimate	Mean	Standard Deviation	Lower Bound	Upper Bound
Baseline I&E (RIS species)	$26,412	$4,732	$18,635	$34,206
Baseline I&E (all species)	$37,731	$6,760	$26,621	$48,866
Benefits of Compliance (RIS species)	$19,863	$4,207	$13,280	$27,220
Benefits of Compliance (all species)	$28,376	$6,010	$18,971	$38,886
Benefits of Compliance in 2023 (RIS species)	$250,772	$53,114	$167,661	$343,655
Benefits of Compliance in 2023 (all species)	$358,246	$75,877	$239,516	$490,936
Benefits of Compliance in 2053 (RIS species)	$420,806	$89,127	$281,342	$576,667
Benefits of Compliance in 2053 (all species)	$601,151	$127,324	$401,917	$823,809

3.3 Results

In our analysis, TER accounts for 100 percent of the impinged organisms. As Table A.1 shows, impingement impacts at DCPP are minimal. The annual economic value of all species lost to impingement is $537 in 2002 dollars. The annual economic benefits of 316(b) compliance from impingement reduction range from about $430 (80 percent of total impingement impacts) to $510 (95 percent of total impingement impacts). Recreational impacts account for 90 percent of total impingement impacts. The main species for impingement are rockfish, surfperch, sanddabs, and sole.[27]

Table A.2 presents entrainment impacts at DCPP for the RIS species. The annual economic value of RIS species lost to entrainment is $25,595 in 2002 dollars. The RIS species account for only 70 percent of all entrainment. To estimate the economic value of all species lost to entrainment, we multiply the economic impacts for the RIS species by (100/70). Thus, the economic value of all species lost to entrainment is $36,564. The annual economic benefits of 316(b) compliance from entrainment reduction range from about $21,939 (60 percent of total entrainment impacts) to $32,908 (90 percent of total entrainment impacts). Recreational impacts account for 55 percent of total entrainment impacts, while commercial impacts account

[27] These species account for 96 percent of all total economic impacts from impingement.

for 31 percent. The main species for entrainment are California halibut, brown rock crab, kelpfishes, and sanddabs.

Table A.3 presents I&E impacts at DCPP. The annual economic value of all impinged organisms and the RIS species lost to entrainment is $26,132 in 2002 dollars. To estimate the economic value of all species lost to I&E, we multiply the economic impacts by (100/70). This is a good approximation as impingement accounts for only 2 percent of the total impacts. Thus, the economic value of all species lost to I&E is approximately $37,331. The annual economic benefits of 316(b) compliance from I&E reduction range from about $22,369 (minimum compliance, i.e., 80 percent of total impingement impacts and 60 percent of total entrainment impacts) to $33,418 (maximum compliance, i.e., 95 percent of total impingement impacts and 90 percent of total entrainment impacts). Recreational impacts account for 55 percent of total I&E impacts while commercial impacts account for 31 percent. The main species for I&E are California halibut, brown rock crab, kelpfishes, and sanddabs.

Tables A.1, A.2, and A.3 present point estimates. In our Monte Carlo analysis, we attached uncertainty estimates to various parameters and assumptions. The annual economic value of all I&E impacts ranges from $26,621 to $48,866 in 2002 dollars. The annual benefits of 316(b) compliance range from $18,971 to $38,886.

Table 4 compares the results of our analysis with ASA's study. We present the undiscounted annual benefits of compliance (because the two studies do not use the same discount rates), the impacts each study measured, the reduction criteria each study applied, and any assumptions necessary to make the comparison. As Table 4 shows, TER's estimates fall within the range of ASA's estimates.

Table 4
Comparison of Compliance Benefits across Studies

Study	Measured Impacts	Economic Benefits Lower Bound	Economic Benefits Upper Bound	Reduction Criterion	Assumptions/ Limitations
TER	Recreational, Commercial, and Forage I&E Impacts	$18,971	$38,886	80% to 95% for impingement, 60% to 90% for entrainment.	Assumes EPA life history parameters are correct.
ASA	Recreational, Commercial, and Indirect Use Entrainment Impacts[a]	$1,949	$134,266	80% for entrainment of 14 RIS fish species (excludes brown rock crabs and slender crabs).	Divided by 0.7 to estimate benefits for all entrainment.

[a] We exclude nonuse impacts from ASA's estimates to make them more comparable to our estimates.

In EPA's estimation, the Northern California region provided annual economic benefits of $683,479 in 2002 dollars (assuming a 3-percent discount rate).[28] For California, EPA estimated annual economic benefits from the Phase II Rule in 2002 dollars at $2.97 million (assuming a 3-percent discount rate).[29] Because of information constraints, it is difficult to separate out the DCPP's contributions to EPA's Northern California and California Regional Studies. Nevertheless, it can be seen from Table 5 that our estimates for the DCPP alone are generally within the range of EPA's benefit estimates over these wider regional areas.

Table 5
Comparison of Compliance Benefits across TER and EPA Studies[a]

Study	Number of Facilities	Economic Benefits (2002 $)
TER	1	$20,424
Northern California	8	$683,479
California	20	$2,970,864

[a] We incorporate only upper-bound commercial benefit estimates for the EPA studies. For the TER study, we present the undiscounted point estimates with no uncertainty attached to the values.

[28] This estimate includes recreational benefits of $663,965 and commercial benefits of $19,514.

[29] This estimate includes recreational benefits of $2.45 million and upper bound commercial benefits of $0.52 million.

4. NONUSE VALUES

As part of the BVS, the 316(b) rule also requires that the benefits assessment consider the nonuse benefits associated with reductions in I&E (EPA 2004 p. 41,647). People hold nonuse values for a resource that are independent of their use of the resource. That is, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist. As the rule points out, the economic literature commonly refers to these two components of nonuse values as "bequest" (or "altruistic") values and "existence" values, respectively (EPA 2004 p. A9-3).[30]

Currently, the only method available for estimating nonuse values is survey-based elicitation. However, the reliability of this approach for estimating these impacts is questionable. For example, the contingent valuation literature has long noted and thoroughly documented the difference between people's stated intentions and actual behaviors. This difference between intentions and behavior is called hypothetical bias. Researchers in the natural resource arena recognized hypothetical bias more than 20 years ago, defining it as the "potential error due to not confronting an individual with a real situation" (Rowe, d'Arge, and Brookshire 1980).

Such difficulties have limited the possibilities for directly eliciting nonuse values in this context with an original survey. In fact, because of conceptual and empirical challenges, the Agency decided in the final rule that "...none of the available methods for estimating either use or nonuse values of ecological resources is perfectly accurate; all have shortcomings" (EPA 2004 p. 41624). More importantly, EPA decided that "none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004 p. 41624).

As a result of this conclusion, EPA provides guidance in the rule as to how each facility should address the nonuse values associated with reductions in I&E. This

[30]The only distinction between bequest and altruistic values is whether one values uses of the resource by one's progeny or other people. Thus, both concepts are often combined under either one of the two terms.

section begins by presenting the methods EPA evaluated in its assessment of nonuse values and discussing their relevance for this assessment. The section then presents EPA's guidelines in the Final Phase II Rule for addressing nonuse values and describes how we have used those guidelines to assess the nonuse values associated with reductions in I&E at DCPP.

4.1 EPA Approach: Proposed Rule

In the proposed rule, EPA presented three potential approaches for quantifying nonuse values. These include the Habitat Replacement Cost (HRC) method, the Societal Revealed Preference (SRP) approach, and the Fisher-Raucher approximation. After public comment and further review EPA repudiated these methods. The following sub-sections describe each approach.

4.1.1 Habitat Replacement Cost Method

In the Proposed Rule, EPA presented two cost-based methods for approximating benefits. For the HRC method, the costs estimated by EPA are the total costs of restoring habitats so that they produce ecological services equivalent to those expected from technological alternatives.[31] Numerous reviewers commented that these costs are not benefits. Rather, they are alternative costs for achieving the objectives of the proposed regulation. Mitigation approaches such as stocking and habitat restoration may be acceptable alternatives to technology installation. However, the cost of such alternatives bears no implicit relationship to the benefits of reducing I&E. Therefore, it is important not to confuse this method of mitigation scaling with measuring the benefits of the mitigation.

Appropriate economic measures of benefits require that they be based on the willingness-to-pay principle, and HRC is not based on this principle. In many cases, the cost of developing a resource can substantially exceed the resource's value. Although EPA extensively evaluated HRC during its development of the Phase II rule, EPA ultimately decided that the HRC method should not be used as a means of estimating

[31] Although the Phase II Rule for existing facilities allows the use of restoration measures to achieve compliance with either national or site-specific standards, a similar provision was found to be invalid in the Phase I regulations for new facilities by the U.S. Court of Appeals, Second Circuit. Environmental groups and six States contesting the Phase II regulation are again challenging the validity of restoration in the Phase II regulation, which is being heard by the same Circuit Court of Appeal.

benefits due to "limitations and uncertainties regarding the application of this methodology" (*Fed. Reg.*, Volume 69, No. 131, p. 41,625). Accordingly, the HRC approach is not employed in this assessment.

4.1.2 Societal Revealed Preference Method

The second cost-based methodology employed by EPA in the Proposed Rule is called Societal Revealed Preference (SRP). Rather than using the cost of a hypothetical alternative, SRP uses historical costs under prior government mandates to measure benefits. Like the HRC method, this cost-based approach has no foundation in economic theory and is not accepted by economists as a legitimate method of empirical valuation. In fact, the SRP method is a corrupted application of the legitimate revealed preference method. An essential characteristic of revealed preference analysis and not SRP is that willingness to pay is revealed by those who are doing the paying. The SRP methodology takes the fact that a program exists as evidence that its benefits exceed its costs. EPA removed the disputed results of the SRP analyses from its benefits estimates for the final rule. Accordingly, the SRP method is not employed in this assessment.

4.1.3 Fisher-Raucher Approximation

For the Proposed Rule analysis, EPA also presented the Fisher-Raucher or "50 percent" rule. This approach approximates nonuse values at 50 percent of recreational use values. The approximation is derived from a comparison of use and nonuse values for water quality improvements.[32] The 50-percent rule is inappropriate in this context because there is no reason to believe that the ratio of nonuse to use benefits from water quality improvements could be applied to the environmental improvement from reductions in I&E. Moreover, because use values for fish often arise from their *consumption*, there is no conceptual reason to believe that there is a positive association between use and nonuse values in this context. EPA does not employ the 50-percent rule in its final analysis and this approach is not employed in this assessment.

[32] Fisher, A. and R. Raucher. 1984. Intrinsic benefits of improved water quality: Conceptual and empirical perspectives. *Advances in Applied Micro-Economics.* 3:37–66.

4.2 EPA Approach: Notice of Data Availability (NODA)

EPA used two approaches to evaluate nonuse values in the NODA. These include a revised form of the HRC method and the Production Forgone method. After public comment and further review EPA repudiated the revised HRC method. The Production Forgone method is included in EPA's final benefits analysis but not quantified in dollar terms because of time constraints. The following sub-sections describe each approach.

4.2.1 Revised Habitat Replacement Cost

In the NODA, EPA presented a "revised HRC" methodology that evaluated nonuse benefits based on estimated willingness to pay values for the resource improvements that would be achieved by equivalent restoration. It was based on a transfer approach that combines an estimate of the amount of habitat required to offset I&E losses by means of wild fish production with a benefits transfer estimate of willingness to pay for aquatic habitat preservation/restoration.

This approach is fundamentally flawed for a number of reasons (Bingham, Desvousges, and Mohamed 2003). A theoretical shortcoming of this approach is that there is no good reason to presume that willingness to pay values for habitat restoration are an appropriate proxy for either the total value or the nonuse value of the fishery resources that would be preserved due to reduced I&E. EPA does not employ this revised HRC approach in its final analysis and this approach is not employed in this assessment.

4.2.2 Production Forgone

When calculating benefits for the NODA, EPA valued forage fish based upon their value as inputs to recreational and commercial stocks. The Production Forgone methodology recognizes that the value of forage species is through indirect use rather than nonuse. This methodology passes the biological effects of increased biomass availability through trophic levels until it reaches commercially and recreationally valuable species. At this point, catch changes and recreational and commercial values are calculated. Although commenters disagreed on certain assumptions, the approach was generally accepted.[33] Valuing forage losses in this manner accounted for nearly all biomass but led to only marginally higher estimates of economic impacts to recreational and commercial fishing.[34] This analysis employs EPA's production forgone methodology as presented in the NODA. The resulting benefits estimates account for nearly all lost fish and shellfish biomass.[35]

4.3 EPA Approach: Final Rule

EPA ultimately determined that none of the available methods for estimating nonuse values were appropriate for inclusion in the final rule. Thus, in the absence of impacts to populations or threatened and endangered species, EPA decided to "rely on a qualitative discussion of nonuse benefits."

4.4 Qualitative Discussion of Nonuse Values for Diablo Canyon

As the previous section shows, EPA examined a variety of methods to quantify the nonuse values associated with reducing I&E. Based on this examination EPA, "determined that none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004 p. 41,624). EPA then provided guidance in the final rule as to how each facility should assess the nonuse benefits associated with reductions in I&E.

This section provides the assessment of nonuse benefits for Diablo Canyon. Section 4.4.1 begins by presenting the specific guidance EPA provides in the rule. Section 4.4.2 uses that guidance to present the results of the assessment of nonuse benefits for Diablo Canyon.

4.4.1 EPA Guidance on Assessing Nonuse Benefits

In the final Phase II Rule, EPA provides the following guidance on how to assess the nonuse benefits associated with reductions in I&E (EPA 2004 p. 41,647–41,648):

---

[33]For example, Barnthouse (2002) indicates that the transfer efficiency is not correct.

[34]The recreational and commercial fishing mortality rates specified by EPA indicate that very few of these fish are expected to die naturally. Valuing forage fish in terms of production forgone added less than 20 percent to total losses.

[35]According to EPA calculations, approximately 99 percent of Age-1 equivalents are forage fish. All of these fish are valued in this analysis using the Production Forgone methodology.

- Nonuse benefits may arise from reduced impacts to ecological resources that the public considers important, such as threatened and endangered species. Nonuse benefits can generally only be monetized through the use of stated preference methods. When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information.
- In cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, nonuse benefits should be monetized.[36]
- In cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, monetization is not necessary.

The DCPP 316(b) Study demonstrated that the Plant's CWIS does not have any effect on any threatened or endangered species, that the Plant has only relatively minor impacts on commercially and recreationally important species, and that the most significant impacts were to three species of nearshore forage species having no direct commercial or recreational value. There also are no identified problems with the maintenance of community structure in the vicinity of the DCPP. Based on these results and the guidance presented above, there is no need to monetize nonuse values in this study.[37] We therefore provide a qualitative description below.

4.4.2 A Qualitative Description of Nonuse Values for Diablo Canyon

The original concept of nonuse values is credited to Krutilla (1967), who argued that individuals do not have to be active consumers of unique, irreplaceable resources in order to derive value from the continuing existence of such resources. He wrote that "when the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals" (p. 779).

[36] In cases where harm cannot be clearly explained to the public, monetization is not feasible because stated preference methods are not reliable when the environmental improvement being valued cannot be characterized in a meaningful way for survey respondents. [Note that this footnote is in fact part of the quoted EPA text.]

[37] The production forgone methodology is employed to account for indirect use rather than nonuse impacts.

Krutilla's argument has two crucial components. First, nonuse values are related to unique resources. Second, nonuse values are related to the continuing existence of a resource. Thus, it follows from Krutilla that common resources that suffer from limited injury do not generate significant nonuse values.

This perspective has pervaded the economic literature in the years since Krutilla introduced it. The extensive economic literature on nonuse values emphasizes the relationship between the existence of nonuse values and the uniqueness of the resource in question and the irreversibility of the loss or injury (Freeman 1993). Freeman summarizes this relationship in the economic literature in the following example:

> ...economists have suggested that there are important nonuse values in ...preventing the global or local extinction of species and the destruction of unique ecological communities. In contrast, resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes (p. 162).

As Freeman's example illustrates, common resources (i.e., resources that are not unique) that do not experience irreversible losses are not likely to generate significant nonuse values, if any at all. Such is the case with respect to the effects of I&E at DCPP.

First, the DCPP 316(b) Study demonstrated that the Plant's CWIS does not have any effect on any threatened or endangered species: This is important because of the relationship between the uniqueness of the resource, the irreversibility associated with changes to the resource, and the extent of potential nonuse values. Because there are no threatened and endangered species associated with I&E at the Plant, the species being impinged and entrained are not a unique resource and the effect on the resource is not irreversible. Therefore, the nonuse values associated with reducing I&E at the site are small, if anything at all.

Moreover, EPA's guidance on nonuse values is that monetization is not necessary "in cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species..."

(EPA 2004 p. 41,648). Therefore, it is not necessary to attempt to quantify whether there are any nonuse benefits associated with reducing the I&E at the Plant.

Second, the Plant has relatively minor impacts on commercially and recreationally important species, and the most significant impacts were to three nearshore forage species having no direct commercial or recreational value. To account for these lost forage species, the analysis values them in terms of forgone production of recreational and commercial species. This methodology passes the biological effects of increased biomass availability through trophic levels until it reaches traditionally valuable species. At this point, catch changes and recreational and commercial values are calculated. EPA performed these calculations in the benefits assessment of the Phase II NODA. Although commenters disagreed on certain assumptions, the approach was generally accepted.[38] By valuing forage species through the production forgone methodology, this BVS has monetized all meaningful I&E impacts at DCPP.

[38] For example, Barnthouse (2002) indicates that the transfer efficiency is not correct.

REFERENCES

Barnthouse, Lawrence. 2002. *Review of Methodology Used by EPA to Evaluate Impacts of Entrainment and Impingement Losses and Comments on the PISCES (August 2002) Report Prepared for the Riverkeeper Inc.* Prepared for EPRI. Oak Ridge, TN: LWB Environmental Services.

Beggs, S., S. Cardell, and J. Hausman. 1981. "Assessing the Potential Demand for Electric Cars." *Journal of Econometrics* 17(1):1–19.

Bingham, M.F., A.F. Mohamed, and W.H. Desvousges. 2003. *Comments on Benefit Estimation in EPA's Proposed Phase II 316(b) Rule as Summarized in the Notice of Data Availability*. Durham, NC: Triangle Economic Research.

California Department of Fish and Game. 2004. http://www.dfg.ca.gov/mrd/landings01/table8.pdf

Cameron, Trudy Ann. 1985. "A Nested Logit Model of Energy Conservation Activity By Owners of Existing Single Family Dwellings." *The Review of Economics and Statistics* 67(2):205–211.

Desvousges, W.H., D.M. Clark, M.F. Bingham, A.F. Mohammed, S.M. Small, and D.F. Ludwig. 2002. *Comments on the Benefit Estimates of EPA's Proposed Phase II 316(b) Rule: Final Report.* Prepared for The Utility Water Act Group. Durham, NC: Triangle Economic Research.

EPRI. 2003. *Impacts of Volumetric Flow Rate of Water Intakes on Fish Populations and Communities: Final Report.* Palo Alto, CA: Electric Power Research Institute, Inc. March.

Finkel, A.M. 1990. "A Simple Formula for Calculating the 'Mass Density' of a Lognormally Distributed Characteristic: Applications to Risk Analysis." *Risk Analysis* 10(2):291–301.

Fisher, A., and R. Raucher. 1984. "Intrinsic Benefits of Improved Water Quality: Conceptual and Empirical Perspectives." *Advances in Applied Micro-Economics* 3:37–66.

Freeman III, A. Myrick. 1993. "Nonuse Values in Natural Resource Damage Assessment," in Raymond J. Kopp and V. Kerry Smith (eds.), *Valuing Natural Resource Assets: The Economics of Natural Resource Damage Assessment.* Washington, DC: Resources for the Future, Inc.

Froese, R., and D. Pauly, eds. 2004. *FishBase*. World Wide Web electronic publication. www.fishbase.org, version 06/2004.

Hensher, David A. 1991. "The Use of Discrete Choice Models in the Determination of Community Choices in Public Issue Areas Impacting on Business Decision Making." *Journal of Business Research* 23(4):299–309.

Krutilla, John V. 1967. "Conservation Reconsidered." *American Economic Review* 57(4):777–796.

McFadden, Daniel. 1997. "Modelling the Choice of Residential Location." In *The Economics of Housing*, Volume 1, J.M. Quigley, ed. Northampton, MA: Elgar.

National Marine Fisheries Statistics. 2004. http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html

Ricker, W.E. 1975. "Computation and Interpretation of Biological Statistics of Fish Populations." Fisheries Research Board of Canada, Bulletin 191.

Rowe, R.D., R. d'Arge, and D.S. Brookshire. 1980. "An Experiment on the Economic Value of Visibility." *Journal of Environmental Economics and Management* 7:1–19.

Schaefer, M.B. 1954. "Some Aspects of the Dynamics of Populations Important to the Management of Commercial Marine Fisheries." *Bulletin of the Inter-American Tropical Tuna Commission* 1:5–56.

Schaefer, M.B. 1957. "Some Considerations of Population Dynamics and Economics in Relation to the Management of Marine Fisheries." *Journal of the Fisheries Research Board of Canada* 14:669–681.

Tenera Environmental Services. 1988. *Pacific Gas and Electric Company, Diablo Canyon Power Plant, Cooling Water Intake Structure 316(b) Demonstration.* Submitted to Pacific Gas and Electric Company, San Francisco, California.

Tenera Environmental Services. 2000. *Diablo Canyon Power Plant 316(b) Demonstration Report*. Prepared for Pacific Gas and Electric Company. March 1. Document No. E9-055.0.

U.S. Environmental Protection Agency. 1977. *Draft Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500.*

U.S. Environmental Protection Agency. 1998. *Guidelines for Ecological Risk Assessment*. EPA/630/R-95/002F. Washington, DC: U.S. Environmental Protection Agency, Risk Assessment Forum.

U.S. Environmental Protection Agency. 2002. *Economic and Benefits Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule.* Report Number 821-R-02-001. Washington, DC: USEPA. February.

U.S. Environmental Protection Agency. 2003. "National Pollutant Discharge Elimination System—Proposed Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities, Notice of Data Availability, Proposed Rule." *Federal Register* Vol. 68, No. 53 (Wednesday, March 19):13,522–13,577.

U.S. Environmental Protection Agency. 2004. "National Pollutant Discharge Elimination System—Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities; Final Rule." *Federal Register* Vol. 69, No. 131 (Friday, July 9):41,576–41,693.

Appendix A

Impingement and Entrainment Estimates

Table A.1
TER's Estimates of Total Impingement Losses at Diablo Canyon Power Plant Using Actual Data

Species	Impingement (# of organisms)[a]	Age-1 Equivalents[b]	Recreational Value[c]		Commercial Value[d]			Forage Value[e]	
			Forgone Recreational Yield (# of fish)	Recreational Loss ($)	Forgone Commercial Yield (lbs)	Commercial Catch Value ($/lb)	Commercial Loss ($)	Pounds of Fish	Commercial and Recreational Species Forgone Value ($)
Pipefish	296	402	—	—	—	—	—	6.07	$0.17
Rockfish	1,141	1,278	64	$89.36	24.2	$0.87	$21.15	—	—
Greenling	14	33	—	—	—	—	—	0.12	$0.00
Sculpin	323	519	—	—	—	—	—	1.98	$0.06
Surfperch	370	445	165	$229.74	—	—	—	—	—
Kelpfish	161	389	—	—	—	—	—	1.48	$0.04
Gunnell	29	75	—	—	—	—	—	0.29	$0.01
Sole	78	105	8	$67.18	23.2	$0.36	$8.44	—	—
Plainfin Midshipman	200	565	—	—	—	—	—	2.15	$0.06
Queenfish	121	121	7	$9.30	13.4	$0.77	$10.37	—	—
Other (Sanddab)	373	446	11	$88.90	30.8	$0.39	$12.00	—	—
	3,106	**4,378**	**254**	**$484.00**	**92**		**$52.00**	**12**	**$0.34**

Total Losses: $537

[a] Raw impingement numbers from Diablo_Input.xls in EPA NODA Docket (#OW-2002-0049).
[b] Age-1 equivalent transformation based upon EPA method and life history parameters from the Northern California and California Regional Studies. Raw impingement numbers increase when converted to Age-1's because many fish are impinged at older ages.
[c] Recreational numbers calculated using EPA method and California random utility model parameters.
[d] Commercial numbers calculated using EPA method and 1981 to 2002 National Marine Fisheries Statistics data.
[e] Forage pounds and values calculated using EPA's commercial production forgone method. We convert lost recreational and commercial fishery values to forage species-specific values.

Table A.2. TER's Estimates of Total Entrainment Losses at Diablo Canyon Power Plant Using Actual Data

Species	Entrainment (# of eggs/larvae)[a]	Age-1 Equivalents[b]	Recreational Value[c]: Forgone Recreational Yield (# of fish)	Recreational Value[c]: Recreational Loss ($)	Commercial Value[d]: Forgone Commercial Yield (lbs)	Commercial Value[d]: Commercial Catch Value ($/lb)	Commercial Value[d]: Commercial Loss ($)	Forage Value[e]: Pounds of Fish	Forage Value[e]: Commercial and Recreational Species Forgone Value ($)
Blackeye Goby	118,500,000	309,726	—	—	—	—	—	600.87	$6.79
Blue Rockfish Complex	58,920,000	362	16	$22.87	7.9	$1.22	$9.66	—	—
Brown Rock Crab[f]	26,465,790,000	5,057,594	1,586	$771.17	4,143.0	$0.91	$3,784.17	—	—
Cabezon	44,100,000	297	—	—	—	—	—	50.14	$0.57
California Halibut	17,970,000	8,526	1,406	$11,902.92	924.0	$2.97	$2,745.10		—
Clinid Kelpfishes	275,062,500	75,716,670	—	—	—	—	—	288,480.51	$3,258.33
KGB Rockfish Complex	248,500,000	1,528	101	$140.27	14.3	$4.66	$66.40	—	—
Monkeyface Prickleback	72,300,000	18,016	363	$176.36	2.7	$4.03	$10.89	—	—
Northern Anchovy	384,000,000	20,902	—	—	2,896.2	$0.05	$155.11	—	—
Pacific Sardine	23,302,500	159,655	—	—	22,124.2	$0.05	$1,005.75	—	—
Painted Greenling	16,905,000	4,653,453	—	—	—	—	—	17,729.65	$200.25
Sanddabs	6,525,000	5,640	133	$1,125.06	389.3	$0.39	$151.80	—	—
Slender Crab[f,g]	429,440,000	95,395	120	$58.18	—	—	—	—	—
Smoothhead Sculpin	86,350,000	21,517	—	—	—	—	—	81.98	$0.93
Snubnose Sculpin	96,750,000	24,109	—	—	—	—	—	91.85	$1.04
White Croaker	558,750,000	8	0	$0.43	0.9	$0.87	$0.75	—	—
	28,903,165,000	**86,093,398**	**3,725**	**$14,197.00**	**30,502.0**		**$7,930.00**	**307,035.00**	**$3,468.00**

Total Losses: $25,595

[a] Raw entrainment numbers from Diablo_Input.xls in EPA NODA Docket (#OW-2002-0049).
[b] Age-1 equivalent transformation based upon EPA method and life history parameters from the Northern California and California Regional Studies.
Raw entrainment numbers decrease when converted to Age-1's because many eggs and larvae would not reach Age 1.
[c] Recreational numbers calculated using EPA method and California random utility model parameters.
[d] Commercial numbers calculated using EPA method and 1981 to 2002 National Marine Fisheries Statistics data.
[e] Forage pounds and values calculated using EPA's commercial production forgone method. We convert lost recreational and commercial fishery values to forage species-specific values.
[f] Entrainment estimates for brown rock crab and slender crab include all larval life stages. We verified the number of Age-1 equivalents with John Steinbeck at Tenera Environmental.
[g] We use EPA's designation that slender crab is a recreationally valuable species.

TER
A BBL Com

Table A.3. TER's Estimates of Total Impingement & Entrainment Losses at Diablo Canyon Power Plant

Species	Impingement & Entrainment (# of organisms /eggs-larvae)[a]	Age-1 Equivalents[b]	Recreational Value[c]: Forgone Recreational Yield (# of fish)	Recreational Value[c]: Recreational Loss $)	Commercial Value[d]: Forgone Commercial Yield (lbs)	Commercial Value[d]: Commercial Loss ($)	Forage Value[e]: Pounds of Fish	Forage Value[e]: Commercial & Recreational Species Forgone Value ($)
Blackeye Goby	118,500,000	309,726	—	—	—	—	600.87	$6.79
Blue Rockfish Complex	58,920,000	362	16	$22.87	8	$9.66	—	—
Brown Rock Crab[f]	26,465,790,000	5,057,594	1,586	$771.17	4,143	$3,784.17	—	—
Cabezon	44,100,000	297	—	—	—	—	50.14	$0.57
California Halibut	17,970,000	8,526	1,406	$11,902.92	924	$2,745.10	—	—
Kelpfish	275,062,661	75,717,059	—	—	—	—	288,482.00	$3,258.37
KGB Rockfish Complex	248,500,000	1,528	101	$140.27	14	$66.40	—	—
Monkeyface Prickleback	72,300,000	18,016	363	$176.36	3	$10.89	—	—
Northern Anchovy	384,000,000	20,902	—	—	2,896	$155.11	—	—
Pacific Sardine	23,302,500	159,655	—	—	22,124	$1,005.75	—	—
Painted Greenling	16,905,000	4,653,453	—	—	—	—	17,729.65	$200.25
Sanddabs	6,525,373	6,085	143	$1,213.96	420	$163.80	—	—
Slender Crab[f,g]	429,440,000	95,395	120	$58.18	—	—	—	—
Smoothhead Sculpin	86,350,000	21,517	—	—	—	—	81.98	$0.93
Snubnose Sculpin	96,750,000	24,109	—	—	—	—	91.85	$1.04
White Croaker	558,750,000	8	0	$0.43	1	$0.75	—	—
Pipefish	296	402	—	—	—	—	6.07	$0.17
Rockfish	1,141	1,278	64	$89.36	24	$21.15	—	—
Greenling	14	33	—	—	—	—	0.12	$0.00
Sculpin	323	519	—	—	—	—	1.98	$0.06
Surfperch	370	445	165	$229.74	—	—	—	—
Gunnell	29	75	—	—	—	—	0.29	$0.01
Sole	78	105	8	$67.18	23	$8.44	—	—
Plainfin Midshipman	200	565	—	—	—	—	2.15	$0.06
Queenfish	121	121	7	$9.30	13	$10.37	—	—
	28,903,168,106	86,097,776	3,979	$14,682.00	30,594	$7,982	307,047.00	$3,468.00

Total Losses: $26,132

[a] Raw impingement/entrainment numbers from Diablo_Input.xls in EPA NODA Docket (#OW-2002-0049).
[b] Age-1 equivalent transformation based upon EPA method and life history parameters from the Northern California and California Regional Studies. Raw impingement numbers increase when converted to Age-1's because many fish are impinged at older ages. Raw entrainment numbers decrease when converted to Age-1's because many eggs and larvae would not reach Age 1.
[c] Recreational numbers calculated using EPA method and California random utility model parameters.
[d] Commercial numbers calculated using EPA method and 1981 to 2002 National Marine Fisheries Statistics data.
[e] Forage pounds and values calculated using EPA's commercial production forgone method. We convert lost recreational and commercial fishery values to forage species-specific values.
[f] Entrainment estimates for brown rock crab and slender crab include all larval life stages. We verified the number of Age-1 equivalents with John Steinbeck at Tenera Environmental.
[g] We use EPA's designation that slender crab is a recreationally valuable species.

Appendix B

Detailed Monte Carlo Analysis

Ranges Applied to Impingement and Entrainment Parameters in the Monte Carlo Analysis

TER includes a Monte Carlo analysis in our 316(b) benefit analysis to account for uncertainty existing in current data and/or estimation methods. A Monte Carlo Analysis treats each parameter as a mean and creates a distribution around the mean by using specified percent ranges.[39] Our Monte Carlo simulates the benefit calculation process 10,000 times using randomly chosen values from each parameter's distribution. Output of the Monte Carlo is a range of benefit values around our calculated mean that accounts for uncertainty. This appendix reports the ranges we apply to each parameter in the Monte Carlo analysis.

B.1 Number of Organisms/Eggs and Larvae Impinged and Entrained

Because fish populations fluctuate from year to year, we attach a range to our estimated number of organisms impinged and number of eggs and larvae entrained. Including this range around the actual number of organisms impinged and entrained accounts for uncertainty in fish community composition and abundance (uncertainty in the ecological system).

Entrainment: We use DCPP entrainment data from Diablo_Input.xls in the NODA Docket (#OW-2002-0049). The estimates we use are an average of 1997 and 1998 plant data. We calculate and apply the percent range of each entrained species between 1997 and 1998 to total egg and larvae estimates. The ranges we apply vary from a low of 4 percent for brown rock crabs to a high of 69 percent for sanddabs. Ranges for all DCPP entrained species are shown in Table B.1.

[39]Ranges are applied to both ends of a mean. A range of 4 percent translates to an 8-percent range around the mean.

Table B.1
Ranges for Entrainment Estimates

Entrained Species	Range
Blackeye Goby	8%
Blue Rockfish	43%
Brown Rock Crab	4%
Cabezon	18%
California Halibut	31%
Clinid Kelpfish	26%
KGB Rockfish	11%
Monkeyface Prickleback	15%
Northern Anchovy	47%
Pacific Sardine	45%
Painted Greenling	43%
Sanddabs	65%
Slender Crab	42%
Smoothhead Sculpin	33%
Snubnose Sculpin	14%
White Croaker	18%
Average	29%

Impingement: We use DCPP impingement data from Diablo_Input.xls in the NODA Docket (#OW-2002-0049). Impingement data are available for only one year, 1998. We calculate the average percent range for all entrained species between 1997 and 1998 (29 percent) and apply it to total numbers of impinged organisms. Because we have only one year of impingement data, we are unable to calculate ranges by species.

B.2 *Recreational and Commercial Species Life Stage Survival Rates*

The life history parameters we use to calculate Age-1 equivalents are transferred from EPA case studies. In some cases, we transfer life history parameters from a similar species or an aggregate species group to DCPP species. The ranges we apply to life stage survival rates are based upon the quality of the match between DCPP species and EPA case study species life histories. Table B.2 reports the criteria we use to assign ranges to recreational and commercial species transfers. Table B.3 presents the EPA species and sources we transfer to DCPP recreational and commercial species as well as the percent ranges applied to the transferred parameters. These ranges account for uncertainty as suggested by EPA:

- Biological/Life History—natural mortality rates
- Stock characteristics—fishing mortality rates.

Table B.2
Uncertainty Applied to EPA Transfers

Criterion Number	Transfer Criterion	Standard Deviation Applied
1.	Exact Species Transfer	0.0%
2.	Different Species Transfer, Similar Life History Match	5.0%
3.	Aggregate Group Transfer, One Exact Species Match	5.0%
4.	Aggregate Group Transfer, Similar Life History Match	7.5%
5.	Different Species Transfer, Best Available Match	10.0%

Table B.3
Recreational and Commercial EPA Species Transfers

	Species	EPA Species Transfer	Life History Basis	EPA Source[a]	Standard Deviation Applied	Criterion Number[b]
Entrained Species	Blue Rockfish Complex	Rockfish	Blue Rockfish	NCCS	5.0%	3
	KGB Rockfish Complex	Rockfish	Blue Rockfish	NCCS	7.5%	4
	Brown Rock Crab	Rock Crab	Brown Rock Crab	NCCS	0.0%	1
	Slender Crab	Rock Crab	Brown Rock Crab	NCCS	5.0%	2
	California Halibut	California Halibut	California Halibut	NCCS	0.0%	1
	Monkeyface prickleback	Other Forage Fish	Multiple species	CRS	5.0%	2
	Northern Anchovy	Anchovies	Northern Anchovy	NCCS	0.0%	1
	Pacific Sardine	Herrings	Pacific Herring	NCCS	0.0%	1
	Sanddabs	Flounders	Speckled Sanddab	NCCS	5.0%	3
	White Croaker	Drums/ Croakers	White Croaker	NCCS	0.0%	1
Impinged Species	Rockfish	Rockfish	Blue Rockfish	NCCS	5.0%	3
	Surfperch	Surfperches	Walleye Surfperch	NCCS	5.0%	2
	Queenfish	Drums/ Croakers	White Croaker	NCCS	5.0%	2
	Sole	Flounders	Multiple species	CRS	5.0%	2
	Other (Sanddab)	Flounders	Multiple species	CRS	10.0%[c]	5

[a] NCCS = Northern California Case Study from EPA NODA Docket.
CRS = California Regional Study from EPA Regional Analysis Document for the Final Phase II Rule.

[b] The criterion number matches the criterion transfer and standard deviation from Table B.2.

[c] 10.0% was used for "Other (Sanddab)" because this category includes species other than Sanddab.

B.3 Commercial and Recreational Species Life Stage Breakdown

Entrainment: One-half of DCPP species entrained lay adhesive eggs (monkeyface prickleback), are livebearers (rockfish), or carry eggs in abdominal flaps (crabs) and are not entrained during the egg life stage. Therefore, entrainment of these species is 100 percent larvae; we apply no uncertainty to their life stage breakdown. We assume a 50-percent breakdown between eggs and larvae for remaining entrained species (California halibut, Northern anchovy, Pacific sardine, sanddabs, and white croaker) based on best available data. We apply a 5-percent range to the egg/larvae breakdown for these species to account for the uncertainty of the estimate.

Impingement: We estimate the breakdown of impinged organisms into percent Age-1 fish and percent Age-2 fish based on EPA case-study impingement data combined with species-specific life history parameters. Since the breakdown is based upon transferred data, we apply a 5-percent range to the assumed age of impinged organisms.

B.4 Commercial and Recreational Species Values

Commercial Values: To calculate DCPP commercial species per-pound values, we use NMFS commercial fishery data from Northern California. We calculate the species-specific average commercial price per pound using catch data from 1981 to 2002 and 2002 price per pound. Taking the average value over a large timeframe includes the natural variations that occur in commercial prices. Because of the quality of our commercial value data, we apply a 0 percent range to these values.

Recreational Values: To calculate DCPP recreational species per-fish values, we use estimated changes in DCPP catch rates and values from EPA's California Regional RUM Study. We account for uncertainty in these non-fixed values by applying a 2.5-percent range to all per-fish recreational values. This step accounts for uncertainty in the economic value of lost recreational fish.

B.5 Forage Species Calculations

Most life history parameters that we transfer to DCPP forage fish are from the "Other Forage Fish" of the California Regional Study. We calculate recreational and commercial production forgone from entrainment and impingement of forage fish using EPA's recreational and commercial species parameters. Because of the uncertainty of the numbers of forage fish impinged and entrained, EPA's "Other Forage Fish" composition, and their recreational and commercial species parameters, we apply a 29-percent range to the final entrainment and impingement forage values calculated. The range of entrainment estimates between 1997 and 1998 is 29 percent. We apply the 29-percent range to the values of the species listed in Table B.4, which presents the EPA species and sources we transfer to DCPP forage species.

Table B.4
Forage EPA Species Transfers

	Species	EPA Species Transfer	Life History Basis	EPA Source[a]
Entrained Species	Blackeye Goby	Gobies	Blackeye Goby	NCCS
	Cabezon	Cabezon	Cabezon	NCCS
	Painted Greenling	Other Forage Fish	Multiple Species	CRS
	Smoothhead Sculpin	Other Forage Fish	Multiple Species	CRS
	Snubnose Sculpin	Other Forage Fish	Multiple Species	CRS
	Clinid Kelpfishes	Other Forage Fish	Multiple Species	CRS
Impinged Species	Pipefish	Chain Pipefish	Chain Pipefish	NARS
	Greenling	Other Forage Fish	Multiple Species	CRS
	Sculpin	Other Forage Fish	Multiple Species	CRS
	Kelpfish	Other Forage Fish	Multiple Species	CRS
	Gunnell	Other Forage Fish	Multiple Species	CRS
	Plainfin Midshipman	Other Forage Fish	Multiple Species	CRS

[a] NCCS = Northern California Case Study from EPA NODA Docket.
CRS = California Regional Study from EPA Regional Analysis Document for the Final Phase II Rule.
NARS = North Atlantic Regional Study from the EPA NODA Docket.

B.6 Compliance Range

Under EPA's Final Phase II Rule, DCPP must reduce its entrainment levels 60 percent to 90 percent and its impingement levels 80 percent to 95 percent from calculation baseline. We include these compliance ranges in Monte Carlo analysis. We report a compliance benefit range that estimates benefits ranging from minimum compliance (60 percent entrainment and 80 percent impingement mortality reduction) to maximum compliance (90 percent entrainment and 95 percent impingement mortality reduction).

Appendix C
Life History Parameters

Table C.1
Blackeye Goby
(Transferred from "Gobies" of Northern California Case Study, Table 2-11: Based on Blackeye Goby)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(–Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	1.0000	0.000	0.00	0.00	1.0000	0	0.0000115
Larvae	2	0.0031	5.766	0.00	5.77	0.0062	0	0.0000190
Juvenile	3	0.4185	0.871	0.00	0.87	0.5901	0	0.0001690
Age 1	4	0.3329	1.100	0.00	1.10	0.4995	0	0.0019400
Age 2	5	0.3329	1.100	0.000	1.10	0.4995	0	0.0041400
Age 3	6	0.3329	1.100	0.000	1.10	0.4995	0	0.0076300
Age 4	7	0.3329	1.100	0.000	1.10	0.4995	0	0.0310000
Age 5	8	0.3329	1.100	0.000	1.10	0.4995	0	0.0810000

Table C.2
Blue/KGB Rockfish Complex (entrainment)/Rockfish (impingement) (Transferred from "Rockfish" of Northern California Case Study, Table 2-17: Based on Blue Rockfish)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(-Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Larvae	1	0.0024	6.040	0.00	6.04	0.0048	0	0.000181
Juvenile	2	0.0013	6.650	0.00	6.65	0.0026	0	0.007600
Age 1	3	0.8065	0.215	0.00	0.22	0.8929	0	0.044400
Age 2	4	0.8065	0.215	0.00	0.22	0.8929	0	0.150000
Age 3	5	0.7703	0.261	0.00	0.26	0.8702	0	0.308000
Age 4	6	0.7703	0.131	0.13	0.26	0.8702	0.25	0.458000
Age 5	7	0.7703	0.131	0.13	0.26	0.8702	0.5	0.689000
Age 6	8	0.7703	0.131	0.13	0.26	0.8702	0.75	0.878000
Age 7	9	0.7703	0.131	0.13	0.26	0.8702	1	1.050000
Age 8	10	0.7703	0.131	0.13	0.26	0.8702	1	1.210000
Age 9	11	0.7703	0.131	0.13	0.26	0.8702	1	1.340000
Age 10	12	0.7703	0.131	0.13	0.26	0.8702	1	1.460000
Age 11	13	0.7703	0.131	0.13	0.26	0.8702	1	1.550000
Age 12	14	0.7703	0.131	0.13	0.26	0.8702	1	1.630000
Age 13	15	0.7703	0.131	0.13	0.26	0.8702	1	1.700000
Age 14	16	0.7703	0.131	0.13	0.26	0.8702	1	1.750000
Age 15	17	0.7703	0.131	0.13	0.26	0.8702	1	1.80000[illegible]
Age 16	18	0.7703	0.131	0.13	0.26	0.8702	1	1.8300[illegible]
Age 17	19	0.7703	0.131	0.13	0.26	0.8702	1	1.860000
Age 18	20	0.7703	0.131	0.13	0.26	0.8702	1	1.880000
Age 19	21	0.7703	0.131	0.13	0.26	0.8702	1	1.900000
Age 20	22	0.7703	0.131	0.13	0.26	0.8702	1	1.920000
Age 21	23	0.7703	0.131	0.13	0.26	0.8702	1	1.930000
Age 22	24	0.7703	0.131	0.13	0.26	0.8702	1	1.940000
Age 23	25	0.7703	0.131	0.13	0.26	0.8702	1	1.950000
Age 24	26	0.7703	0.131	0.13	0.26	0.8702	1	1.950000

Table C.3
Slender/Brown Rock Crab
(Transferred from "Rock Crab" of Northern California Case Study, Table 2-16: Based on Brown Rock Crab)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(-Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	1.0000	0.000	0.000	0.00	1.0000	0	0.000000151
Zoea. 1	2	0.2060	1.580	0.000	1.58	0.3416	0	0.000027900
Zoea. 2	3	0.3875	0.948	0.000	0.95	0.5586	0	0.000155000
Zoea. 3	4	0.3875	0.948	0.000	0.95	0.5586	0	0.000445000
Zoea. 4	5	0.3875	0.948	0.000	0.95	0.5586	0	0.000956000
Zoea. 5	6	0.2837	1.260	0.000	1.26	0.4419	0	0.000059800
Megalopae	7	0.0993	2.310	0.000	2.31	0.1806	0	0.000134000
Age 0/Juvenile	8	0.0880	2.430	0.000	2.43	0.1618	0	0.000019200
Age 1	9	0.0880	2.430	0.000	2.43	0.1618	0	0.289000000
Age 2	10	0.0880	2.430	0.000	2.43	0.1618	0	0.654000000
Age 3	11	0.0880	2.430	0.000	2.43	0.1618	0	1.260000000
Age 4	12	0.0880	1.820	0.610	2.43	0.1618	0.5	1.970000000
Age 5	13	0.0880	1.820	0.610	2.43	0.1618	1	2.550000000
Age 6	14	0.0880	1.820	0.610	2.43	0.1618	1	3.000000000

Table C.4
Cabezon
(Northern California Case Study, Table 2-4)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(−Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.7498	0.288	0.000	0.288	0.8570	0	0.00000043
Larvae	2	0.0025	6.000	0.000	6.000	0.0049	0	0.00060500
Juvenile	3	0.0014	6.600	0.000	6.600	0.0027	0	0.00825000
Age 1	4	0.8659	0.144	0.000	0.144	0.9281	0	0.16900000
Age 2	5	0.7498	0.144	0.144	0.288	0.8570	0.5	1.06000000
Age 3	6	0.7498	0.144	0.144	0.288	0.8570	1	3.26000000
Age 4	7	0.7498	0.144	0.144	0.288	0.8570	1	4.72000000
Age 5	8	0.7498	0.144	0.144	0.288	0.8570	1	5.30000000
Age 6	9	0.7498	0.144	0.144	0.288	0.8570	1	6.13000000
Age 7	10	0.7498	0.144	0.144	0.288	0.8570	1	6.78000000
Age 8	11	0.7498	0.144	0.144	0.288	0.8570	1	7.37000000
Age 9	12	0.7498	0.144	0.144	0.288	0.8570	1	8.76000000
Age 10	13	0.7498	0.144	0.144	0.288	0.8570	1	9.23000000
Age 11	14	0.7498	0.144	0.144	0.288	0.8570	1	10.50000000
Age 12	15	0.7498	0.144	0.144	0.288	0.8570	1	12.0000[illegible]
Age 13	16	0.7498	0.144	0.144	0.288	0.8570	1	13.7000[illegible]

Table C.5
California Halibut
(Northern California Case Study, Table 2-5)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(−Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.8001	0.223	0.000	0.22	0.8890	0	0.000000548
Larvae	2	0.0015	6.500	0.000	6.50	0.0030	0	0.000004440
Juvenile	3	0.2187	1.520	0.000	1.52	0.3589	0	0.017000000
Age 1	4	0.8353	0.180	0.000	0.18	0.9102	0	0.130000000
Age 2	5	0.8353	0.180	0.000	0.18	0.9102	0	0.739000000
Age 3	6	0.8353	0.180	0.000	0.18	0.9102	0	1.940000000
Age 4	7	0.8353	0.180	0.000	0.18	0.9102	0	3.870000000
Age 5	8	0.8353	0.180	0.000	0.18	0.9102	0	6.210000000
Age 6	9	0.5599	0.180	0.400	0.58	0.7179	1	8.890000000
Age 7	10	0.5599	0.180	0.400	0.58	0.7179	1	12.200000000
Age 8	11	0.5599	0.180	0.400	0.58	0.7179	1	15.300000000
Age 9	12	0.5599	0.180	0.400	0.58	0.7179	1	18.900000000
Age 10	13	0.5599	0.180	0.400	0.58	0.7179	1	21.300000000
Age 11	14	0.5599	0.180	0.400	0.58	0.7179	1	23.800000000
Age 12	15	0.5599	0.180	0.400	0.58	0.7179	1	26.600000000
Age 13	16	0.5599	0.180	0.400	0.58	0.7179	1	28.600000000
Age 14	17	0.5599	0.180	0.400	0.58	0.7179	1	30.700000000
Age 15	18	0.5599	0.180	0.400	0.58	0.7179	1	33.000000000
Age 16	19	0.5599	0.180	0.400	0.58	0.7179	1	35.300000000
Age 17	20	0.5599	0.180	0.400	0.58	0.7179	1	37.700000000
Age 18	21	0.5599	0.180	0.400	0.58	0.7179	1	40.200000000
Age 19	22	0.5599	0.180	0.400	0.58	0.7179	1	42.900000000
Age 20	23	0.5599	0.180	0.400	0.58	0.7179	1	45.700000000
Age 21	24	0.5599	0.180	0.400	0.58	0.7179	1	48.500000000
Age 22	25	0.5599	0.180	0.400	0.58	0.7179	1	51.500000000
Age 23	26	0.5599	0.180	0.400	0.58	0.7179	1	54.700000000
Age 24	27	0.5599	0.180	0.400	0.58	0.7179	1	57.900000000
Age 25	28	0.5599	0.180	0.400	0.58	0.7179	1	61.300000000
Age 26	29	0.5599	0.180	0.400	0.58	0.7179	1	64.800000000
Age 27	30	0.5599	0.180	0.400	0.58	0.7179	1	68.400000000
Age 28	31	0.5599	0.180	0.400	0.58	0.7179	1	72.200000000
Age 29	32	0.5599	0.180	0.400	0.58	0.7179	1	76.100000000
Age 30	33	0.5599	0.180	0.400	0.58	0.7179	1	80.100000000

Table C.6
Clinid Kelpfishes (entrainment)/Kelpfish (impingement)
(Transferred from "Other Forage Species" of California Regional Study, Table B1-39)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(-Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.3535	1.04	0.00	1.04	0.5223	0	0.0000000186
Larvae	2	0.0005	7.70	0.00	7.70	0.0009	0	0.0000015800
Juvenile	3	0.2753	1.29	0.00	1.29	0.4317	0	0.0004810000
Age 1	4	0.1979	1.62	0.00	1.62	0.3304	0	0.0038100000
Age 2	5	0.1979	1.62	0.00	1.62	0.3304	0	0.0049600000
Age 3	6	0.1979	1.62	0.00	1.62	0.3304	0	0.0050500000

Table C.7
Gunnell
(Transferred from "Other Forage Fish" of California Regional Study, Table B1-39)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(-Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.3535	1.04	0.000	1.04	0.5223	0	0.0000000186
Larvae	2	0.0005	7.70	0.000	7.70	0.0009	0	0.0000015800
Juvenile	3	0.2753	1.29	0.000	1.29	0.4317	0	0.0004810000
Age 1	4	0.1979	1.62	0.000	1.62	0.3304	0	0.0038100000
Age 2	5	0.1979	1.62	0.000	1.62	0.3304	0	0.0049600000
Age 3	6	0.1979	1.62	0.000	1.62	0.3304	0	0.0050500000

Table C.8
Monkeyface Prickleback
(Transferred from "Other Forage Fish" of California Regional Study, Table B1-39)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(−Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.3535	1.04	0.00	1.04	0.5223	0	0.0000000186
Larvae	2	0.0005	7.70	0.00	7.70	0.0009	0	0.0000015800
Juvenile	3	0.2753	1.29	0.00	1.29	0.4317	0	0.0004810000
Age 1	4	0.1979	1.62	0.00	1.62	0.3304	0	0.0038100000
Age 2	5	0.1979	1.62	0.00	1.62	0.3304	0	0.0049600000
Age 3	6	0.1979	1.62	0.00	1.62	0.3304	0	0.0050500000

Table C.9
Northern Anchovy
(Transferred from "Anchovies" of Northern California Case Study, Table 2-1: Based on Northern Anchovy)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(−Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.5122	0.669	0.00	0.669	0.6774	0	0.00000138
Larvae	2	0.0003	7.990	0.00	7.990	0.0007	0	0.00110000
Juvenile	3	0.1200	2.120	0.00	2.120	0.2143	0	0.02200000
Age 1	4	0.4819	0.700	0.03	0.730	0.6504	0.5	0.04080000
Age 2	5	0.4819	0.700	0.03	0.730	0.6504	1	0.05290000
Age 3	6	0.4819	0.700	0.03	0.730	0.6504	1	0.06090000
Age 4	7	0.4819	0.700	0.03	0.730	0.6504	1	0.06840000
Age 5	8	0.4819	0.700	0.03	0.730	0.6504	1	0.07630000
Age 6	9	0.4819	0.700	0.03	0.730	0.6504	1	0.07890000

Table C.10
Pacific Sardine
(Transferred from "Herrings" of Northern California Case Study, Table 2-12: Based on Pacific Herring)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(–Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.7945	0.230	0.00	0.23	0.8855	0	0.0000039
Larvae	2	0.0100	4.610	0.00	4.61	0.0197	0	0.0000609
Juvenile	3	0.4805	0.693	0.04	0.73	0.6491	0	0.0126000
Age 1	4	0.5102	0.473	0.20	0.67	0.6757	0	0.0408000
Age 2	5	0.6225	0.274	0.20	0.47	0.7673	0.5	0.1280000
Age 3	6	0.6225	0.274	0.20	0.47	0.7673	1	0.1670000
Age 4	7	0.6225	0.274	0.20	0.47	0.7673	1	0.2110000
Age 5	8	0.6225	0.274	0.20	0.47	0.7673	1	0.2580000
Age 6	9	0.6225	0.274	0.20	0.47	0.7673	1	0.2880000
Age 7	10	0.6225	0.274	0.20	0.47	0.7673	1	0.3300000
Age 8	11	0.6225	0.274	0.20	0.47	0.7673	1	0.3450000
Age 9	12	0.6225	0.274	0.20	0.47	0.7673	1	0.3530000
Age 10	13	0.6225	0.274	0.20	0.47	0.7673	1	0.3640000
Age 11	14	0.6225	0.274	0.20	0.47	0.7673	1	0.3750000

Table C.11
Painted Greenling (entrainment)/Greenling (impingement)
(Transferred from "Other Forage Species" of California Regional Study, Table B1-39)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(–Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.3535	1.04	0.00	1.04	0.5223	0	0.0000000186
Larvae	2	0.0005	7.70	0.00	7.70	0.0009	0	0.0000015800
Juvenile	3	0.2753	1.29	0.00	1.29	0.4317	0	0.0004810000
Age 1	4	0.1979	1.62	0.00	1.62	0.3304	0	0.0038100000
Age 2	5	0.1979	1.62	0.00	1.62	0.3304	0	0.0049600000
Age 3	6	0.1979	1.62	0.00	1.62	0.3304	0	0.0050500000

Table C.12
Pipefish
(Transferred from "Chain Pipefish" of North Atlantic Regional Study, Table C1-21)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(–Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.1003	2.300	0.000	2.30	0.1822	0	0.0000007730
Larvae	2	0.0907	2.400	0.000	2.40	0.1663	0	0.0000122000
Juvenile	3	0.4001	0.916	0.000	0.92	0.5715	0	0.0078500000
Age 1	4	0.4724	0.750	0.000	0.75	0.6416	0	0.0151000000
Age 2	5	0.4724	0.750	0.000	0.75	0.6416	0	0.0180000000
Age 3	6	0.4724	0.750	0.000	0.75	0.6416	0	0.0212000000
Age 4	7	0.4724	0.750	0.000	0.75	0.6416	0	0.0247000000
Age 5	8	0.4724	0.750	0.000	0.75	0.6416	0	0.0285000000

Table C.13
Plainfin Midshipman
(Transferred from "Other Forage Species" of California Regional Study, Table B1-39)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(-Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.3535	1.04	0.00	1.04	0.5223	0	0.0000000186
Larvae	2	0.0005	7.70	0.00	7.70	0.0009	0	0.0000015800
Juvenile	3	0.2753	1.29	0.00	1.29	0.4317	0	0.0004810000
Age 1	4	0.1979	1.62	0.00	1.62	0.3304	0	0.0038100000
Age 2	5	0.1979	1.62	0.00	1.62	0.3304	0	0.0049600000
Age 3	6	0.1979	1.62	0.00	1.62	0.3304	0	0.0050500000

Table C.14
Smooth/Snubnose Sculpin (entrainment)/Sculpin (impingement)
(Transferred from "Other Forage Fish" of California Regional Study, Table B1-39)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(-Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.3535	1.04	0.00	1.04	0.5223	0	0.0000000186
Larvae	2	0.0005	7.70	0.00	7.70	0.0009	0	0.0000015800
Juvenile	3	0.2753	1.29	0.00	1.29	0.4317	0	0.0004810000
Age 1	4	0.1979	1.62	0.00	1.62	0.3304	0	0.0038100000
Age 2	5	0.1979	1.62	0.00	1.62	0.3304	0	0.0049600000
Age 3	6	0.1979	1.62	0.00	1.62	0.3304	0	0.0050500000

Table C.15
Sole
(Transferred from "Flounders" of California Regional Study, Table B1-15)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(–Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Eggs	1	0.8001	0.223	0.000	0.22	0.8890	0	0.00000030300
Larvae	2	0.0019	6.280	0.000	6.28	0.0037	0	0.00121000000
Juvenile	3	0.3198	1.140	0.000	1.14	0.4846	0	0.00882000000
Age 1	4	0.5472	0.363	0.240	0.60	0.7073	0.5	0.06720000000
Age 2	5	0.3399	0.649	0.430	1.08	0.5074	1	0.22600000000
Age 3	6	0.2859	0.752	0.500	1.25	0.4447	1	0.55300000000
Age 4	7	0.2859	0.752	0.500	1.25	0.4447	1	1.13000000000

Table C.16
Speckled/Pacific Sanddabs (entrainment)/Sanddab (impingement)
(Transferred from "Flounders" of Northern California Case Study, Table 2-10: Based on Speckled Sanddab)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(–Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.8001	0.223	0.000	0.223	0.8890	0	0.00000030
Larvae	2	0.0019	6.280	0.000	6.280	0.0037	0	0.00121000
Juvenile	3	0.3198	1.140	0.000	1.140	0.4846	0	0.00882000
Age 1	4	0.5461	0.363	0.242	0.605	0.7064	0.5	0.06720000
Age 2	5	0.3393	0.649	0.432	1.081	0.5066	1	0.22600000
Age 3	6	0.2856	0.752	0.501	1.253	0.4444	1	0.55300000
Age 4	7	0.2856	0.752	0.501	1.253	0.4444	1	1.13000000

Table C.17
Surfperches
(Transferred from "Surfperches" of Northern California Case Study, Table 2-23: Based on Walleye Surfperch)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(−Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Juvenile	1	0.5712	0.560	0.000	0.56	0.7271	0	0.0044300
Age 1	2	0.7558	0.280	0.000	0.28	0.8609	0	0.0429000
Age 2	3	0.5712	0.280	0.280	0.56	0.7271	0.5	0.1250000
Age 3	4	0.5712	0.280	0.280	0.56	0.7271	1	0.2030000
Age 4	5	0.5712	0.280	0.280	0.56	0.7271	1	0.2610000
Age 5	6	0.5712	0.280	0.280	0.56	0.7271	1	0.3000000
Age 6	7	0.5712	0.280	0.280	0.56	0.7271	1	0.3240000

Table C.18
White Croaker (entrainment)/Queenfish (impingement)
(Transferred from "Drums/Croakers" of Northern California Case Study, Table 2-8: Based on White Croaker)

Life Stage	Life Stage Sequence	Survival by Stage Fraction (S=exp(−Z))	Natural Mortality Rate (M)	Fishing Mortality Rate (F)	Total Mortality Rate (Z)	Adjusted S	Fraction Vulnerable to Fishery	Weight (lb.)
Egg	1	0.6065	0.500	0.000	0.5	0.7551	0	0.000000722
Larvae	2	0.0100	4.610	0.000	4.6	0.0197	0	0.000004640
Juvenile	3	0.0000	13.800	0.000	13.8	0.0000	0	0.000212000
Age 1	4	0.6570	0.420	0.000	0.4	0.7930	0	0.120000000
Age 2	5	0.6570	0.420	0.000	0.4	0.7930	0	0.156000000
Age 3	6	0.7342	0.210	0.099	0.3	0.8467	0.5	0.195000000
Age 4	7	0.6570	0.210	0.210	0.4	0.7930	1	0.239000000
Age 5	8	0.6570	0.210	0.210	0.4	0.7930	1	0.287000000
Age 6	9	0.6570	0.210	0.210	0.4	0.7930	1	0.340000000
Age 7	10	0.6570	0.210	0.210	0.4	0.7930	1	0.398000000
Age 8	11	0.6570	0.210	0.210	0.4	0.7930	1	0.458000000
Age 9	12	0.6570	0.210	0.210	0.4	0.7930	1	0.519000000
Age 10	13	0.6570	0.210	0.210	0.4	0.7930	1	0.584000000
Age 11	14	0.6570	0.210	0.210	0.4	0.7930	1	0.648000000
Age 12	15	0.6570	0.210	0.210	0.4	0.7930	1	0.723000000

TRIANGLE ECONOMIC RESEARCH
A BBL Company

Review of Independent Scientists' Report with Consideration of Stratus Report

Final Report

Prepared for:

Kathy Jones
Pacific Gas and Electric Company
77 Beale Street
San Francisco, CA 94105

Prepared by:

Matthew F. Bingham
William H. Desvousges

August 29, 2005

2775 Meridian Parkway
Durham, NC 27713

•

Phone: 919-544-2244
Fax: 919-544-3935
E-mail: info@ter.com

Review of Independent Scientists (IS) Report with Consideration of Stratus Report

Final Report

Prepared for:

Kathy Jones
Pacific Gas and Electric Company
77 Beale Street
San Francisco, CA 94105

Prepared by:

Matthew F. Bingham
William H. Desvousges

Triangle Economic Research
2775 Meridian Parkway
Durham, NC 27713

August 29, 2005

Project No. 23205 (FR)

Table of Contents

1. EXECUTIVE SUMMARY

Cooling water intake structures (CWIS) at large, existing power plants are regulated by the Clean Water Act 316(b) Phase II Rule. The Rule requires impingement reductions of 80 to 95 percent and entrainment reductions of 60 to 90 percent, but also provides for site-specific determinations where the costs of best technology available (BTA), including restoration measures, are significantly greater than the benefits. The correct economic valuation of the benefits of reducing impingement mortality and entrainment (I&E) is therefore an important component of the Phase II Rule, which sets forth requirements for benefits valuation studies (BVSs) that in general must value commercial, recreational and, in appropriate circumstances, nonuse benefits derived from I&E reductions.

This report provides an overview of the basic economic principles that are required to conduct a reliable benefit valuation study. These economic valuation principles are based on a long period of conceptual development, refinement, and extensive empirical testing. Using these economic principles, we lay the foundations for both the Diablo Canyon Power Plant (DCPP) 316(b) BVS conducted by TER in 2005, and our critical assessment of the 2005 Independent Scientists (IS) report, "Diablo Canyon Power Plant, Independent Scientist's Recommendations to the Regional Board Regarding 'Mitigation' for Cooling Water Impacts" (IS Report).

In our critical assessment, we demonstrate that the IS Report (2005) is seriously flawed. We show that it is inconsistent with basic economic principles such as:

- The valuation concepts in the IS Report are based on costs, not values, which lead to implausible and sometimes nonsensical results. The IS Report is therefore inconsistent with basic economic principles and is also contrary to EPA's Phase II Rule requirements for BVSs.
- The IS Report fails to provide any plausible economic justification for the presumption that the effects of the DCPP on forage fish populations would result in significant nonuse values. In fact, the lack of general public awareness about such marginal population changes, the uncertainty about whether or not they would occur, and the large number of substitute resources make significant nonuse values extremely unlikely.

- The IS Report fails to develop any linkages between impingement and entrainment effects, ecological services, and humans. Consequently, it is unable to develop a reliable approach for scaling the size of the proposed artificial reef mitigation project.
- The IS Report fails to consider the basic principle of discounting to standardize the timing of services from the artificial reef relative to the potential impingement and entrainment effects from the DCPP. Given the fact that the reef would provide services into perpetuity while the plant has a finite economic lifetime, the failure to consider discounting results in a substantial overstatement of the size of the reef that would be required to offset any potential effects on services, should they occur.
- The IS Report uses methods that are completely inconsistent with the EPA Phase II regulations for CWIS by, among other things, proposing a restoration project with costs significantly greater than the benefits of reducing I&E at the DCPP.

Given these flaws, it is not at all surprising that the range of costs from $10.6 million to $26 million for the proposed artificial reef greatly exceed the approximately $1 million upper bound in estimated benefits from reducing I&E at the DCPP (TER 2005). As explained below, there is no conceptual or empirical economic rationale that would suggest that such a large differential could be justified by either omitted benefits or unvalued effects. In fact, our estimate of benefits includes the effects of DCPP on forage fish based on EPA's recommended trophic transfer approach. Thus, the only category of benefits not included in our range of monetized damages is the potential existence value of forage fish and other organisms that are not captured through the food web. Even the most forceful advocates of monetizing nonuse values argue that a multiple of 2 to 3 of use benefits would account for such benefits. Thus, even the lower bound of the IS Report is ten times the upper bound estimate of our analysis. This fact indicates that the biological valuation approach used in the IS Report results in economic conclusions that are totally implausible. Moreover, it serves to illustrate the type of outcome that can result when an approach ignores such basic economic principles as values based on preferences not costs, and the discounting of future services.

2. BACKGROUND

Recently, two BVSs were conducted specifically for Diablo Canyon Power Plant (DCPP) CWIS impacts:

- ASA Study (2003): ASA used EPA's then-existing draft 316(b) Phase II economic guidelines to evaluate commercial, recreational, ecological, and nonuse benefits (using the 50 percent rule of thumb). ASA estimated total value of 80 percent entrainment reduction through 2053 to be $23,000 to $4.2 million, of which $5,000 to $935,000 was estimated to be nonuse value. The estimate included all fish species entrained (not just the Representative Important Species (RIS)), but excluded crabs. The study included no separate estimate for impingement, and used trophic transfer rates that were changed in the final guidance.
- TER Study (2005): We used EPA's final Phase II economic guidelines to estimate total value of reducing impingement by 80 to 95 percent and entrainment by 60 to 90 percent through 2053 to be approximately $564,000 to $1 million for all fish species and two crab species. We conclude that nonuse values do not need to be monetized under EPA final Phase II guidelines because I&E had only marginal population effects on non-unique species, and, on the basis of a qualitative analysis, that such values would be low in any event.

The ASA Study is somewhat outdated because of changes in U.S. EPA's economic approach. For example, EPA eliminated the use of the 50 percent nonuse rule of thumb in the final rule. The Agency also changed the trophic transfer factor used to account for the entrainment effects on forage species in terms of forgone production of recreational and commercial species. Finally, the ASA report does not provide a separate estimate of impingement and does account for any crab species in its results.

TER's report is the best estimate of the economic value of I&E reductions at the DCPP. The analysis contained in the report is performed in a manner that complies with EPA Phase II regulations. Additionally, the report uses the latest and most appropriate data on impingement and entrainment at DCPP, and evaluates all fish species, including forage species and two species of crabs. This evaluation incorporates an adjustment factor to reflect the fact that the biological data are based only on representative individual species. It also includes an analysis of the potential uncertainty in the benefits estimation that is consistent with the state-of-the art in statistical estimation and the EPA regulatory requirements. Finally, the report uses qualitative analysis to assess potential nonuse benefits from reducing I&E impacts at DCPP. This analysis, which is based on standard economic principles, concludes that the potential for such benefits from reducing I&E at DCPP are negligible.

More recently the IS Study (2005) was produced to evaluate potential mitigation alternatives for I&E impacts at DCPP. The IS used a habitat replacement cost approach (HRC) to project the value of I&E reduction based on the costs of constructing sufficient new artificial reefs to produce sufficient larvae to offset losses. The IS valued I&E reduction at $10.6 million to $26 million. The report also considers Marine Protection Areas and other potential mitigation alternatives, but devotes most of its attention to the artificial reef construction.

The IS Report, which is discussed in more detail in this report, is inconsistent with Phase II regulatory requirements for benefit valuation studies, because it employs a methodology (HRC) that EPA considered but ultimately rejected in the promulgation of the final 316(b) rule. Moreover, the use of habitat replacement costs as a measure of economic benefits is completely contradictory to long-established economic valuation principles. In particular, the method uses costs to approximate values, a notion which as demonstrated later in this report may lead to nonsensical results. In the case of the DCPP, the method grossly overstates the true value of I&E reductions.

3. BASIC ECONOMIC PRINCIPLES

3.1 Economic Concept of Value

The economic concept of value has developed over a long series of contributions from many scholars dating to Adam Smith, Alfred Marshall, and John Hicks. Unlike other broader concepts of value that are linked to inherent or abstract principles, economic value is comparative in nature. In essence, economic value derives from trade-offs: how much of one thing is a person willing to forego to obtain more of another? In economics, people hold values and are the arbiter of how much something is worth to them. Thus, people have value for preserving fish populations in an economic sense.[1]

This anthropocentric nature of economic value differentiates it from valuation concepts arising from an ecological paradigm. In that paradigm, ecological systems are viewed as inherently valuable. For example, Banzhaf and Boyd (2004) note:

> Economics is based on an anthropocentric ecological value, while ecology is more concerned with the status, functions, and quality of ecosystems themselves, rather than as producers of human benefit (p. 17).

Bockstael et al. 2000, add to this distinction by indicating that:

> Some ecologists and other natural scientists have begun developing their own estimates of the "economic value" of ecosystem services. They believe...that economists fail to appreciate the intricate web of physical interrelationships that can link harm in one part of an ecosystem to negative effects in another. Failing to recognize the complexity of the system can result in an underestimate of the benefits of ecosystem protection (p. 1).

Not surprisingly, given such differences in the fundamental concept of value, disagreements among economists and ecologists over the benefits associated with a specific policy change are common.[2] In the context of the 316(b) regulations, however, Congress has determined that CWIS permitting decisions are to be based on economic valuations, As EPA made clear in the Preamble to the Phase II regulations:

> EPA has established in today's rule national requirements for facilities to install technology that is technically available, *economically practicable, and cost effective* while at the same time authorizing a range of technologies that achieve comparable reductions in adverse environmental impact (69 *Fed. Reg.* 41576, 41583 (col. 2) July 9, 2004) (*emphasis added*).

[1] Bockstael et al. 2000 note that the economic concept of value depends on the distribution of income among individuals and economics measures values in a comparative rather than an absolute sense.

[2] The National Research Council (2004) argues that differences in terminology and perspectives compound the disagreements between ecologists and economists.

The economic concept of value depends on an individual's determining how much something is worth to him, usually expressed as his or her willingness to pay to have additional units of a good or service. In practice, economic values are used to answer basic questions that are relevant to the evaluation of any public policy choice: how does one determine whether an individual is better off with a policy change or without it? And how does one aggregate the gains and losses from a particular policy?

In economics, two (and sometimes more) alternatives are being compared. An economic valuation estimate will depend on the circumstances in which the valuation question arises. Again, Bockstael et al. (2000) illustrate this key point:

> For example, suppose a power plant is being considered for a location that would eliminate a swimming beach. Different people can have quite different values for this change, depending on whether they would use the beach, gain from the lower cost of electricity, or both (p. 3).

They further note that the answer to this valuation question would depend on whether there was another beach close by (a substitute) or whether the loss of the beach would affect any other services, such as surfing or any unique ecological function, such as habitat for an endangered species. Clearly, valuation depends on the context in which the policy is being considered.

Services are an integral part of the economic valuation framework. When economists place a value on a natural resource, they value the services that flow from the natural asset, rather than the asset itself (Smith and Kopp 1993). The services that natural resources provide to humans are relatively straightforward concepts. For example, fish can be combined with other economic inputs to produce recreational or commercial fishing. The value of these services can be determined by observing the choices that people make and making inferences about their value.

Ecological services may also exist, but are much less clear cut. Generally, ecological services involve the services that one natural resource provides to another. However, Banzhaf and Boyd (2004) add further to this concept of ecological services by noting that:

> Services are tangible ecological elements (e.g., a population) or qualities (air [or water] quality) that result from ecological functions and processes. Ecological assets are inputs to an ecological production function that yields an ecological service (p. 12).

As Boyd and Banzhaf (2005) discuss, services are the end products of nature that yield human well being. They argue that although ecological services must be derived from the natural environment, they must result in an end-product that is useful to humans. Thus, in the economic paradigm, ecological services are more than simply ecological functions. They include the interaction or at least awareness between people and the natural environment.

Not surprisingly, the valuation of ecological services is the subject of considerable confusion and controversy. Boyd indicates one of the primary reasons for some of the controversy:

> Nature and the services that it provides are a significant contributor to human well-being, and society makes decisions every day about whether we will have more or less of it. Knowing nature's value helps us make those decisions. The difficulty is that nature never comes with a convenient price tag attached (Boyd 2004, p. 18).

It has been the attempts to develop such price tags, which has added to the controversy. The disagreements arise, at least in part, from the contention by some that people may have value for natural resources that exceeds the value of their direct uses. These "nonuse values" may stem from a variety of motives, with the most frequently mentioned ones being the preservation of the existence of the resource or the desire to preserve a natural resource for future generations to enjoy.

As we discuss below, nonuse values usually are thought to arise from unique resources that are irreplaceable—i.e., they have few if any substitutes in the economics lexicon. These nonuse values are usually addressed in a qualitative manner, or are measured using survey-based approaches that attempt to simulate a market for the resource services. One of the primary concerns about survey-based measures is that they are based on hypothetical responses, not actual market decisions or choices. The economics literature has clearly demonstrated that such questions lead to hypothetical bias, which implies that survey based methods overstate the true value of the natural resource (List 2001; Champ and Bishop 2001). Finally, the nature and magnitude of that bias is not sufficiently well understood such that a reliable calibration factor can be developed (Desvousges, Gable, and Johnson 1995).

3.2 Nonuse values are not always significant

As noted above, the total value of a natural resource such as a fish population consists of its direct and indirect use values (i.e., typically commercial and recreational fishing) and, in appropriate cases, nonuse values. A key assumption of the IS Report (as well as the Stratus report [2004]) is that the nonuse values of I&E impacts on fish populations (and in particular on forage species which account for the vast majority of the fish species entrained) may be very significant indeed.[3] For example, the report claims that benefit-cost analyses of environmental actions typically evaluate only a small subset of easily measured values (i.e., commercial and recreational fishing values), and typically omit nonuse benefits (such as the contribution of forage species to ecological functions) that may also be associated with I&E impacts. The assertion that nonuse impacts of I&E are significant wrongly fails to recognize that I&E impacts bear very little resemblance to the types of resources that economists have theorized might have significant nonuse values.

The original formulation of nonuse values considered the "existence of a grand scenic wonder or unique and fragile ecosystem" and hypothesized that certain people hold value for such a resource's "preservation and continued availability" (Krutilla 1967). Krutilla's example, the Grand Canyon, certainly qualifies as a grand scenic wonder. Since Krutilla's time, economists' expectations for the sort of resource typically expected to have nonuse values have not strayed far from this original formulation. For example nonuse values have been empirically evaluated for the survival of endangered species such as blue whales (Samples, Dixon, and Gowen 1986), eagles and striped shiners (Boyle and Bishop 1987). When economists have empirically evaluated nonuse values for population impacts, they have looked at significant and certain impacts to populations that are relevant to the survey respondents. For example,

[3] EPA has concluded that the best way to value forage species is through trophic transfer models, which allow economists to value forage species in terms of the larger populations of commercially and recreationally important species that could be supported if larger populations of forage species were available to sustain them (EPA 2004b).

Kinnell et al. (2002) evaluates use and nonuse values for certain decreases of 30% and 75% in the total duck populations using a survey frame of Pennsylvania duck hunters. By contrast, the I&E impacts of DCPP on average have much lower percentage impacts on the larvae of fish species, and even lower impacts on the number of adult fishes forgone as a result of the larval entrainment (since most fish larvae have short natural life spans anyway). To our knowledge there has never been a serious theoretical or empirical evaluation demonstrating support for nonuse values for the sorts of marginal impacts to obscure, sustainable, regenerating populations that are hypothesized to occur in the case of most I&E impacts.

3.3 To the extent that nonuse values exist for I&E reductions, they are not likely to be meaningful

To the extent that nonuse values do exist for marginal changes in fish populations, there are no theoretical or empirical reasons to believe that they are meaningful. Except for the rare situations involving I&E of threatened and endangered species, fish are a renewable resource. The factors that typically support significant nonuse values—significant existence values and lack of substitute goods—simply do not apply in the same way for changes in renewable common fish populations as they do for unique, non-renewable resources.

A comparison of use and nonuse values for fish populations makes this apparent. People are the top predators in the food chain for fish. If nonuse values were truly substantial for changes in fish populations, we would expect that people would stop eating fish because the value of preserving their survival would be greater than their use values (commercial and recreational fishing). There is no empirical data to support the notion that such actions are prevalent, and indeed the fact that commercial and recreational fishing continue supports the conclusion that there is no significant existence value for marginal changes in fish populations.

The reason we do not anticipate meaningful nonuse values for marginal changes in fish population resulting from I&E at the DCPP is the lack of uniqueness at both the level of individual fish and the population. For the types of marginal effects on fish populations anticipated here, the number of substitutes is likely to be quite high. If, for example, the population of a certain type of fish decreases by 2 percent, there are many substitutes that would exist so that this change would be covered by other fish populations in the same area, as well as fish populations in other locations. A large number of substitutes, which certainly would be the case for forage species, indicates that the per-unit value of any changes in a fish population is likely to be modest, if even measurable.

Clearly, there is a lack of any conceptual rationale for the presumption that there are significant nonuse values associated with I&E impacts. There is also no empirical evidence that large nonuse values are associated with I&E impacts. The Stratus Report's notion that substantial nonuse values are not being included in benefit-cost analyses apparently was based on an empirical study that is totally without any valid economic foundation. Helm et al. (2004) summarize 33 valuation studies that they consider most relevant for measuring the potential nonuse values for the Phase III Section 316(b) rule, which currently is being developed for another category of existing CWISs. They use these studies in a meta-analysis to develop a preliminary estimate of the potential nonuse benefits that would be associated with I&E impacts. As a result of this analysis, the authors (wrongly) conclude that nonuse values would be of a sizeable magnitude.

The analysis contained in the Helm memorandum is fundamentally flawed in a number of areas. Specifically, few of these studies value fish populations, much less the value of marginal changes in fish populations. Most if not all of the studies included involve substantial resource areas, such as large rivers, estuaries, and the water quality for the entire United States. Moreover, many of the studies involve large changes in environmental quality, such as changing an entire river from boatable to fishable water quality, or changing all waterbodies in the United States by the same amount. Some of these studies measure substantial amounts of nonuse values as a percentage of total value. However, even if one assumes that nonuse values are significant for major changes in significant resources, the argument that people will hold similar nonuse values for marginal changes in renewable populations of forage species is without any logical economic foundation.

3.4 Cost does not provide a reliable proxy for value

In contrast to the economic paradigm of resource valuation, the ecological paradigm prefers to use approaches such as the habitat productivity method or habitat equivalency analysis as alternatives to measures based on the willingness to pay. Such approaches balance organism losses with the amount of habitat needed to produce an offsetting number of organisms and calculate the cost of the restoration. The IS endorse the interpretation of habitat replacement costs as benefits in their Report:

> The cost associated with the construction of the artificial reef is the single best estimate of the value of the lost resources.

Nevertheless, the IS Report does recognize that cost does not measure value (p. 34):

> We realize that the cost of an artificial reef is not equivalent to the "value" of entrainment losses as estimated from a resource economy model.

Despite the foregoing acknowledgement, the IS state that:

> 3) As of July 2004, the estimated cost for the construction of an artificial reef ranged from 10.6 million (85 hectares) to 26 million (200 hectares) dollars (cost of transportation of material could cause these estimates to increase).
>
> 4) The cost associated with the construction of the artificial reef is the single best estimate of the value of the lost resources. If the reef is of sufficient size and of proper design, it has the potential to compensate for almost all entrainment impacts measured and unmeasured.

The fact of the matter from an economic perspective, however, is that the costs of creating habitat have nothing to do with the value of larvae. Costs are affected entirely by forces that are independent of the factors that influence preferences and value for fish. For example, the recent rise in fuel costs would cause transportation costs associated with reef construction to rise, which would imply that the reef, and hence the larvae, would be even more valuable than before. By the same token, if such prices decline in the future, the value of the reef would decline. Of course, all of these changes in value would have occurred despite no change in the ecological functioning of the reef.

Costs generally do not equate with a willingness to pay, and therefore do not constitute a proxy for economic value. By way of further example:

- The costs in time and materials that are involved in creating a work or art or sculpture would not represent its value. For some artists or sculptures the market would value their work far greater than the costs, while for others the costs required to make the work would exceed its value.
- Towing an iceberg from a polar region would be an extremely costly way to provide water in California. It is inconceivable that the value of water produced from the method would bear any relationship to its costs.

Thus, there is no economic foundation for the notion that the cost of providing any natural resource or service is a reasonable proxy for its value. Such a conclusion is apparent even within the text of the Stratus and IS Reports.

In recognizing that there is no economic rationale for measuring benefits with costs, the Stratus report asserts that this approach is "cautious" and "preservationist." As noted in the discussion of nonuse values, however, there is very little theoretical or empirical evidence that there are linkages between CWIS impacts and significant nonuse values. Moreover, the viewpoint that measuring benefits incorrectly is cautious or preservationist is incorrect. A better description in this context is that this approach is unfounded. The HRC approach is particularly troublesome when combined with the Stratus Report's stated view that estimated HRC costs "should be compared with the estimated costs of implementing BTA, which is the relevant regulatory benchmark for comparison." In fact, neither of these is an appropriate criteria for decision-making.

To further illustrate the fallacy of using the HRC approach to measuring the benefits of reductions in I&E, it is useful to make a simple comparison with commercial fishing. Commercial fishing and I&E have similar impacts in that they both harvest individuals from a population. A well-known concept in fisheries management is maximum sustainable yield (MSY), which refers to the maximum number of fish that can be removed annually without causing stock depletion. At MSY, removals and natural mortality are balanced by stable recruitment and growth. The MSY concept is an established method of informed fisheries management that leads to sustainable yields.[4] However, under the HRC paradigm, the economic value of fish removed at MSY is equal to the cost of creating habitat that produces the harvest. By extension, when the habitat replacement cost method is used to value *sustainable* levels of commercial fishing, we are led to the illogical conclusion that the economic impacts of commercial fishing are equivalent to the cost of *creating* the habitat that supports commercial stocks.

Finally, some proponents have argued that because HRC involves natural resources, which have some inherent value, it is acceptable to merely assume that costs are equal to value. However, such an argument is fallacious. Specifically, the decision of society to invest financial resources to protect natural resources, such as fish, imposes an opportunity cost on society that must be considered. Such funds must be taken away from some other useful economic purpose. Only if the value of that purpose is less, would such a decision be justified. The decision to invest more in natural environments can only come at the cost of not investing elsewhere. The position that the cost of a reef (or any restoration activity) represents value could be used to support clearly absurd ideas such as that water usage should be valued or priced according to the cost of bringing icebergs from the North Pole.

Thus, the HRC approach is not consistent with economic principles, in particular with the principle that costs are not equal to values. Nor does the approach incorporate the fundamental building block of an economic evaluation—the concept of services. Given these shortcomings, EPA decided not to endorse this biological approach. Instead, as discussed in the next section, it promulgated a rule that incorporates the economic approach to valuation.

[4] The recent PEW Oceans Commission (2003) report characterizes the state of the world's fisheries. Commercial over-fishing is cited as a primary factor in depressed stocks (I&E is not mentioned). This over-harvesting is a result of the failure of the enforcement mechanisms not the concept of a maximum sustainable yield.

4. 316(B) REGULATORY REQUIREMENTS

In July of 2004, the EPA promulgated regulations for determining the impact of CWIS on fish populations for existing power plants, the so-called Phase II regulations. [5] The regulations require impingement reductions of 80 to 95 percent and entrainment reductions of 60 to 90 percent and provide for site-specific determinations where costs of best technology available (BTA), including restoration measures, are significantly greater than the benefits.

Additionally, an evaluation of benefits of reducing I&E impacts is an important component of the Phase II regulations. Specifically, EPA has specified requirements for benefits valuation studies (BVSs) that in general must value commercial, recreational and, in appropriate circumstances, nonuse benefits derived from impingement and entrainment (I&E) reductions. Specifically, the regulations state:

> If you are seeking a site-specific determination of best technology available for minimizing adverse environmental impact because of costs significantly greater than the benefits of meeting the applicable performance standards of Section 125.94(b) at your facility, you must use a comprehensive methodology to fully value the impacts of impingement mortality and entrainment at your site and the benefits achievable by meeting the applicable performance standards (EPA 2004a, p. 41,690).

The regulations go on to specify the additional requirements of an uncertainty analysis and a peer review of the comprehensive benefits estimation methodology. In a comprehensive benefits study, recreational benefits are measured using valuation estimates based on people's choices of recreation sites that reveal the value of improved fish catch. Commercial fishing benefits are measured using market prices for the landed species. Equally important, the value of additional forage fish is included in the benefits analysis using the trophic transfer approach. This approach recognizes that the biological consequences of changes in forage fish stocks are measured

[5] *Federal Register*, Environmental Protection Agency, 40 *CFR* Parts 9, 122, July 9, 2004.

through a bioeconomic model that links increased recreational and commercial catch to increased numbers of forage fish. (See Stavins 2004.)[6]

Forage fish that are not part of the food chain for recreational or commercial species would not be valued in the production foregone approach adopted by EPA in the final rule. Nonetheless, the remaining value of these fish would be modest because they are not likely to have significant nonuse values. (See Section 3.2 and 3.3 above.) Moreover, as we discuss below, EPA provides for the ability to analyze nonuse values on a case-by-case basis using qualitative analysis. Nevertheless, the Agency requires that these qualitative assessments be based on conventional economic valuation principles, not cost based approaches.[7] (See EPA 2004a.)

Equally important, EPA expressly rejected the proposals to include cost-based measures as an alternative to economic valuation. Specifically, the Agency states:

> In general, costs should not be confused with values (EPA 2004b, p. 2496).

The Agency goes on to further state in response to Dr. Robert Stavins (2004) comments on the proposed rule that argued against habitat replacement costs:

> EPA agrees with Dr. Stavins' initial statement: "EPA's [proposed but abandoned] HRC method, which the Agency claims in its economic analysis is an alternative method for valuing benefits, is actually nothing of the kind. The Habitat Replacement Cost method is-pure and simple-a measure of costs not benefits. The habitat replacement costs are the design, implementation, administration, maintenance, and monitoring costs of various identified means of restoring aquatic habitats in the hopes of producing the same in situ services and service flows that are associated with the various technological alternatives under consideration. In other words, these are the costs of another alternative-and one that can be very costly for achieving the same functions as targeted by the proposed regulation (EPA 2004b, p. 2502).

[6] In its response to comments on the notice of data availability for the proposed draft Phase II rule, EPA specifically acknowledges that valuing impacts on forage fish is best accomplished by examining the impacts of forage fish on commercial and recreational species. The Agency views the production foregone as the preferred methodology (EPA 2004b, p. 2522.)

[7] There is no support in the final regulations for the Water Board staff's position that habitat replacement cost is a qualitative benefits approach. Even qualitative approaches should reflect the same valuation concepts that are embodied in a quantitative estimate. That is, value is based on willingness to pay and that substitutes are an essential part of the valuation context.

Although EPA extensively evaluated HRC during its development of the Phase II Rule, EPA ultimately decided that the HRC method should not be used as a means of estimating benefits due to "limitations and uncertainties regarding the application of this methodology" (EPA 2004a, p. 41,625). In fact, EPA ultimately determined that "none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004a, p. 41,624).

The Phase II regulations also incorporate EPA's Economic Guidelines for Preparing Economic Analyses (hereafter EPA Guidelines) (EPA 2000), which also recognize that there is no basis in economic theory or practice for using replacement costs to approximate benefits.[8] The EPA Guidelines are quite explicit:

> From the perspective of economic theory, the appropriate measure of benefits of a policy is the sum of the individual willingness to pay for that policy (EPA 2000, p. 62).
>
> Alternative approaches that estimate the total value of ecosystems based on the cost of the entire ecosystem or its embodied energy...have received considerable attention as of late. However, the results of these studies should not be incorporated into benefit assessments. The methods adopted in these studies are not well-grounded in economic theory, nor are they typically applicable to policy analysis (EPA 2000, p. 98).

Clearly, the EPA Guidelines recognize that the measurement of value is based on individuals' preferences, not costs. Moreover, there is no reason to expect that costs would be even a reasonable proxy for benefits. Costs may be higher, lower, or the same as benefits, but that will depend on the unique circumstances of each situation.

In the final Phase II Rule, EPA provides the following guidance on how to assess the nonuse benefits associated with reductions in I&E (EPA 2004a, p. 41,647–41,648):

[8] Mitigation cost or replacements costs may be used to approximate value in a very limited context. For example, the action to mitigate must be a voluntary action. Second, the action must be the least cost alternative for achieving the mitigation. Neither of these conditions applies to valuing reductions in CWIS impacts. (See Stavins 2004, Bockstael et al. 2000.)

- Nonuse benefits may arise from reduced impacts to ecological resources that the public considers important, such as threatened and endangered species. Nonuse benefits can generally only be monetized through the use of stated preference methods. When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information.
- In cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, nonuse benefits should be monetized.[9]
- In cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, monetization is not necessary.

As we demonstrated in our BVS (TER 2005), a qualitative assessment can be based on economic principles without explicitly including monetized benefits. Such an approach demonstrates that there is no basis for thinking considerable nonuse values are being excluded from the BVS. Most likely, these benefits would be negligible.

5. THE IS REPORT IS INCONSISTENT WITH BASIC ECONOMIC PRINCIPLES AND THE EPA 316(B) REGULATIONS

This section consists of three subsections which demonstrate that the IS Report is neither consistent with economic principles nor is it consistent with the EPA Phase II regulations.

[9] In cases where harm cannot be clearly explained to the public, monetization is not feasible because stated preference methods are not reliable when the environmental improvement being valued cannot be characterized in a meaningful way for survey respondents. (Note that this footnote is in fact part of the quoted EPA text.)

5.1 The IS Report is not consistent with the EPA Phase II regulations

As noted above, the IS have offered a report on mitigation impacts to the Regional Water Board. Specifically, the IS Report states that the goal of the IS is to

> ...provide the Regional Board with our best professional judgment regarding environmentally beneficial projects (type of projects, scale, and balance) that might be funded as part of PG&E's Diablo Canyon Power Plant permit.

In evaluating mitigation, however, the IS Report moved from biology into the realm of economics. This movement is a consequence of the methodology chosen by the IS to evaluate mitigation, which focuses on evaluating the productivity of habitat to replace organisms that may be lost as a result of I&E at DCPP. The IS Report is thus based on a foundation of using the cost of replacement habitat to value the I&E impacts associated with the DCPP.

As noted above, however, EPA specifically rejected the notion of using cost as a proxy for value because it was inconsistent with the Agency's own Principles and Guidelines for conducting economic analysis. As we have demonstrated in this report, the confusion of costs with values leads to nonsensical results.

Finally, the IS Report results in a scale of mitigation projects that is substantially greater than what would be justified on the measured benefits. Specifically, the IS Report implicitly argues that nonuse values from I&E losses at DCPP are sufficiently large to justify a mitigation project that has lower bound costs that are ten times greater than the upper bound of the economic benefits that are estimated for reducing such losses (TER 2005). However, EPA's Phase II regulations clearly state that such benefits need only be addressed in a qualitative manner except in unusual circumstances, such as the impingement or entrainment of endangered species. The TER (2005) report shows that such a qualitative assessment demonstrates that nonuse benefits would be modest at most because of the marginal nature of the impacts and the presence of substitute resources.

However, assuming for the sake of argument granting that nonuse benefits might be significant (which is not the case), there is little or no chance that such benefits would be large enough to justify even the lower end of the range of costs estimated by the IS Report. For example, even the most ardent advocates for the notion of sizeable nonuse benefits only argue for an adjustment factor of 2 to 3 times greater than use benefits.[10] Including such an adjustment would still only justify a reef about one-half the size of the smaller reef proposed by the IS Report. Thus, by ignoring the Phase II regulations, the IS Report has proposed a scale for the mitigation alternative that is substantially greater than what would be required to offset the loss in both human use and ecological services.

5.2 The approach followed by the IS is not sufficient for determining the appropriate scale of restoration

We also do not believe that the IS methodology is capable of evaluating the correct *scale* of restoration. While the appropriate type of project is an ecological issue, the appropriate scale is an economic and regulatory matter.

An evaluation of the Rule supports this contention. Under the final Phase II Rule, restoration is possible under either Alternative 3 or Alternative 5. Under Alternative 3, restoration measures must be scaled such that they can (EPA 2004a, p. 41,609).

> ...increase fish and shellfish in an impacted waterbody or watershed and result in performance substantially similar to that which would otherwise be achieved through reductions in impingement mortality and entrainment...

However, when the actions required to comply under Alternative 3 result in costs that are significantly greater than the benefits of meeting the performance standards, the site-specific approach (Alternative 5) is triggered (EPA 2004a, p. 41,597):

> In today's final rule, a facility that demonstrates to the Director that the costs of compliance with the performance standards and/or restoration

[10] Ackerman (2002) one of the most ardent critics of economic analysis argues for a factor between two and three times use benefits in his comments on EPA's proposed rule.

> requirements would be significantly greater than the benefits will be given a site-specific determination of best technology available for minimizing adverse environmental impact.

In our economic assessment (TER 2005) that employed the methodologies EPA used to calculate national benefits, we estimated the total value of meeting reduction standards (reducing impingement by 80 to 95 percent and entrainment by 60 to 90 percent) through 2053 to be $564,000 to $1 million for all fish species and 2 crab species. This assessment concludes that nonuse values would not need to be monetized under EPA guidelines because I&E had only marginal population effects on non-unique species.[11]

A site-specific determination implies that implementing a restoration solution that does not meet the performance standards is appropriate, as indicated by the following text (EPA 2004a, p. 41,597):

> The standards of the rule have not changed since proposal, with the exception of one clarification: in the final rule, the alternative site-specific requirements established by the Director must achieve an efficacy that is as close as practicable to the performance standards and/or restoration requirements specified in § 125.94(b) and (c).

The relevant regulatory document is the Site-Specific Restoration Plan. As stated by EPA, this plan must contain the following information (EPA 2004a, p. 41,690):

> A demonstration that the proposed and/or implemented design and construction technologies, operational measures, and/or restoration measures achieve an efficacy that is as close as practicable to the applicable performance standards of § 125.94(b) without resulting in costs significantly greater than either the costs considered by the Administrator for a facility like yours in establishing the applicable performance standards, or as appropriate, the benefits of complying with the applicable performance standards at your facility;

[11]By way of comparison, EPA estimates that the commercial and recreational benefits for the entire California Region would be only $3 million dollars, which is only one-third the *lower* bound cost of the artificial reef in the IS Report (EPA 2004b).

Based on this language, restoration efforts should not only be scaled commensurate with biological impacts, but should also limited by economic considerations where the cost of 316(b) compliance is significantly greater than the economic benefits. Therefore, quantifying the magnitude of benefits and appropriately applying the concept "significantly greater" provide the regulatory framework for expected compliance expenditures and scale of restoration efforts under the Phase II Rule. As we discussed above, even the lower end of the mitigation alternative proposed by the IS Report results in costs that are ten times greater than the measured economic benefits. Even if substantial nonuse benefits have been ignored (which is not the case), they would not be of sufficient magnitude to justify the scale of the proposed restoration alternative.

5.3 The equating of restoration impacts to biological impacts has methodological flaws

The IS Report apparently uses the concept of value to equate impacts of the proposed artificial reef to impacts caused by the DCPP. The proposition that these impacts are appropriately matched by the methodology has serious methodological flaws in that it does not measure changes in ecological services nor does it account for uncertainty or discounting in the scaling of restoration alternatives.

The IS Report provides estimates of mortality for the species that are impinged and entrained at DCPP. It also frequently discusses the types of organisms such as phytoplankton that are not quantified in the studies that measure I&E effects. However, noticeably lacking in the Report is any quantification of whether the loss in various organisms has reduced any ecological services. To the extent that such organisms are vital to ecological functions, and to the extent that such functions are important to people's well-being, it would seem logical that noticeable reductions in some types of services would have observed during the history of DCPP operation.[12] The IS Report simply equates reductions in organisms to reductions in services. As Banzhaf and Boyd (2004) argue, services involve changes in populations, not simply a reduction in

[12] The lack of a focus on services results in other statements in the IS Report that are not substantiated. For example, the geographic scale from which the losses occur is large, so the scale of the project should be large (IS Report, p. 5). In the services paradigm, the scale of the restoration would be determined by the loss in services, not simply whether the reductions would occur over a large area.

ecological functions. Although quantifying such service reductions can be challenging, the equation of organisms to services nevertheless implies that such populations have no opportunity to compensate for the reductions, and that the loss in individual members of a species automatically reduces ecological services.

Additionally, the IS Report has not fully explored the implications of uncertainty in developing its conclusions. For example, the IS Report reiterates the important point that the ecological effects of the artificial reef are uncertain (IS Report, p. 5 and p. 20). However, it is also clear that although the numbers of individual organisms that are impinged and entrained is rigorously measured, the population impacts of the loss in these organisms are not known with any degree of scientific certainty.[13] The IS Report approach taken does not attempt to identify even relative levels of uncertainty. Moreover, the importance of uncertainty to human decisions (our best indicator of value) has been recognized and mathematically formalized since the middle of last century (von Neumann and Morgenstern 1944). The quantification of the value of uncertainty is in the measurement of risk aversion. The intuition is that when people face choices with comparable returns, they will choose the less-risky alternative (Friedman and Savage 1948). With respect to the financial quantification of uncertainty, this issue was detailed by Markowitz (1952a, 1952b) and Tobin (1958).

A comparison of high yield bonds to treasury bills provides a good illustration of how uncertainty influences value. These bonds pay high yields to bondholders because the borrowers don't have any other option. Their credit ratings are less than pristine, meaning there is substantial risk of default. To compensate for this uncertainty, purchasers of high yield bonds require higher payments. By comparison, treasury bills carry a comparatively low yield. In this case, the backing of the government lends a level of certainty to the investment, reducing the yield requirement.

So, understanding the value relationship between the impact of DCPP and the effectiveness of the reef requires understanding the uncertainty in each. This is especially important if there is a meaningful difference in uncertainty. For example,

[13]Some studies that have evaluated the effect of I&E on fish populations have concluded that there is no measurable impact (EPRI 2003; Texas Commission 2003).

considering both ranges of uncertainty, it is possible that DCPP is not impacting fish at the population level, because of biological compensation for the loss of individuals, for example. It is also likely that any restoration activity will be productive. Thus, the IS Report is comparing a mitigation alternative (the artificial reef) that is certain to produce positive benefits to a potential loss that is sufficiently uncertain that it may or may not occur. Given this relative difference in uncertainty, one would expect that even a smaller reef would be a prudent and reasonable outcome.

The IS methodological approach is also flawed because it ignores discounting. The approach used to identify equivalence matches current production to current impacts. However, as exhibited by the following quote, there is a high likelihood that restoration projects will provide permanent benefits, while it is a certainty that DCPP will eventually cease operation.

> The benefits of marine reserves are permanent, and will likely be manifested throughout the ecosystem. By contrast, entrainment losses are temporary (IS Report 2005, p. 23).

An implication of the foregoing is that proposed projects will be productive when there is no impact to offset. This situation leaves open the question of how these more-than-offsetting future impacts should be valued. When the value of such projects is from future *use* values, such as benefits to commercial and recreational fisheries, the accepted approach is to discount these values appropriately. For example, OMB guidance supports a 3% annual social discount rate which would be used for recreational fishing benefits, and a 7% commercial discount rate for commercial fishing benefits (OMB 1992). For values in the distant future, the rate of discounting can have a substantial effect. For example, a $100 payment 50 years in the future has a current value of $22.81 when the discount rate is 3%; when the discount rate is 7%, the $100 is worth $3.39.

As this example indicates, when *use* values are being considered, discounting lessens the relevance of impacts that are in the future. This means that when permanent projects are intended to offset temporary impacts to use values, projects that are somewhat less than offsetting of current impacts can be completely offsetting of impacts over time. However, a major rationale (at least implicitly) in the IS Report for the equating of value in the manner employed is that there are substantial *nonuse* value impacts. Present value calculations are well-suited to value use benefits. However, when discounting is applied to the benefits provided by natural systems the effect is to discount the interests of future generations. The bequest component of nonuse values is based on the interests of future generations. Bequest value is current value for all future nonuse existence value. Much like a time capsule, bequest values are *more* are valuable because they are experienced in the future—not less valuable.

The implication is that when part of the value of a restoration project is nonuse value arising from ecological services a small permanent restoration project can offset much larger impermanent impacts. This is because when the plant shuts down, permanent nonuse/ecological services more than offset temporary impacts. The bequest component of nonuse value realized at that point and into the future is not subject to discounting. Because these values would not be subject to discounting, a *small* amount of more-than-offsetting ecological/nonuse benefits realized at some point in the future, and continuing indefinitely can be offsetting. This view is consistent with economic theories related to nonuse and the regulatory evaluation requirements of nonuse values in the 316(b) context. In particular, economic theory tells us it is irreversible impacts that have large nonuse impacts. EPA recognizes the importance of permanent impacts with the requirement to quantify nonuse only when there are impacts to threatened and endangered species.

Finally, even if one were to adopt the conventional discount rate for social investments of 3%, it would still be likely that the size of the IS-recommended reef is much larger than necessary to offset any potential service losses. Specifically, suppose that the DCPP has an economic lifetime until the year 2053 or 48 years, and the artificial reef would produce benefits into perpetuity. Using the 3%discount rate would imply that the artificial reef would produce benefits into the future for at least 22 years longer than the economic lifetime of the plant, if we assume that most of the benefits are discounted in 70 years. During this last 22-year time period, there would be no offsetting I&E impacts, thus the net impact would be even greater than during the first 48 years of the reef's lifetime. In summary, the failure to consider the potential roles that discounting services would play, along with the role of services themselves, results in a mitigation alternative that is substantially larger than is necessary.

6. CONCLUSIONS

The IS Report has proposed an artificial reef to mitigate the I&E impacts at the DCPP. This report has considered the consistency of this mitigation alternative with basic economic principles and the EPA Phase II regulations. Our analysis demonstrates that the IS Report is not consistent with basic economic principles, especially in that it rejects the economic valuation concepts that people are the best judge of value and that cost is an inappropriate proxy for value. Moreover, the IS Report fails to consider the differences between the economics and ecological views of natural resource services. Furthermore, the IS Report does not evaluate the potential effects of discounting on the scale of the restoration alternatives they evaluate. Nor, does the IS Report evaluate the differences in the relative uncertainties between the mitigation alternative and the potential I&E impacts. All of these concepts are endorsed by the EPA regulations. The consequence of these omissions is that the IS Report proposes a mitigation alternative that is ten to twenty-six times larger than what would be justified based on any reasonable scientific measurement of economic benefits.

7. REFERENCES

Ackerman, Frank. 2002. "Comments on Proposed Rule, RIN 2040-AD62, Clean Water Act § 316(b)." Tarrytown, NY: Riverkeeper Inc.

ASA Analysis & Communication, Inc., and Ivar Strand. 2003. *Estimation of Potential Economic Benefits of Cooling Tower Installation at the Diablo Canyon Power Plant: Final Report*. June. New Hampton, NY: ASA Analysis & Communication, Inc.

Banzhaf, Spencer, and James Boyd. 2004. "The Architecture and Measurement of an Ecosystem Services Index." Working paper. Washington, DC: Resources for the Future.

Bockstael, N.E., A.M. Freeman III, R.J. Kopp, P.R. Portney, and V.K. Smith. 2000. "On Measuring Economic Values for Nature." *Environmental Science & Technology* 34(8):1384–1389.

Boyd, James. 2004. "What's Nature Worth? Using Indicators to Open the Black Box of Ecological Valuation." *Resources* Summer:18–22.

Boyd, James W., and H. Spencer Banzhaf. 2005. "Ecosystem Services and Government Accountability: the Need for a New Way of Judging Nature's Value." *Resources* Summer(158):16–19.

Boyle, K., and R. Bishop. 1987. "The Economic Valuation of Endangered Species of Wildlife." *Water Resources Research* 23(5):153–161.

Champ, Patricia A., and Richard C. Bishop. 2001. "Donation Payment Mechanisms and Contingent Valuation: An Empirical Study of Hypothetical Bias." *Environmental and Resource Economics* 19:383–402.

Desvousges, W.H., A.R. Gable, and F.R. Johnson. 1995. "Calibrating Contingent Valuation Estimates: A Review of the Literature and Suggestions for Future Research." TER White Paper. Durham, NC: Triangle Economic Research.

Electric Power Research Institute (EPRI). 2003. *Impacts of Volumetric Flow Rate of Water Intakes on Fish Populations and Communities: Final Report*. Palo Alto, CA: Electric Power Research Institute, Inc. March.

Friedman, M., and L.P. Savage. 1948. "The Utility Analysis of Choices involving Risk." *Journal of Political Economy* 56:279–304.

Helm, Erik, et al. 2004. "Memo of Nonuse Data Meta-Analysis." Washington, DC: U.S. EPA Office of Water.

IS Report (Raimondi, Pete, Gregor M. Cailliet, and Michael S. Foster). 2005. "Diablo Canyon Power Plant Independent Scientist's Recommendations to the Regional Board Regarding 'Mitigation' for Cooling Water Impacts." White paper.

Kinnell, J., J. Lazo, A. Fisher, J. Shortle, and D. Epp. 2002. "Perceptions and Values for Preventing Ecosystem Change: Pennsylvania Duck Hunters and the Prairie Pothole Region." *Land Economics* 78(2):228–244.

Krutilla, John V. 1967. "Conservation Reconsidered." *American Economic Review* 57(4):777–796.

List, John A. 2001. "Do Explicit Warnings Eliminate the Hypothetical Bias in Elicitation Procedures? Evidence from Field Auctions for Sportscards." *The American Economic Review* 91(5):1498–1507.

Markowitz, H. 1952a. "Portfolio Selection." *Journal of Finance* 7:77–91.

Markowitz, H. 1952b. "The Utility of Wealth." *Journal of Political Economy* 60:151–158.

National Research Council. 2004. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. Washington, DC: The National Academies Press.

Office of Management and Budget. 1992. "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. Circular No. A-94. http://www.whitehouse.gov/omb/circulars/a094/a094.html. Retrieved on October 24, 2001.

Pew Oceans Commission. 2003. *America's Living Oceans: Charting a Course for Sea Change*. May.

Samples, K.C., J.A. Dixon, and M.M. Gowen. 1986. "Information Disclosure and Endangered Species Valuation." *Land Economics* 62(3):306–312.

Smith, V.K., and R.J. Kopp, eds. 1993. *Valuing Natural Resource Assets: The Economics of Natural Resource Damage Assessment*. Washington, DC: Resources for the Future, Inc.

Stavins, Robert N. 2004. Comment ID 316bEFR.005.027 in *EPA Response to Public Comment: CWA Section 316(b) Phase II Existing Facility Rule—Final*. Washington, DC: U.S. Environmental Protection Agency.

Stratus Consulting Inc. 2004. *Research on Estimating the Environmental Benefits of Restoration to Mitigate or Avoid Environmental Impacts Caused by California Power Plant Cooling Water Intake Structures*. Prepared for California Energy Commission, Public Interest Energy Research Program. Contract No. 500-04-092. Boulder, CO: Stratus Consulting Inc.

TER (Bingham, Matthew F., Ateesha F. Mohamed, Jason C. Kinnell, Leigh A. Hostetter, and William H. Desvousges). 2005. *Benefits Valuation Study for Diablo Canyon Power Plant*. February 21. Durham, NC: Triangle Economic Research.

Texas Commission on Environmental Quality (TCEQ). 2003. *An Evaluation of Nekton at Two Cooling Water Intake Systems in the Houston Ship Channel from 1997 to 2001*. Report Number AS-190. March.

Tobin, J. 1958. "Liquidity Preference as a Behavior toward Risk." *Review of Economic Studies* 25:65–86.

U.S. Environmental Protection Agency. 2000. *Guidelines for Preparing Economic Analyses.* Report Number 240-R-00-003. Washington, DC: USEPA. September.

U.S. Environmental Protection Agency. 2004a. "National Pollutant Discharge Elimination System—Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities; Final Rule." *Federal Register* Vol. 69, No. 131 (Friday, July 9):41,576–41,693.

U.S. Environmental Protection Agency. 2004b. *EPA Response to Public Comment: CWA Section 316(b) Phase II Existing Facility Rule—Final.* March 29. 5,143 pp.

von Neumann, John, and Oscar Morgenstern. 1944. *Theory of Games and Economic Behavior.* Princeton, NJ: Princeton University Press.

William H. Desvousges
President

Triangle Economic Research
2775 Meridian Parkway
Durham, NC 27713
Phone: (919) 544-2244
Fax: (919) 544-3935
E-mail: wdesvousges@ter.com

Employment Chronology

1994 to date	**President** Triangle Economic Research Durham, NC
1996 to date	**Research Professor** Duke University Durham, NC
1989 to 1994	**Program Director/Senior Program Director** Center for Economics Research Research Triangle Institute Research Triangle Park, NC
1980 to 1989	**Senior Economist** Center for Economics Research Research Triangle Institute Research Triangle Park, NC
1975 to 1980	**Assistant/Associate Professor** Department of Economics University of Missouri at Rolla Rolla, MO
1986	**Visiting Lecturer** Meredith College Raleigh, NC
1984 to 1985	**Visiting Lecturer** University of North Carolina at Chapel Hill Chapel Hill, NC
1980 to 1984	**Visiting Lecturer** North Carolina State University Raleigh, NC

Education

Ph.D., 1977, Economics, Florida State University, Tallahassee, Florida

M.S., 1974, Economics, Florida State University, Tallahassee, Florida

B.A., 1972, Economics, Stetson University, Deland, Florida

Key Projects

- "Evaluation of the Use of Survey Methods by Appraisers to Value a Commercial Property" (ChevronTexaco)
- "Evaluation of the Use of Contingent Valuation Surveys to Measure Diminished Property Values in Mississippi" (confidential client)
- "Evaluation of Market and Survey-Based Methods for Measuring Damages from Underground Storage Tanks (USTs) to Both Residential and Commercial Properties" (confidential client)
- "The Role of Individual Factors in Using Market and Survey-Based Methods for Measuring Potential Damages to Classes of Residential Properties in Colorado Springs, Colorado" (Davis Graham Stubbs)
- "The Role of Individual Factors in Using Market and Survey-Based Methods for Measuring Both Residential and Commercial Properties in Oklahoma" (confidential client)
- "The Reliability of Survey and Market-Based Methods for Measuring Damages from Increased Eutrophication in Lakes" (confidential clients)
- "Comments on the Benefit Estimates of EPA's Proposed Phase II 316(b) Rule" (The Utility Water Act Group)
- "Benefit-Cost Analysis of Various Regulatory Alternatives for 316(b) Compliance in Connecticut" (confidential client)
- "Benefit-Cost Analysis of 316(b) Regulatory Alternatives in California" (confidential client)
- "Groundwater Damages at the South Valley Superfund Site in New Mexico" (confidential client)
- "Creel/Angler Survey on the Lower Passaic River" (Chemical Land Holdings)
- "Human Use Compensatory Restoration Strategy for Onondaga Lake" (Honeywell International)

- "Review of New Jersey's Groundwater Damage Assessment Formula" (New Jersey Site Remediation Industry Network)
- "Environmental Costs for Particulate Matter and Mercury: An Assessment of the Recent Literature" (Xcel Energy)
- NRDA for a major waterway in the Northeast (confidential client)
- "Alternative Santa Clara River HEA" (confidential client)
- "Saginaw Bay and River Natural Resource Damage Assessment" (General Motors)
- "Evaluating the Reliability of Contingent Valuation (U.S. Environmental Protection Agency)
- "Measuring Environmental Costs for Resource Planning" (Northern States Power Company)
- "Natural Resource Damage Assessment for Lavaca Bay, Texas" (Alcoa)
- "Natural Resource Damage Assessment for the Clark Fork Basin in Montana" (ARCO)
- "Using Conjoint Analysis to Value Health" (Health Canada et al.)
- "Wisconsin Energy Research Project" (consortium of Wisconsin utilities)
- "Estimating the Market Potential For 'Green' Products" (Niagara Mohawk)
- "Fox River Natural Resource Damage Assessment" (Fox River Group)
- "Kalamazoo River Natural Resource Damage Assessment" (Kalamazoo River Study Group)
- "St. Lawrence River-Massena Natural Resource Damage Assessment" (Reynolds, Alcoa, General Motors)
- "Wisconsin Externalities Costing: Principles & Practices" (Task Force on Externality Costing, Wisconsin utilities)
- "Measuring Benefits of the Effluent Guidelines: An Evaluation of the Benefits Transfer Technique" (Office of Science and Technology, U.S. Environmental Protection Agency)
- "Information, Risk Perception, and Mitigation: Behavioral Responses to Environmental Risk" (National Science Foundation)
- "Natural Resource Damage Assessments for the Martinez, California; Gasconade River, Missouri; and Arthur Kill, New Jersey Oil Spills" (various clients)
- "Communicating Risk Effectively" (Office of Policy Planning and Evaluation, U.S. Environmental Protection Agency)

- "Valuing Reductions in Hazardous Waste Risks" (Office of Policy Analysis, U.S. Environmental Protection Agency)
- "Evaluating Risks of a High-Level Nuclear Waste Repository" (State of Nevada)
- "A Comparison of Benefit Estimation Approaches" (Office of Policy Analysis, U.S. Environmental Protection Agency)

Expert Reports

- "Expert Report in the Matter of *Beck, et al. v. Koppers Industries, Inc., et al.*" August 1, 2004.
- "Declaration of William H. Desvousges, Ph.D. Pursuant to 28 U.S.C. § 1746." April 15, 2005.
- "Supplemental Report in the Matter of *Palmisano, et al. v. Olin Corporation*." February 7, 2005.
- "Expert Report in the Matter of *LaBauve, et al. v. Olin Corporation.*" December 10, 2004.
- "Expert Report in the Matter of *Cole, et al. v. ASARCO, et al.*" August 23, 2004.
- "Expert Report in the Matter of *Daniels, et al. v. Olin Corporation*." August 16, 2004.
- "Expert Report in the Matter of *Kellum, et al. v. Kuhlman Corporation, et al.*" July 2003.
- "Expert Report in the Matter of *Susann Stalcup, et al. v. Schlage Lock Company, et al.*" April 1, 2003.
- "Expert Report in the matter of *Muise/Tzannetakis et al. v. GPU Energy*." December 2, 2002.
- "Expert Report in the Matter of *State of New Mexico v. General Electric Company et al.*" February 1, 2002.
- "Expert Report in the Matter of *Major Andrews et al. v. Kerr-McGee Corporation, Inc. et al.*" June 29, 2001.
- "Expert Report in the Matter of *State of Montana v. Atlantic Richfield Company.*" June 12, 1995.

Testimony

Provided expert witness testimony in the matter of *LaBauve, et al. v. Olin Corporation.* Civil No. 03-567 in the U.S. District Court, Southern District of Alabama. February 14, 2005.

Provided expert witness testimony in the matter of *Betty Jean Cole, et al. v. ASARCO Incorporated, et al.* Case No. 03-CV-327(H) M in the U.S. District Court, Northern District of Oklahoma. October 8, 2004.

Provided expert witness testimony in the matter of *Daniels, et al. and Palmisano, et al. v. Olin Corporation, et al.* Case No. C 03-01211 RMW in the U.S. District Court, Northern District of California, San Jose Division. September 21 and 22, 2004 and February 23, 2005.

Provided expert witness testimony and participated in Daubert hearing in the matter of *State of New Mexico v. General Electric Company. et al.* Case No. CIV 99-1254, Case No. CIV 99-1118. Consolidated by Order dated June 14, 2000. January 2004.

Provided testimony to the Public Service Commission of Wisconsin in the matter of "Application of Wisconsin Electric Power Company; Wisconsin Energy Corporation; and W.E. Power, LLC for a Certificate of Public Convenience and Necessity for Construction of Three Large Electric Generation Facilities, the Elm Road Generating Station, and Associated High Voltage Transmission Interconnection Facilities to be Located in Milwaukee and Racine Counties. Docket No. 05-CE-130. September 8, 2003.

Provided expert witness testimony in the matter of *Kellum, et al. v. Kuhlman Corporation, et al.* Civil Action No. 2001-0313 through 2001-324 in the Circuit Court of Copiah County, Mississippi. August 19 and August 20, 2003.

Provided expert witness testimony in the matter of *Susann Stalcup, Craig Lewis and Sharon Lewis v. Schlage Lock Company, Ingersoll-Rand Company and Eagle-Picher Industries, Inc.* Case No. 02-RB01188(OES). June 12, 2003.

Provided expert witness testimony in the matter of *Mary Louise Fairey, et al. v. the Exxon Corporation, Standard Oil Company, et al.* Case No. 94-CP-38-118. March 13 and June 3, 2003.

Provided expert witness testimony in the matter of *Muise/Tzannetakis et al. v. GPU Energy.* January 22, 2003.

Provided expert witness testimony in the matter of *Andrews et al. v. Kerr-McGee Corporation et al.* Civil Action No. 1:00-CV-00158-B-A in the U.S. District Court, Northern District of Mississippi, Eastern Division. October 16, 2001.

Provided expert witness testimony in the matter of *State of New Mexico v. General Electric Company. et al.* Case No. CIV 99-1254, Case No. CIV 99-1118. Consolidated by Order dated June 14, 2000.

Provided expert witness testimony in the matter of *State of Montana v. Atlantic Richfield Company* in the U.S. District Court, District of Montana, Helena Division. Case No. CV-83-317-HLN-PGH. July 13, 1995. Rebuttal Testimony provided February 1, 1996.

Provided testimony on the matter of "The Role of Contingent Valuation in Natural Resource Damage Assessment" before the U.S. House of Representatives Subcommittee on Commerce, Trade, and Hazardous Materials. June 20, 1995.

Provided testimony before the Public Utilities Commission of the State of Minnesota in the matter of "The Quantification of Environmental Costs." Docket No. E-999/CI-93-583. Testimony in November 1994. Rebuttal in March 1995, and Sur-rebuttal in April 1995.

Testified before the National Oceanic and Atmospheric Administration (NOAA) Contingent Valuation Panel in the matter of "Using CV to Measure Nonuse Damages: An Assessment of Validity and Reliability." August 12, 1992.

Provided testimony to Wisconsin Public Service Commission in the matter of "Accounting for Environmental Externalities in Electric Utility Planning." November 26, 1991.

Areas of Specialization

Property Valuation

Prepared expert report that critiqued reports provided by the plaintiff's economic experts in a lawsuit alleging groundwater contamination at a Superfund site in the western U.S. Created a sophisticated hedonic property value model demonstrating that the Superfund site had no effect on residential property values.

In several states, directed projects evaluating the use of surveys to measure diminished property values, commercial and residential property values, potential damages to residential and commercial properties, and potential damages from various contaminants.

Critiqued the contingent valuation survey of a plaintiff's expert in a series of lawsuits alleging property damages caused by a wood-treating facility in Mississippi. Demonstrated that the survey is unreliable for use in litigation.

Natural Resource Damage Assessment

Developed comprehensive assessment plans for complex assessments.

Performed preliminary assessments for both oil-spill and hazardous-waste sites.

Designed state-of-the-art studies to measure potential losses for recreation and groundwater services. Studies included data-collection protocols and implementation.

Performed critical analyses of studies that used contingent valuation to measure nonuse values.

Designed and directed studies to measure potential recreation losses and to evaluate potential restoration gains.

Critiqued the transfer study used by the plaintiff's expert in a Louisiana lawsuit seeking restoration funds to convert floatant freshwater marsh habitat to uplands. Provided an alternative estimate of the value of the wetlands.

Benefit/Cost Analysis

Prepared comments on economic issues in EPA's proposed 316(b) regulations for The Utility Water Act Group.

Directed a benefit analysis of technology-based effluent guidelines for municipal and industrial dischargers.

Directing projects to measure benefits of 316(b) regulatory alternatives for several utility clients

Served on peer review committee associated with benefits transfer data needs for Environment Canada.

Served as peer reviewer on benefits transfer for Ontario Ministry of the Environment.

Directed a feasibility study of using benefit-cost techniques to assist in the planning of estuaries cleanup. The study used case studies of two estuaries: the Albemarle and Pamlico Sounds.

Prepared a handbook on benefit-cost assessment for water programs that included chapters on measuring benefits and costs, selecting a discount rate, and assembling a benefit-cost assessment.

Compared alternative approaches for estimating the recreation and related benefits of the Monongahela River in Pennsylvania. Developed a survey questionnaire to measure recreation, user, option, and existence benefits for different levels of water quality. The survey design enabled a comparison of bidding games, direct-question, and contingent-ranking techniques for measuring benefits. Used clustered sampling techniques to sample 393 households, and compared the direct survey results with benefits estimates derived from an indirect estimation technique.

Survey Design and Management

During the past 15 years, designed and managed large-scale surveys. Experienced in using bidding games, direct-question, contingent-ranking, and discrete-choice techniques for measuring benefits of natural resource and environmental policies. Directed focus groups to determine appropriate terminology, to evaluate the effectiveness of alternative visual aids used in the surveys, and to assess the various survey issues. Developed surveys to evaluate the following:

- Health benefits from reduced cardiac and respiratory morbidity using conjoint analysis
- Market penetration for "green" products using conjoint analysis
- Customer willingness to pay for "greener" electricity using conjoint analysis
- The role of quality-of-life measures in the benefits of improved life extension
- Natural resource damages
- Risk-communication effectiveness
- Radon risk perceptions and willingness to pay to reduce perceived risks
- Benefits of hazardous waste management regulations
- Risk perceptions related to the proposed siting of a nuclear waste repository and willingness to pay to reduce those perceived risks
- Recreation benefits demand
- Recreation, user, and option benefits for different levels of water quality

Environmental Costing

Provided analysis and testimony for the eastern Wisconsin utilities in hearings on environmental costing before the Wisconsin Public Service Commission.

Estimated the environmental externality costs of resource planning options for the eastern Wisconsin utilities and for Northern States Power.

Participated in environmental costing workshop and served on peer review committee for Ontario Hydro.

Health Economics

Conducted focus groups and used verbal protocols to develop stated-preference conjoint survey questionnaires.

Conducted large-scale stated-preference conjoint survey to measure benefits of reduced cardiac and respiratory morbidity.

Designed/conducted pilot study of quality of life and enhanced longevity using conjoint stated-preference methods.

Designed and distributed radon information materials that were sent to 2,000 homeowners in the state of New York who had their homes tested for radon. Supervised interviews with homeowners, sequenced over a nine-month to two-year period, to elicit their perceptions of radon risks and tracked any expenditure decisions to reduce these risks. The expenditures were used to estimate a willingness-to-pay measure of the value of reductions in radon risks. The research design also evaluated the effectiveness of an information policy for reducing radon risks.

Developed and evaluated alternative approaches for encouraging Maryland homeowners to test for radon. Developed and pretested risk communication materials that ranged from radio public service announcements to public display posters and brochures. Used a three-community experimental design with 1,500 baseline and follow-up interviews in each community to measure effectiveness.

Professional Associations

- American Economic Association
- Southern Economic Association
- Association of Environmental and Resource Economists (AERE)
- Member of Nominating Committee for AERE, 1983 and 1986
- Society for Risk Analysis
- American Public Opinion Research

Honors and Awards

- Recipient, Research Triangle Institute Professional Development Award, 1985
- Nominated for Outstanding Young Man of Rolla, Missouri, 1979
- Outstanding Teacher Award, University of Missouri at Rolla, 1977 to 1979
- Scholar-Diplomat, U.S. State Department, 1978
- Graduated *cum laude*, Stetson University, 1972

Professional Leadership

- Vice President, Association of Environmental and Resource Economists, 1992 to 1994
- Associate Editor, *International Journal of Energy Studies*, 1989 to 1993
- Associate Editor, *Journal of Environmental Economics and Management*, 1992 to 1994
- Associate Editor, *Water Resources Research*, 1984 to 1987

Journals and Book Reviews

- *American Economic Review*
- *Review of Economics and Statistics*
- *Land Economics*

- *Journal of Environmental Economics and Management*
- *Growth and Change*
- *American Journal of Agricultural Economics*
- *Southern Economics Journal*
- *Mansfield's Principles of Microeconomics*
- *Marine Resource Economics*
- *National Science Foundation*
- *Journal of the American Statistical Association*

Publications

Mathews, K.E., M.L. Freeman, and W.H. Desvousges. Forthcoming. "How and How Much? The Role of Information in CE Questionnaires." In *Using Choice Experiments to Value Environmental Amenities*, Barbara Kanninen, ed. Boston: Kluwer Academic Publishers.

Dunford, R.W., T.C. Ginn, and W.H. Desvousges. 2004. "The Use of Habitat Equivalency Analysis in Natural Resource Damage Assessments." *Ecological Economics* 48(1):49–70.

Mathews, K.E., and W.H. Desvousges. 2003. "Stigma Claims and Survey Reliability: Lessons Learned from Natural Resource Damages Litigation." *Journal of Forensic Economics* 16(1):23–36.

Iannuzzi, T.J., D.F. Ludwig, J.C. Kinnell, J.M. Wallin, W.H. Desvousges, and R.W. Dunford. 2002. *A Common Tragedy: History of an Urban River.* Amherst, MA: Amherst Scientific Publishers.

Mathews, K.E., K.J. Gribben, and W.H. Desvousges. 2002. "Integration of Risk Assessment and Natural Resource Damage Assessment: A Case Study of Lavaca Bay." In *Human and Ecological Risk Assessment: Theory & Practice*, Dennis J. Paustenbach, ed. New York: John Wiley and Sons.

Johnson, F.R., R.W. Dunford, W.H. Desvousges, and H.S. Banzhaf. 2001. "The Role of Knowledge in Assessing Nonuse Damages: A Case Study of the Lower Passaic River." *Growth and Change* 32(Winter):43–68.

Smith, V. Kerry, Donald H. Taylor, Jr., Frank A. Sloan, F. Reed Johnson, and William H. Desvousges. 2001. "Do Smokers Respond to Health Shocks?" *The Review of Economics and Statistics* 83(4):675–687.

Desvousges, W.H., and J.C. Lutz. 2000. "Compensatory Restoration: Economic Principles and Practice." *Arizona Law Review* 42(2):411–432.

Johnson, F.R., M.R. Banzhaf, and W.H. Desvousges. 2000. "Willingness to Pay for Improved Respiratory and Cardiovascular Health: A Multiple-Format Stated-Preference Approach." *Health Economics* 9:295–317.

Payne, J.W., D.A. Schkade, W.H. Desvousges, and C. Aultman. 2000. "Valuation of Multiple Environmental Programs." *Journal of Risk and Uncertainty* 21(1):95–115.

Desvousges, W.H., F.R. Johnson, and H.S. Banzhaf. 1998. *Environmental Policy Analysis With Limited Information: Principles and Applications to the Transfer Method*. Cheltenham, UK: Edward Elgar.

Johnson, F.R., W.H. Desvousges, M.C. Ruby, D. Stieb, and P. De Civita. 1998. "Eliciting Stated Health Preferences: An Application to Willingness to Pay for Longevity." *Medical Decision Making* 18(2):57–67.

Johnson, F.R., and W.H. Desvousges. 1997. "Estimating Stated Preferences With Rated-Pair Data: Environmental, Health, and Employment Effects of Energy Programs." *Journal of Environmental Economics and Management* 34:79–99.

Banzhaf, H.S., W.H. Desvousges, and F.R. Johnson. 1997. "Assessing the Externalities of Electricity Generation in the Midwest." *Resource and Energy Economics* 18:395–421.

Boyle, K.J., F.R. Johnson, D.W. McCollum, W.H. Desvousges, R.W. Dunford, and S.P. Hudson. 1996. "Valuing Public Goods: Discrete Versus Continuous Contingent-Valuation Responses." *Land Economics* 72(3):381–96.

Desvousges, W.H., S.P. Hudson, and M.C. Ruby. 1996. "Evaluating CV Performance: Separating the Light From the Heat." In *The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs*, D.J. Bjornstad and J.R. Kahn, eds. Brookfield, VT: Edward Elgar Publishing Limited.

Smith, V.K., W.H. Desvousges, and J.W. Payne. 1995. "Do Risk Information Programs Promote Mitigating Behavior?" *Journal of Risk and Uncertainty* 10:203–221.

Boyle, K.J., W.H. Desvousges, F.R. Johnson, R.W. Dunford, and S.P. Hudson. 1994. "An Investigation of Part-Whole Biases in Contingent Valuation Studies." *Journal of Environmental Economics and Management* 27(1):64–83.

Desvousges, W.H., H. Kunreuther, P. Slovic, and E.A. Rosa. 1993. "Perceived Risk and Attitudes Toward Nuclear Wastes: National and Nevada Perspectives." In *Public Reactions to Nuclear Waste*, R. Dunlap, M. Kraft, and E.A. Rosa, eds. Durham, NC: Duke University Press.

Desvousges, W.H., F.R. Johnson, R.W. Dunford, K.J. Boyle, S.P. Hudson, and K.N. Wilson. 1993. "Measuring Natural Resource Damages With Contingent Valuation: Tests of Validity and Reliability." In *Contingent Valuation, A Critical Assessment*, J.A. Hausman, ed., pp. 91–164. Amsterdam: Elsevier.

Desvousges, W.H., A.R. Gable, R.W. Dunford, and S.P. Hudson. 1993. "Contingent Valuation: The Wrong Tool for Damage Assessment." *Choices* 8(2):9–11.

Desvousges, W.H., V.K. Smith, and H.H. Rink, III. 1992. "Communicating Radon Risks Effectively: The Maryland Experience." *Journal of Public Policy and Marketing* 11(1):68–78.

Desvousges, W.H., and R.W. Dunford. 1992. "Russian River Basin Formaldehyde Release." In *Natural Resource Damages: Law and Economics*, K.M. Ward and J.W. Duffield, eds. New York: John Wiley and Sons.

Desvousges, W.H., M. Naughton, and G. Parsons. 1992. "Benefits Transfer: Conceptual Problems in Estimating Water Quality Benefits Using Existing Studies." *Water Resources Research* 28(3):675–683.

Kunreuther, H., D. Easterling, W.H. Desvousges, and P. Slovic. 1990. "Public Attitudes Toward Siting a High-Level Nuclear Waste Repository in Nevada." *Risk Analysis* 10(4):469–484.

Smith, V.K., and W.H. Desvousges. 1990. "Risk Communication and the Value of Information: Radon as a Case Study." *Review of Economics and Statistics* 72(1):137–140.

Smith, V.K., W.H., Desvousges, F.R. Johnson, and A. Fisher. 1990. "Can Public Information Programs Affect Risk Perceptions?" *Journal of Policy Analysis and Management* 9(1):41–59.

Desvousges, W.H., and J.H. Frey. 1989. "Integrating Focus Groups and Surveys: Examples from Environmental Risk Studies." *Journal of Official Statistics* 5(4):1–15.

Smith, V.K., and W.H. Desvousges. 1989. "Subjective Versus Technical Risk Estimates: Do Risk Communication Policies Increase Consistency?" *Economic Letters* 31:287–291.

Desvousges, W.H., and V.K. Smith. 1988. "Focus Groups and Risk Communication: The 'Science' of Listening to Data." *Risk Analysis* 8(4):479–484.

Smith, V.K., and W.H. Desvousges. 1988. "Risk Perception, Learning and Individual Behavior." *American Journal of Agricultural Economics* 70(5):1113–1117.

Kunreuther, H., W.H. Desvousges, and P. Slovic. 1988. "Nevada's Predicament: Public Perceptions of Risk From the Proposed Nuclear Waste Repository." *Environment* 30(8):17–20, 30–33.

Smith, V.K., and W.H. Desvousges. 1988. "The Valuation of Environmental Risks and Hazardous Waste Policy." *Land Economics* 64(3):211–219.

Smith, V.K., W.H. Desvousges, A. Fisher, and F.R. Johnson. 1988. "Learning About Radon's Risk." *Journal of Risk and Uncertainty* 1:233–258.

Johnson, F.R., A. Fisher, V.K. Smith, and W.H. Desvousges. 1988. "Informed Choice or Regulated Risks? Lessons From a Social Experiment in Risk Communication." *Environment* 30(4):12–15, 30–35. Reprinted in *Readings in Risk*. 1990. Washington, DC: Resources for the Future.

Desvousges, W.H., V.K. Smith, A. Fisher, and F.R. Johnson. 1988. "Communicating Radon Risks Effectively." In *Managing Environmental Risks, Proceedings of Air Pollution Control Association, Specialty Conference on Risk Management and Risk Communication*. Pittsburgh, PA.

Smith, V.K., and W.H. Desvousges. 1987. "An Empirical Analysis of the Economic Value of Risk Changes." *Journal of Political Economy* 95(1):89–114.

Desvousges, W.H., V.K. Smith, and A. Fisher. 1987. "Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River." *Journal of Environmental Economics and Management* 14:248–267.

Smith, V.K., and W.H. Desvousges. 1986. *Measuring Water Quality Benefits*. Boston: Kluwer Nijhoff.

Smith, V.K., and W.H. Desvousges. 1986. "Asymmetries in the Valuation for Risk Reductions." *American Economic Review* 76(2):291–294.

Smith, V.K., and W.H. Desvousges. 1986. "The Value of Avoiding a LULU: Hazardous Waste Landfill Sites." *Review of Economics and Statistics* 68(2):293–299.

Smith, V.K., and W.H. Desvousges. 1986. "Averting Behavior: Does It Exist?" *Economic Letters* 20:291–296.

Smith, V.K., W.H. Desvousges, and A. Fisher. 1986. "A Comparison of Direct and Indirect Methods for Estimating Environmental Benefits." *American Journal of Agricultural Economics* 68:280–289.

Smith, V.K., and W.H. Desvousges. 1984. "Measuring the Benefits of Water Quality Improvements: Additional Considerations." *Southern Economic Journal* October.

Desvousges, W.H., and M.J. Piette. 1984. "Problems and Prospects: Outer Continental Shelf Petroleum Resources." *Growth and Change* 15(2):3–10.

Smith, V.K., and W.H. Desvousges. 1984. "The Generalized Travel Cost Model and Water Quality Benefits: A Reconsideration." *Southern Economic Journal* 52(2):371–381.

Desvousges, W.H. 1984. "Benefit Cost Assessment of the Toulumne River: A Foreword." *Environmental Defense Fund*, Spring.

Desvousges, W.H., V.K. Smith, and A. Fisher. 1983. "Estimates of the Option Values for Water Quality Improvements." *Economic Letters* 13:81–86.

Smith, V.K., W.H. Desvousges, and M.P. McGivney. 1983. "Estimating Water Quality Benefits: An Econometric Analysis." *Southern Economics Journal* 50(2):422–437.

Smith, V.K., W.H. Desvousges, and M.P. McGivney. 1983. "The Opportunity Cost of Travel Time in Recreation Demand Models." *Land Economics* 59(3):259–278.

Piette, M.J., and W.H. Desvousges. 1981. "Behavior of the Firm: The U.S. Petroleum Pipeline Industry Under Regulatory Constraint." *Growth and Change* 12(2):17–22.

Garbacz, C., and W.H. Desvousges. 1980. "The Impact of Increased Energy Costs on Municipal Budgets in Missouri." *Missouri Municipal League Review*, July.

Desvousges, W.H., and M.J. Piette. 1979. "The Effect of 'Large' Mergers on Concentration Trends in Petroleum Production: 1955–1975." *Southern Economic Journal*, October.

Desvousges, W.H. 1978. *Tourism U.S.A. Volume 1: Appraising Tourism Potential.* United States Department of Commerce, United States Travel Service, Washington, D.C.

Desvousges, W.H. 1978. "Savannah, Georgia." *Profiles in Tourism U.S.A., 1978.* United States Department of Commerce, United States Travel Service, Washington, D.C.

Desvousges, W.H. (et al.). 1975. "Cost-Benefit Analysis of a Token Economy Program." *American Psychologist*, December.

Selected Reports and Working Papers

Desvousges, W.H., M.F. Bingham, J.C. Kinnell, A.F. Mohamed, and K.T. Kuhns. 2005. *Review and Response to the EPA's Response to Comments from the American Chemistry Council et al. and Accompanying Triangle Economic Research (TER) Report.* Prepared for the Utility Water Act Group, General Electric Company, American Chemistry Council, American Forest and Paper Association, American Iron and Steel Institute, American Public Power Association, and American Petroleum Institute. April 20. Durham, NC: Triangle Economic Research.

Desvousges, W.H., M.F. Bingham, J.C. Kinnell, and A.F. Mohamed. 2005. *Comments on Potential Nonuse Values for Proposed Phase III Cooling Water Intake Regulations: Final Report.* Prepared for the Utility Water Act Group, American Chemistry Council, American Forest and Paper Association, American Iron and Steel Institute, American Petroleum Institute, and American Public Power Association. January 24. Durham, NC: Triangle Economic Research.

Bingham, M.F, W.H. Desvousges, and A.F. Mohamed. 2003. *Comments on Benefit Estimation of EPA's Proposed Phase II 316(b) Rule as Summarized in the Notice of Data Availability: Final Report*. Prepared for The Utility Water Act Group. Durham, NC: Triangle Economic Research. June 2.

Mathews, K.E., and W.H. Desvousges. 2002. "The Truth, the Partial Truth, or Anything But the Truth: Survey Reliability and Property Valuation." Paper presented at the Symposium on Environmental & Property Damages: Standards, Due Diligence, Valuation & Strategy, Toronto, Ontario. April 4–6.

Desvousges, W.H., D.M. Clark, M.F. Bingham, A.F. Mohammed, S.M. Small, and D.F. Ludwig. 2002. *Comments on the Benefit Estimates of EPA's Proposed Phase II 316(b) Rule: Final Report*. Prepared for the Utility Water Act Group.

Desvousges, W.H., J.C. Kinnell, K.S. Lievense, and E.A. Keohane. 2001. *Passaic River Study Area Creel/Angler Survey: Data Report*. TER Working Paper No. G-0101. Durham, NC: Triangle Economic Research.

Desvousges, W.H., D.J. MacNair, F.R. Johnson, G.A. Smith, and S.D. Cox. 2000. *Comments on the Federal Trustees' Restoration Scaling and Compensable Value Determination for the Fox River/Green Bay*. Durham, NC: Triangle Economic Research.

Desvousges, W.H., D.J. MacNair, and G.A. Smith. 2000. *Lower Fox River and Green Bay: Assessment of Potential Recreational Fishing Losses and Restoration Offsets*. Durham, NC: Triangle Economic Research.

Desvousges, W.H., R.W. Dunford, K.E. Mathews, C.L. Taylor, and J.L. Teague. 1999. *A Preliminary Economic Evaluation of New Jersey's Proposed Groundwater Damage Assessment Process*. Report prepared for New Jersey Site Remediation Industry Network.

Johnson, F.R., Melissa C. Ruby, William H. Desvousges, and Jonathan R. King. 1998. *Using Stated Preferences and Health-State Classifications to Estimate the Value of Health Effects of Air Pollution*. Report prepared for Environment Canada, Health Canada, Ontario Hydro, and Ontario Ministry of Environment and Energy.

Desvousges, W.H., F. Reed Johnson, M.C. Ruby, and Alicia R. Gable. 1997. *Valuing Stated Preferences for Health Benefits of Improved Air Quality: Results of a Pilot Study*. TER Working Paper No. T-9702. Durham, NC: Triangle Economic Research.

Dunford, R.W., W.H. Desvousges, F.R. Johnson, E.E. Fries, H.J. Michael, and K.E. Mathews. 1997. *Comments on NOAA's Draft Compensatory Restoration Guidance Document*. Submitted to National Oceanic and Atmospheric Administration, Silver Spring, MD.

Dunford, R.W., A.R. Gable, S.P. Hudson, W.H. Desvousges, and F.R. Johnson. 1996. *A Review of the 1996 Contingent Valuation Study on the Value of*

Preventing Oil Spills Along California's Central Coast. Prepared for Ad Hoc Industry Group. Durham, NC: Triangle Economic Research.

Desvousges, W.H., F.R. Johnson, S.P. Hudson, A.R. Gable, and Melissa C. Ruby. 1996. *Using Conjoint Analysis and Health-State Classifications to Estimate the Value of Health Effects of Air Pollution: Pilot Test Results and Implications.* Prepared for Environment Canada, Health Canada, Ontario Hydro, Ontario Ministry of Environment and Energy, and Quebec Ministry of Environment. Durham, NC: Triangle Economic Research.

Desvousges, W.H. 1995. *Volume I: Critique of the State of Montana's Contingent Valuation Study.* Submitted to United States District Court, District of Montana, Helena Division in the matter of *State of Montana v. Atlantic Richfield Company.* Case No. CV-83-317-HLN-PGH.

Desvousges, W.H., and S.M. Waters. 1995. *Volume II: Critique of the State of Montana's Recreation Study.* Submitted to United States District Court, District of Montana, Helena Division in the matter of *State of Montana v. Atlantic Richfield Company.* Case No. CV-83-317-HLN-PGH.

Desvousges, W.H., and S.M. Waters. 1995. *Volume III: Report on Potential Economic Losses Associated with Recreation Services in the Upper Clark Fork River Basin.* Submitted to United States District Court, District of Montana, Helena Division in the matter of *State of Montana v. Atlantic Richfield Company.* Case No. CV-83-317-HLN-PGH.

Desvousges, W.H. 1995. *Volume IV: Critique of the State of Montana's Groundwater Valuation.* Submitted to United States District Court, District of Montana, Helena Division in the matter of *State of Montana v. Atlantic Richfield Company.* Case No. CV-83-317-HLN-PGH.

Desvousges, W.H. 1995. *Volume V: Report on Potential Economic Losses Associated with Groundwater.* Submitted to United States District Court, District of Montana, Helena Division in the matter of *State of Montana v. Atlantic Richfield Company.* Case No. CV-83-317-HLN-PGH.

Desvousges, W.H., and S.M. Waters. 1995. *Volume VI: Additional Economic Critique of the State of Montana's Damage Estimates.* Submitted to United States District Court, District of Montana, Helena Division in the matter of *State of Montana v. Atlantic Richfield Company.* Case No. CV-83-317-HLN-PGH.

Desvousges, W.H., S.M. Waters, and K.E. Train. 1996. *Supplemental Report on Potential Economic Losses Associated with Recreation Services in the Upper Clark Fork River Basin.* Durham, NC: Triangle Economic Research.

Dunford, R.W., K.E. Mathews, A.R. Gable, E.E. Fries, F.R. Johnson, and W.H. Desvousges. 1995. *Nonuse Values for Nonenvironmental Commodities: Preliminary Contingent Valuation Results for Avoiding Job Losses.* Prepared for the U.S. Department of Energy. Durham, NC: Triangle Economic Research.

Dunford, R.W., K.E. Mathews, A.R. Gable, E.E. Fries, F.R. Johnson, and W.H. Desvousges. 1995. *Nonuse Values for Nonenvironmental Commodities: Preliminary Conjoint Survey Results.* Prepared for the U.S. Department of Energy. Durham, NC: Triangle Economic Research.

Gable, A.R., W.H. Desvousges, and F.R. Johnson. 1995. *Calibrating Contingent Valuation Estimates: A Review of the Literature and Suggestions for Future Research.* Prepared for the U.S. Department of Energy. Durham, NC: Triangle Economic Research.

Mathews, K.E., F.R Johnson, R.W. Dunford, and W.H. Desvousges. 1995. *The Potential Role of Conjoint Analysis in Natural Resource Damage Assessments.* TER Working Paper No. G-9503. Durham, NC: Triangle Economic Research.

Desvousges, W.H. 1995. *The Role of Contingent Valuation in Natural Resource Damage Assessment.* TER Working Paper No. G-9502. Durham, NC: Triangle Economic Research.

Desvousges, W.H., K.E. Mathews, R.W. Dunford, R.R. Russell, and H.L. James. 1995. *Comments on NOAA's Proposed NRDA Rule Under the Oil Pollution Act.* Submitted to NOAA. Durham, NC: Triangle Economic Research.

Desvousges, W.H., K.E. Mathews, R.W. Dunford, R.R. Russell, and H.L. James. 1995. *Comments on NOAA's Proposed NRDA Rule Under the Oil Pollution Act: Executive Summary.* Durham, NC: Triangle Economic Research.

Desvousges, W.H., and R.A. Sandefur. 1995. "Modeling Natural Resource Damages for Spills and Releases of Oils and Chemicals." White Paper prepared for API by Arthur D. Little and Triangle Economic Research.

Desvousges, W.H., L.A. Sturtevant, S.E. Holden, and S.P. Hudson. 1995. *Review of DOI's Proposed NRDAM/CME and Associated Regulations.* Prepared by Arthur D. Little, Inc. and Triangle Economic Research.

Desvousges, W.H., S.P. Hudson, A.R. Gable, and S.K. Snow. 1995. *Review of DOI's Proposed NRDAM/GLE and Associated Regulations.* Prepared by Arthur D. Little, Inc., and Triangle Economic Research.

Desvousges, W.H., F.R. Johnson, H.S. Banzhaf, R.R. Russell, E.E. Fries, K.J. Dietz, S.C. Helms, D. Keen, J. Snyder, H. Balentine, V. Sadeghi, and S.A. Martin. 1995. *Assessing Environmental Externality Costs for Electricity Generation in Wisconsin.* Prepared for Wisconsin Task Force on Externality Costing. Seven volumes. Durham, NC: Triangle Economic Research.

Desvousges, W.H., F.R. Johnson, H.S. Banzhaf, R.R. Russell, E.E. Fries, K.J. Dietz, S.C. Helms, D. Keen, J. Snyder, H. Balentine, V. Sadeghi, and S.A. Martin. 1995. *Assessing Environmental Externality Costs for Electricity Generation.* Prepared for Northern States Power Company. Seven volumes. Durham, NC: Triangle Economic Research.

Johnson, F.R., W.H. Desvousges, E.E. Fries, and L.L. Wood. 1995. *Conjoint Analysis of Individual and Aggregate Environmental References*. TER Technical Working Paper No. T-9502. Durham, NC: Triangle Economic Research.

Desvousges, W.H., R.W. Dunford, R.R. Russell, and S.P. Hudson. 1994. *Review of Technical Memorandum: Quantification and Scaling of Resource Services.* Prepared for ASARCO Incorporated, Champion International Corporation, Kaiser Aluminum & Chemical Corporation, Occidental Chemical Corporation, and the City of Tacoma.

Desvousges, W.H., F.R. Johnson, and H. Spencer Banzhaf. 1994. *Assessing Environmental Costs For Electricity Generation*. TER General Working Paper No. G-9402. Durham, NC: Triangle Economic Research.

Desvousges, W.H., S.P. Hudson, S.K. Snow, R.W. Dunford, A.R. Gable, M.C. Ruby, and R.A. Sandefur. 1994. *Comments on the National Oceanic and Atmospheric Administration's Natural Resource Damage Assessment Proposed Rule.* Prepared for NOAA. Durham, NC: Triangle Economic Research.

Desvousges, W.H., L.L. Wood, A.E. Kenyon, F.R. Johnson, R. Iachan, and E.E. Fries. 1994. *Willingness-to-Pay Results and Market Penetration Forecasts.* Prepared for the Electric Power Research Institute.

Desvousges, W.H., S.P. Hudson, and R.R. Russell. 1993. *Comments on the Department of the Interior's Natural Resource Damage Assessment Proposed Rule.* Prepared for the Office of Environmental Affairs, U.S. Department of the Interior.

Desvousges, W.H., and F.R. Johnson. 1992. *A Review of "Methods for Measuring Nonuse Values: A Contingent Valuation Study of Groundwater Cleanup,"* by McClelland, Schulze, et al. Prepared for the Environmental Advisory Committee, U.S. Environmental Protection Agency.

Desvousges, W.H., F.R. Johnson, R.W. Dunford, K.N. Wilson, H.S. Banzhaf, and K.J. Stettler. 1992. *Using Contingent Valuation to Measure Nonuse Damages: An Assessment of Validity and Reliability.* Prepared for the NOAA Contingent Valuation Panel.

Desvousges, W.H., F.R. Johnson, R.W. Dunford, K.J. Boyle, S.P. Hudson, and K.N. Wilson. 1992. *Measuring Nonuse Damages Using Contingent Valuation: An Experimental Evaluation of Accuracy*. Monograph 92-1, Prepared for Exxon Company, USA. Research Triangle Park, NC: Research Triangle Institute.

Desvousges, W.H., K.E. Mathews, N. Dean, J.S. Smith, and K.N. Wilson. 1992. *Measuring Benefits of the Effluent Guidelines: An Evaluation of Benefits-Transfer Technique.* Prepared for the Office of Science and Technology, U.S. Environmental Protection Agency.

Desvousges, W.H., F.R. Johnson, J.A. Mauskopf, S.A. Johnston, J.S. Smith, K.N. Wilson, and M. Benerofe. 1991. *Accounting for Externality Costs* *in Wisconsin Electric Utility Planning.* Prepared for the Wisconsin Public Service Commission.

Desvousges, W.H., and A.J. Milliken. 1991. *An Economic Assessment of Natural Resource Damages from the Arthur Kill Oil Spill.* Prepared for Exxon Company, USA.

Desvousges, W.H., and R.W. Dunford. 1991. *Comments on the Proposed Revision in the NRDA Rule Pursuant to the 1989 Ohio vs. Interior Ruling.* Submitted to the U.S. Department of the Interior.

Robilliard, G.A., W.H. Desvousges, R.W. Dunford, and J. Milliken. 1991. *Natural Resource Injury and Damage Assessment Guidance Manual.* Prepared for the Petroleum Environmental Research Forum.

Regan, M.J., and W.H. Desvousges. 1990. *Communicating Environmental Risks: A Guide to Practical Evaluations.* Prepared for the U.S. Environmental Protection Agency.

Mauskopf, J.A., A. Forrest, and W.H. Desvousges. 1990. *Hazardous Substances in Our Environment: A Citizen's Guide to Understanding Health Risks and Reducing Exposure.* Prepared for the Risk Communication Program, U.S. Environmental Protection Agency.

Regan, M.J., J.L. Creighton, and W.H. Desvousges. 1990. *Sites for Our Solid Wastes: A Guidebook for Effective Public Involvement.* Prepared for the Office of Solid Waste, U.S. Environmental Protection Agency.

Desvousges, W.H., R.W. Dunford, and J.L. Domanico. 1989. *Measuring Natural Resource Damages: An Economic Appraisal.* Prepared for the American Petroleum Institute.

Desvousges, W.H., V.K. Smith, and H.H. Rink, III. 1988. *Communicating Radon Risk Effectively: Radon Testing in Maryland.* Prepared for the Office of Policy, Planning, and Evaluation, U.S. Environmental Protection Agency.

Desvousges, W.H., V.K. Smith, A. Fisher, and F.R. Johnson. 1987. *Communicating Radon Risks Effectively.* Cooperative Agreement report to the Office of Policy Analysis, U.S. Environmental Protection Agency.

Smith, V. Kerry, William H. Desvousges, Ann Fisher, and F. Reed Johnson. 1987. *Radon Risk Perceptions and Risk Communications: Preliminary Results.* Interim report prepared for the Office of Policy Analysis, U.S. Environmental Protection Agency.

Desvousges, W.H., R.W. Dunford, J. Frey, H. Kunreuther, R. Kasperson, and P. Slovic. 1987. *High-Level Nuclear Waste Repository Risks: Focus Group Findings and Implications for Surveys.* Prepared for Mountain West and the State of Nevada.

Desvousges, W.H., R.W. Dunford, and H.H. Rink, III. 1987. *The Social Cost of a Formaldehyde Release in the Russian River Basin.* Prepared for the U.S. Department of Justice.

Desvousges, W.H., R.W. Dunford, J. Frey, H. Kunreuther, R. Kasperson, and P. Slovic. 1986. *High Level Nuclear Waste Risk Surveys: Integrated Survey Plan*. Prepared for Mountain West and the State of Nevada.

Desvousges, W.H., and V.A. Skahen. 1986. *Techniques to Measure Damages to Natural Resources: Final Report*. Prepared for CERCLA 301 Task Force, U.S. Department of the Interior. Durham, NC: Research Triangle Institute.

Desvousges, W.H., and M.C. Naughton. 1985. *Water Quality Benefits of the BCT Regulations for the Pulp and Paper Industry*. Prepared for the Economic Analysis Division, U.S. Environmental Protection Agency.

Desvousges, W.H., and V.K. Smith. 1984. *The Travel Cost Approach for Valuing Improved Water Quality: Additional Considerations*. Prepared for the Economic Analysis Division, U.S. Environmental Protection Agency.

Desvousges, W.H., V.K. Smith, and M.P. McGivney. 1983. *A Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvements*. Prepared for the Economic Analysis Division, U.S. Environmental Protection Agency.

Selected Presentations

Desvousges, W.H., and M.F. Bingham. 2004. "Benefit-Cost Analysis and 316(b) Compliance." Presented at the UWAG/EPRI (316(b) Legal Advisory Session, Atlanta, GA. May 12.

Desvousges, W.H., and K.E. Mathews. 2004. "Evaluating Mass Tort-Class Action Claims for Property Stigma Damages from Environmental Contamination." American Bar Association Conference on Environmental Law, Keystone, Colorado. March 11.

Kinnell, J.C., M.F. Bingham, E.A. Keohane, and W.H. Desvousges. 2002. "Using Intercept and Count Data to Estimate the Population of Anglers in an Urban and Industrial River." Presented at the 2002 W-133 Conference, Monterey, CA. February.

Kinnell, J.C., D.J. MacNair, and W.H. Desvousges. 2001. "Using RP and SP Data For Valuing Recreational Access in a Compensatory Restoration Framework." Presented at the 2001 W-133 Conference, Miami, FL. February.

MacNair, D.J., and W.H. Desvousges. 2001. "Using RP and SP Data to Measure the Effect of Fish Consumption Advisories on Recreational Anglers." Presented at the 2001 W-133 Conference, Miami, FL. February.

Bingham, M.T., G. Smith, and W.H. Desvousges. 1999. "A Cognitive Approach to Modeling the WTP Decision Under Dichotomous Choice and Open-

Ended Contingent-Valuation Survey Formats." Presented at the American Agricultural Economics Association Meeting, Nashville, Tennessee. August.

Kinnell, J.C., M.F. Bingham, and W.H. Desvousges. 1999. "Sequencing Effects in Valuing Multiple Environmental Programs." Presented at the American Agricultural Economics Association Meeting in Nashville, Tennessee. August.

Desvousges, W.H., and F.R. Johnson. 1998. "Measuring and Influencing Health-Related Attitudes, Perceptions, and Behavior." August.

Johnson, F.R., W.H. Desvousges, and M.J. Bingham. 1998. "Trade-off Preferences for Pharmaceuticals Development, Marketing, and Outcome Evaluation." Third international meeting of the International Society for Pharmacoeconomics and Outcomes Research, Philadelphia, PA. May.

MacNair, D.J., W.H. Desvousges, and J.C. Lutz. 1998. "An In-Kind Damage Assessment of Recreational Fishing Using Revealed and Stated Preference Data." The American Agricultural Economics Association Meeting, Salt Lake City, UT. August.

Desvousges, W.H. 1997. "Scaling and Selecting Compensatory-Restoration Projects: An Economic Perspective." Conference on Restoration of Lost Human Uses of the Environment, Washington, DC. May.

Desvousges, W.H. 1996. "NRDA From an Economist's Viewpoint." Blasland, Bouck and Lee, Inc. Sediment Management Seminar, Orlando, FL. February.

Fries, E.E., F.R. Johnson, K.E. Mathews, W.H. Desvousges, and R.W. Dunford. 1996. "The Consistency of Stated Preferences: An Analysis of Salmon-Preservation and Job-Loss Trade-offs." Camp Resources, Wilmington, N.C. August.

Johnson, F.R., M.C. Ruby, and W.H. Desvousges. 1996. "Valuing Stated Preferences for Health Benefits of Improved Air Quality: Results of a Pilot Study." Department of Economics at Stockholm School of Economics in Stockholm, Sweden. September.

Desvousges, W.H. 1995. "The Reliability of Contingent Valuation for NRDA." Panel Presentation at the Southern Economic Association Meetings in New Orleans, LA. November.

Johnson, F.R., W.H. Desvousges, and H.S. Banzhaf. 1995. "Assessing the Externalities of Electricity Generation in the Midwest." Southern Economic Association Meetings in New Orleans, Louisiana. November.

Desvousges, W.H., S.P. Hudson, and M.C. Ruby. 1994. "Evaluating CV Performance: Separating the Light from the Heat." DOE/EPA Workshop on Using Contingent Valuation to Measure Nonmarket Values, Herndon, VA. May.

Desvousges, W.H., and S.P. Hudson. 1994. "Contingent Valuation: Is it Accurate Enough for Damage Assessments?" American Bar Association Seminar on Natural Resource Damage Assessments, Chicago, IL. May.

Desvousges, W.H. 1993. "Using Contingent Valuation to Measure Nonuse Damages: A Lesson in Unreliability." Meeting of the Society for Environmental Toxicology and Chemistry, Houston, TX. November.

Robilliard, G.A., Fischel, W.H. Desvousges, R.W. Dunford, and K.E. Mathews. 1993. "Evaluation of Compensation Formulae to Measure Natural Resource Damages." International Oil Spill Conference, Tampa, FL. March.

Dunford, R.W., S.P. Hudson, and W.H. Desvousges. 1993. "Experimental Contingent Values for Reducing Environmental Damage from Oil Spills." International Oil Spill Conference, Tampa, FL. March.

Desvousges, W.H., R.W. Dunford, K.E. Mathews, and H.S. Banzhaf. 1993. "NRDA Case Study: The Arthur Kill Oil Spill." International Oil Spill Conference, Tampa, FL. March.

Desvousges, W.H., F.R. Johnson, R.W. Dunford, K.J. Boyle, and S.P. Hudson. 1993. "The Validity of Expressed Nonuse Values for Environmental Commodities." American Agricultural Economics Association meeting, Baltimore, MD. August.

Desvousges, W.H., F.R. Johnson, R.W. Dunford, K.J. Boyle, S.P. Hudson, and K.N. Wilson. 1992. "Measuring Natural Resource Damages with Contingent Valuation: Tests of Validity and Reliability." Cambridge Economics, Inc., symposium titled, "Contingent Valuation: A Critical Assessment." Washington, DC. April.

Dunford, R.W., and W.H. Desvousges. 1992. "Oil Spill Liability: Recent Legal and Economic Developments." American Economics Association meeting, New Orleans, LA. January.

Johnson, F.R., and W.H. Desvousges. 1991. "Nonuse Values in Natural Resource Damage Assessments." Southern Economic Association meeting, Nashville, TN. November.

Desvousges, W.H. 1991. "Valuing Ecological Risks." National Academy of Sciences Workshop on Ecological Risks, Warrenton, VA. February.

Dunford, R.W., S.P. Hudson, and W.H. Desvousges. 1991. "Linkages Between Oil Spill Removal Activities and Natural Resource Damages." Presented at the International Oil Spill Conference in San Diego, CA. March.

Desvousges, W.H. 1990. "Economics and the NRDA: One Economist's View." Workshop on Natural Resource Damages, American Bar Association, Washington, DC. May.

Desvousges, W.H. 1989. "Risk Perceptions and Nuclear Wastes." Engineering Foundation Conference on Risk Decision-Making, Santa Barbara, CA. October.

Desvousges, W.H., H. Kunreuther, and P. Slovic. 1989. "Perceived Risk and Nuclear Waste—A National and Nevada Perspective." American Association for the Advancement of Science Annual Meeting, San Francisco, CA. January.

Desvousges, W.H. 1987. "Hazardous Waste and Radon Risks: Good News and Bad News for Economists." Engineering Foundation Conference on Risk Management, Santa Barbara, CA. November.

Desvousges, W.H. 1987. "The Use of Focus Groups in Complex Environmental Surveys." American Association of Public Opinion Research Annual meeting, Hershey, PA.

Smith, V.K., and W.H. Desvousges. 1986. "Information and the Valuation of Risk Reductions," American Economics Association meeting, New Orleans, LA. December.

Desvousges, W.H. 1986. "Methods for Measuring Natural Resource Damages." Conference on Natural Resource Damages, Washington, DC. November.

Smith, V.K., and W.H. Desvousges. 1985. "Values for Risk Reductions: Some Considerations for Siting Decisions." American Economics Association meeting, New York, NY. December.

United States
Environmental Protection
Agency

Office of Water
(4303)

EPA-821-R-02-003
February 12, 2004

EPA

Regional Analysis Document for the Final Section 316(b) Phase II Existing Facilities Rule

Part B: California

Chapter B1: Background

Introduction

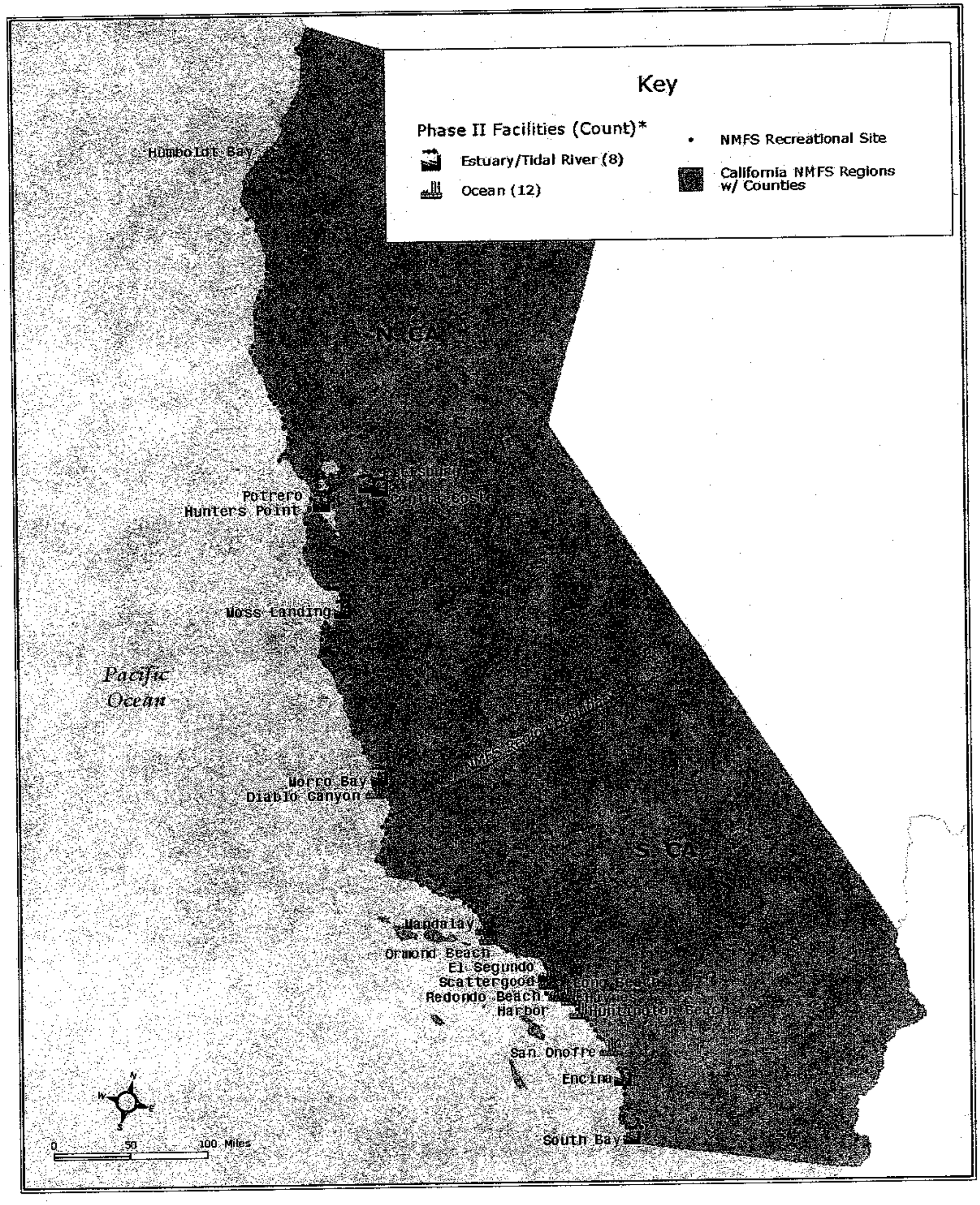
This chapter presents an overview of the Phase II facilities in the California study region and summarizes their key operating, economic, technical, and compliance characteristics. For further discussion of operating and economic characteristics of Phase II facilities, refer to Chapter A3 of the *Economic and Benefits Analysis for the Final Section 316(b) Phase II Existing Facilities Rule*; for further discussion of the technical and compliance characteristics of Phase II facilities, refer to the *Technical Development Document for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004a,b).

Chapter Contents

B1-1 Overview

The California Regional Study includes 20 facilities that are in scope for the final Phase II regulation. Of these 20 facilities, 8 are located in Northern California and 12 are located in Southern California. Eight of the 20 facilities withdraw cooling water from an estuary or tidal river while 12 withdraw water from the Pacific Ocean. Figure B1-1 presents a map of the 20 in-scope Phase II facilities located in the California Regional Study area.

Figure B1-1: In-Scope Phase II Facilities in the California Regional Study



Source: U.S. EPA analysis for this report.

B1-2 Operating and Economic Characteristics

Most of the 20 California Regional Study facilities (16) are oil/gas facilities; two are nuclear facilities; one is a combined-cycle facility; and one uses another type of steam-electric prime mover. In 2001, these 20 facilities accounted for 21 gigawatts of generating capacity, 93,000 gigawatt hours of generation, and $6.1 billion in revenues.

The operating and economic characteristics of the California Regional Study facilities are summarized in Table B1-1. Section B1-4 provides further information on each facility [including facility subregion, North American Electric Reliability Council (NERC) region, plant type, capacity, 2001 generation, and whether impingement and entrainment estimates were developed for the facility].

Table B1-1: Operating and Economic Characteristics of Phase II Facilities

Waterbody Type	Number of Facilities by Plant Type[a]					Total Capacity (MW)[b]	Total Generation (MWh)[b]	Electric Revenue (millions)
	Combined Cycle	Nuclear	Oil/Gas Steam	Other Steam	Total			
Northern California								
Estuary/Tidal River	-	-	6	-	6	6,294	27,936,568	$1,089
Ocean	-	1	1	-	2	2,403	18,755,346	$1,408
Subtotal	-	*1*	*7*	-	*8*	*8,697*	*46,691,914*	*$2,497*
Southern California								
Estuary/Tidal River	-	-	2	-	2	1,736	6,004,221	$256
Ocean	1	1	7	1	10	10,518	39,981,138	$3,299
Subtotal	*1*	*1*	*9*	*1*	*12*	*12,254*	*45,985,359*	*$3,555*
TOTAL	**1**	**2**	**16**	**1**	**20**	**20,951**	**92,677,273**	**$6,052**

[a] Based on largest steam-electric capacity at facilities.
[b] MW is an abbreviation for megawatt; MWh is an abbreviation for megawatt hour.

Sources: Plant type (IPM Analysis, U.S. EPA, 2002; Form EIA-860, U.S. DOE, 2001a); capacity (Form EIA-860, U.S. DOE, 2001a); generation (Form EIA-906, U.S. DOE, 2001c); revenue (Form EIA-861, U.S. DOE, 2001b; Form EIA-906, U.S. DOE, 2001c).

B1-3 TECHNICAL AND COMPLIANCE CHARACTERISTICS

Nineteen of the 20 California Regional Study facilities employ a once-through cooling system and one facility employs a combination system in the baseline. The 19 facilities with once-through cooling systems incur a combined pre-tax compliance cost of $30.7 million. Table B1-2 summarizes the flow, compliance responses, and compliance costs for these 20 facilities.

Table B1-2: Technical and Compliance Characteristics of Phase II Facilities

	Cooling Water System (CWS) Type[a]		
	Once-Through	**Combination**	**All**
Design Flow (MGD)	**17,136**	**691**	**17,827**
Number of Facilities by Compliance Response			
Fish H&R	5	1	6
Fine Mesh Traveling Screens w/Fish H&R	2	-	2
Passive Fine Mesh Screens	4	-	4
Fish Barrier Net/Gunderboom	3	-	3
Velocity Cap	1	-	1
None	4	-	4
Total	**19**	**1**	**20**
Compliance Cost (2002$, millions)	**$30.7**	**w[b]**	**w[b]**

[a] Combination CWSs are costed as if they were once-through CWSs.
[b] Data withheld because of confidentiality reasons.

Source: U.S. EPA analysis for this report.

B1-4 PHASE II FACILITIES IN THE CALIFORNIA REGIONAL STUDY

Table B1-3 presents economic and operating characteristics of the California Regional Study facilities.

Table B1-3: Phase II Facilities in the California Regional Study

EIA Code	Plant Name	Plant Subregion	NERC Region	Steam Plant Type	2001 Capacity (MW)	2001 Net Generation (MWh)	I&E Data?
Northern California							
Estuary/Tidal River							
228	Contra Costa	CN	WSCC	O/G Steam	690	3,295,794	Y
247	Hunters Point	CN	WSCC	O/G Steam	427	436,130	Y
259	Morro Bay	CN	WSCC	O/G Steam	1,056	4,197,701	Y
260	Moss Landing	CN	WSCC	O/G Steam	1,624	8,349,240	Y
271	Pittsburg	CN	WSCC	O/G Steam	2,080	10,388,204	Y
273	Potrero	CN	WSCC	O/G Steam	417	1,269,499	Y
Ocean							
246	Humboldt Bay	CN	WSCC	O/G Steam	102	677,633	Y
6099	Diablo Canyon	CN	WSCC	Nuclear	2,300	18,077,713	Y
Southern California							
Estuary/Tidal River							
302	Encina	CS	WSCC	O/G Steam	1,007	4,043,079	Y
310	South Bay	CS	WSCC	O/G Steam	729	1,961,142	N
Ocean							
330	El Segundo	CS	WSCC	O/G Steam	996	2,909,876	Y
335	Huntington Beach	CS	WSCC	O/G Steam	563	1,305,859	Y
341	Long Beach	CS	WSCC	Other Steam	587	866,159	N
345	Mandalay	CS	WSCC	O/G Steam	574	2,066,920	Y
350	Ormond Beach	CS	WSCC	O/G Steam	1,500	6,008,123	Y
356	Redondo Beach	CS	WSCC	O/G Steam	1,321	5,631,001	Y
360	San Onofre	CS	WSCC	Nuclear	2,254	15,141,807	Y
399	Harbor	CS	WSCC	Combined Cycle	293	889,857	Y
400	Haynes	CS	WSCC	O/G Steam	1,606	3,315,253	Y
404	Scattergood	CS	WSCC	O/G Steam	823	1,846,283	Y

Source: U.S. EPA analysis for this report.

Chapter B2: Evaluation of Impingement and Entrainment in California

CHAPTER CONTENTS

BACKGROUND: CALIFORNIA MARINE FISHERIES

The oceanic transition zone off Point Conception creates a natural ecological separation between northern and southern California (Leet et al., 2001). North of Point Conception, coastal waters are cold and oceanic conditions are harsh, whereas to the south waters are warmer and conditions are moderate. As a result, the fish species composition differs between the two regions. Surface and bottom temperatures along the continental shelf off northern California support polar and cold-temperate species such as chinook salmon, coho salmon, striped bass, rock gunnels, and lanternfish (Leet et al., 2001). In Southern California, warm waters from the south join with the cold California current to provide habitat for a wide variety of seasonal subtropical visitors like yellowtail, white seabass, Pacific bonito, and California barracuda, all found in close association with the abundant strands of giant kelp (Pacific Fishery Management Council, 2003b). Major resident species such as kelp bass, sheephead, halfmoon and olive rockfish sustain year-round nearshore fisheries (Leet et al., 2001).

California fisheries are managed by the Pacific Fishery Management Council (PFMC), which governs commercial and recreational fisheries in Federal waters from 3 to 200 nautical miles off the coasts of Washington, Oregon, and California (Pacific Fishery Management Council, 2003a). The National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center provides scientific and technical support for management, conservation, and fisheries development for Northern California. The NMFS Southwest Fisheries Science Center provides support for Southern California.

There are 83 species of groundfish included under PFMC's Groundfish Fishery Management Plan, including nearly 50 species of rockfish (*Sebastes* spp.) (Table 3 in NMFS, 2002a). The midwater trawl fishery for Pacific whiting (*Merluccius productus*) dominates the commercial fishery, accounting for 78 percent of Pacific Coast landings (NMFS, 1999b). Important deepwater trawl fisheries also exist for sablefish, Dover sole, and thornyheads. During the 1990s a major fishery developed for nearshore species, including rockfishes, cabezon, and sheephead (Leet et al., 2001). Rockfishes are important for both commercial and recreational fisheries (NMFS, 1999b). In 1994, a limited entry program was implemented for the groundfish fishery because of concerns about overfishing (NMFS, 1999b). Most major West Coast groundfishes are now fully harvested, and catches have recently been controlled by quotas and trip limits (Pacific Fishery Management Council, 2003c).

Pacific Coast pelagic species managed by the PFMC include Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), and California market squid (*Loligo opalescens*) (NMFS, 2002a). These species typically fluctuate widely in abundance, and currently most stocks are low relative to historical levels (NMFS, 1999b). Pacific mackerel and Pacific sardine are not overfished, but the stock size of the other species governed by the Coastal Pelagic FMP is unknown (Table 3 in NMFS, 2002a). Because of increases in abundance in recent years, Pacific mackerel now accounts for over half of recent landings of Pacific Coast pelagic species (NMFS, 1999b). At times, Pacific sardine has been the most abundant fish species in the California current. When the population is large, it is abundant from the tip of Baja California to southeastern Alaska (Pacific Fishery Management Council, 2003b).

Five species of anadromous Pacific salmon support coastal and freshwater commercial and recreational fisheries along the Pacific Coast, including chinook (*Oncorhynchus tshawytscha)*, coho (*O. kisutch*), sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum (*O. keta*) salmon (NMFS, 1999b). The Sacramento River is a major producer of chinook salmon in California. Since 1991, NMFS has listed 20 Evolutionary Significant Units (ESUs)[1] of Pacific Coast salmon and steelhead trout (*O. mykiss*) under the Federal Endangered Species Act (ESA) (NMFS, 1999c). In NMFS's Northern California region, listed species include steelhead, coho salmon, and chinook salmon of the central California Coast and steelhead and chinook salmon of California's Central Valley.

Ocean fisheries for chinook and coho salmon are managed by the PFMC under the Pacific Coast Salmon FMP. In Puget Sound and the Columbia River, chinook and coho fisheries are managed by the States and Tribal fishery agencies. Declines in chinook and coho salmon along the coast have led to reductions and closures of ocean fisheries in recent years (NMFS, 1999b).

The Pacific Salmon FMP contains no fishery management objectives for sockeye, chum, even-year pink, and steelhead stocks because fishery impacts are considered inconsequential (Table 3 in NMFS, 2002a). Pink, chum, and sockeye salmon are managed jointly by the Pacific Salmon Commission, Washington State, and Tribal agencies (NMFS, 1999b).

Pacific Coast shellfish resources are important both commercially and recreationally (NMFS, 1999b). Shrimps, crabs, abalones, and clams command high prices and contribute substantially to the value of Pacific Coast fisheries, even though landings are small.

B2-1 Fishery Species Impinged and Entrained

Available impingement and entrainment (I&E) data indicate that 20 of the 248 distinct species that are impinged and entrained by California facilities are harvested species subject to FMPs developed by the PFMC. Table B2-1 summarizes information on the stock status of these species. Note that stock status is known for only 4 of these species. Most of the species listed are rockfish species. Northern anchovy falls under the Coastal Pelagic FMP, and the other species in the table are included in the Groundfish FMP. Although under the jurisdiction of the PFMC, there are no fishery management objectives for Central Valley chinook salmon and Central California Coast coho salmon because of their ESA listing (NMFS, 2002a). There are also no fishery management goals for steelhead because fishery impacts are considered inconsequential (NMFS, 2002a).

Table B2-1: Summary of Stock Status of Harvested Species in California that are Impinged and Entrained and are Included in Federal FMPs

Stock (Species in bold are major stocks, with annual landings over 200,000 pounds)	Overfishing? (Is fishing mortality above threshold?)	Overfished? (Is stock size below threshold?)	Approaching Overfished Condition?
Aurora rockfish	Unknown	Unknown	Unknown
Black rockfish	No	No	No
Black-and-yellow rockfish	Unknown	Unknown	Unknown
Blue rockfish	Unknown	Unknown	Unknown
Bocaccio	No	Yes	N/A
Cabezon	Unknown	Unknown	Unknown
California scorpionfish	Unknown	Unknown	Unknown
Central California Coast coho salmon[a]	N/A	N/A	N/A

[1] An Evolutionarily Significant Unit (ESU) is a term introduced by NMFS in 1991 to refer to the Endangered Species Act (ESA) interpretation of "distinct population segment." A stock must satisfy two criteria to be considered an ESU: (1) "it must be substantially reproductively isolated from other conspecific population units," and (2) "it must represent an important component in the evolutionary legacy of the species."

Table B2-1: Summary of Stock Status of Harvested Species in California that are Impinged and Entrained and are Included in Federal FMPs			
Stock (Species in bold are major stocks, with annual landings over 200,000 pounds)	Overfishing? (Is fishing mortality above threshold?)	Overfished? (Is stock size below threshold?)	Approaching Overfished Condition?
Central Valley chinook salmon[a]	N/A	N/A	N/A
Chilipepper rockfish	No	No	No
Copper rockfish	Unknown	Unknown	Unknown
Gopher rockfish	Unknown	Unknown	Unknown
Grass rockfish	Unknown	Unknown	Unknown
Kelp rockfish	Unknown	Unknown	Unknown
Northern anchovy-central subpopulation		Undefined	Unknown
Olive rockfish	Unknown	Unknown	Unknown
Shortbelly rockfish	No	No	No
Starry flounder	Unknown	Unknown	Unknown
Steelhead[b]	N/A	N/A	N/A
Yellowtail rockfish	No	No	No

[a] There are no fishery management goals for Central Valley chinook salmon and Central California Coast coho salmon because of their ESA listing (NMFS, 2002a).
[b] There are no fishery management goals for steelhead because fishery impacts are considered inconsequential (NMFS, 2002a).

Source: Table 4 in NMFS (2002a).

B2-2 I&E Species and Species Groups Evaluated

Table B2-2 provides a list of species in the California region that are impinged and entrained at cooling water intake structures in scope of the section 316(b) Phase II rule that were evaluated in EPA's analysis of regional I&E. Life histories of the species with the highest losses are summarized in the following section. The life history data used in EPA's analysis and associated data sources are provided in Appendix B1 of this report.

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California					
Species Group	Species	Recreational	Commercial	Forage	Special Status[a]
Anchovies	Deepbody anchovy		X		
	Northern anchovy		X		
	Slough anchovy		X		
Blennies	Bay blenny			X	
	Combtooth blennies			X	
	Mussel blenny			X	
	Orangethroat pikeblenny			X	
	Rockpool blenny			X	
	Tube blenny			X	
Cabezon	Cabezon	X	X		
California halibut	California halibut	X	X		
California scorpionfish	California scorpionfish	X	X		

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California					
Species Group	**Species**	**Recreational**	**Commercial**	**Forage**	**Special Status[a]**
	Spotted scorpionfish	X	X		
Chinook salmon	Chinook salmon				X (FT, ST, FE, SE, FCT)
Commercial sea basses	Giant sea bass		X		
Commercial shrimp	Alaskan bay shrimp		X		
	Franciscan bay shrimp		X		
	Ghost shrimp		X		
	Smooth bay shrimp		X		
	Black-tailed shrimp		X		
Delta smelt	Delta smelt				X (FT, ST)
Drums croakers	Black croaker	X	X		
	California corbina	X	X		
	Queenfish	X	X		
	Spotfin croaker	X	X		
	White croaker	X	X		
	White sea bass	X	X		
	Yellowfin croaker	X	X		
Dungeness crab	Dungeness crab		X		
Flounders	Bigmouth sole	X	X		
	CO sole	X	X		
	Curlfin sole	X	X		
	Diamond turbot	X	X		
	Dover sole	X	X		
	English sole	X	X		
	Fantail sole	X	X		
	Hornyhead turbot	X	X		
	Longfin sanddab	X	X		
	Pacific sand sole	X	X		
	Pacific sanddab	X	X		
	Petrale sole	X	X		
	Rock sole	X	X		
	Slender sole	X	X		
	Speckled sanddab	X	X		
	Spotted turbot	X	X		
	Starry flounder	X	X		
Forage shrimp	Anemone shrimp			X	
	Blue mud shrimp			X	
	Broken back shrimp			X	
	California green shrimp			X	
	Dock shrimp			X	

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California

Species Group	Species	Recreational	Commercial	Forage	Special Status[a]
	Mysids			X	
	Opossum shrimp			X	
	Oriental shrimp			X	
	Pistol shrimp			X	
	Sidestriped shrimp			X	
	Skeleton shrimp			X	
	Stout bodied shrimp			X	
	Striped shrimp			X	
	Tidepool shrimp			X	
	Twistclaw pistol shrimp			X	
Gobies	Arrow goby			X	
	Bay goby			X	
	Blackeyed goby			X	
	Blind goby			X	
	Chameleon goby			X	
	Cheekspot goby			X	
	Long jaw mudsucker			X	
	Shadow goby			X	
	Yellowfin goby			X	
Herrings	Middling thread herring			X	
	Pacific herring			X	
	Pacific sardine			X	
	Round herring			X	
	Threadfin shad			X	
Longfin smelt	Longfin smelt				X (SOC)
Other commercial species	Basketweave cusk-eel		X		
	California moray		X		
	Catalina conger		X		
	Leopard shark		X		
	Monkeyface prickleback		X		
	Moray eel		X		
	Pacific hagfish		X		
	Pacific hake		X		
	Pricklebreast poacher		X		
	Rock prickleback		X		
	Spotted cusk-eel		X		
	Yellow snake-eel		X		
Other forage species	Barcheek pipefish			X	
	Bay pipefish			X	
	Bigscale goatfish			X	

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California					
Species Group	**Species**	**Recreational**	**Commercial**	**Forage**	**Special Status[a]**
	Black bullhead			X	
	Blacksmith			X	
	Blue lanternfish			X	
	Broadfin lampfish			X	
	Bullseye puffer			X	
	California clingfish			X	
	California flyingfish			X	
	California killifish			X	
	California lizardfish			X	
	California needlefish			X	
	California tonguefish			X	
	Combfish			X	
	Cortez angelfish			X	
	Crevice kelpfish			X	
	Finescale triggerfish			X	
	Flathead mullet			X	
	Fringehead			X	
	Garibaldi			X	
	Giant kelpfish			X	
	Hatchet fish			X	
	High cockscomb			X	
	Island kelpfish			X	
	Kelp gunnel			X	
	Kelp pipefish			X	
	Kelpfish			X	
	Lampfish			X	
	Lanternfish			X	
	Longfin lanternfish			X	
	Longspine combfish			X	
	Medusafish			X	
	Mexican lampfish			X	
	Northern clingfish			X	
	Northern lampfish			X	
	Northern spearnose poacher			X	
	Ocean sunfish			X	
	Ocean whitefish			X	
	Onespot fringehead			X	
	Pacific butterfish			X	
	Pacific cornetfish			X	
	Pacific cutlassfish			X	

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California

Species Group	Species	Recreational	Commercial	Forage	Special Status[a]
	Pacific lampray			X	
	Pacific sand lance			X	
	Penpoint gunnel			X	
	Pipefish species			X	
	Plainfin midshipman			X	
	Popeye smelt			X	
	Pygmy poacher			X	
	Ratfish			X	
	Red brotula			X	
	Reef finspot			X	
	Ribbonfish			X	
	Rockweed gunnel			X	
	Ronquil			X	
	Saddleback gunnel			X	
	Salema			X	
	Sarcastic fringehead			X	
	Sargo			X	
	Scarlet kelpfish			X	
	Sea porcupine			X	
	Sharksucker			X	
	Shovelnose guitarfish			X	
	Slimy snailfish			X	
	Smalleye squaretail			X	
	Snubnose pipefish			X	
	Southern poacher			X	
	Southern spearnose poacher			X	
	Specklefin midshipman			X	
	Spotted kelpfish			X	
	Spotted ratfish			X	
	Squid			X	
	Striped kelpfish			X	
	Thornback			X	
	Threespine stickleback			X	
	Tubesnout			X	
	Zebra perch			X	
Other recreational species	Angel shark	X			
	Bat ray	X			
	Big skate	X			
	Black skate	X			
	Broadnose sevengill shark	X			

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California					
Species Group	Species	Recreational	Commercial	Forage	Special Status[a]
	Brown smoothhound	X			
	California butterfly ray	X			
	Chub mackerel	X			
	Diamond stingray	X			
	Gray smoothhound	X			
	Halfmoon	X			
	Horn shark	X			
	Kelp greenling	X			
	Mexican scad	X			
	Monterey spanish mackerel	X			
	Opaleye	X			
	Pacific angel shark	X			
	Pacific bonito	X			
	Pacific bumper	X			
	Pacific electric ray	X			
	Pacific mackerel	X			
	Pacific moonfish	X			
	Pacific pompano	X			
	Painted greenling	X			
	Rock wrasse	X			
	Round stingray	X			
	Senorita	X			
	Sevengill shark	X			
	Soupfin shark	X			
	Striped mullet	X			
	Swellshark	X			
	Thornback ray	X			
	California sheephead	X			
	Jack mackerel	X			
	Lingcod	X			
	Pacific barracuda	X			
	Piked dogfish	X			
	Spiny dogfish	X			
Other commercial crabs	Anthonys rock crab		X		
	Black clawed crab		X		
	Brown rock crab		X		
	Common rock crab		X		
	Cryptic kelp crab		X		
	Dwarf crab		X		
	Elbow crab		X		

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California					
Species Group	Species	Recreational	Commercial	Forage	Special Status[a]
	European green crab		X		
	Graceful kelp crab		X		
	Hairy rock crab		X		
	Kelp crab		X		
	Lined shore crab		X		
	Lumpy crab		X		
	Majid crab		X		
	Masking crab		X		
	Mole crab		X		
	Moss crab		X		
	Mud/Stone crab		X		
	Northern kelp crab		X		
	Pacific sand crab		X		
	Pea crab		X		
	Pebble crab		X		
	Porcelain crab		X		
	Porcelain crabs		X		
	Purple shore crab		X		
	Red crab		X		
	Red rock crab		X		
	Sharp nosed crab		X		
	Shore crab		X		
	Slender crab		X		
	Slender rock crab		X		
	Southern kelp crab		X		
	Spider crab		X		
	Striped shore crab		X		
	Thickclaw porcelain crab		X		
	Xantus swimming crab		X		
	Yellow crab		X		
	Yellow shore crab		X		
Rec sea basses	Barred sand bass	X			
	Broomtail grouper	X			
	Kelp bass	X			
	Spotted sand bass	X			
Rockfishes	Aurora rockfish	X	X		
	Black and yellow rockfish	X	X		
	Black rockfish	X	X		
	Blue rockfish	X	X		
	Bocaccio	X	X		

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California

Species Group	Species	Recreational	Commercial	Forage	Special Status[a]
	Brown rockfish	X	X		
	Calico rockfish	X	X		
	Chilipepper	X	X		
	Copper rockfish	X	X		
	Flag rockfish	X	X		
	Grass rockfish	X	X		
	Kelp rockfish	X	X		
	Olive rockfish	X	X		
	Shortbelly rockfish	X	X		
	Treefish	X	X		
	Vermilion rockfish	X	X		
	Yellowtail rockfish	X	X		
Sacramento splittail	Sacramento splittail				X (FT)
Salmon	Coho salmon	X			
Sculpins	Bonehead sculpin	X	X		
	Brown Irish lord	X	X		
	Buffalo sculpin	X	X		
	Coralline sculpin	X	X		
	Fluffy sculpin	X	X		
	Manacled sculpin	X	X		
	Pacific staghorn sculpin	X	X		
	Prickly sculpin	X	X		
	Rosy sculpin	X	X		
	Roughcheek sculpin	X	X		
	Roughneck sculpin	X	X		
	Smoothhead sculpin	X	X		
	Snubnose sculpin	X	X		
	Staghorn sculpin	X	X		
	Tidepool sculpin	X	X		
	Woolly sculpin	X	X		
Silversides	California grunion			X	
	Jacksmelt			X	
	Topsmelt			X	
Smelts	Night smelt	X	X		
	Surf smelt	X	X		
Steelhead	Steelhead				X (FT)
Striped bass	Striped bass	X			
Surfperches	Barred surfperch	X	X		
	Black surfperch	X	X		
	Calico surfperch	X	X		

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California					
Species Group	Species	Recreational	Commercial	Forage	Special Status[a]
	Dwarf surfperch	X	X		
	Island surfperch	X	X		
	Kelp surfperch	X	X		
	Pile surfperch	X	X		
	Pink seaperch	X	X		
	Rainbow surfperch	X	X		
	Rubberlip surfperch	X	X		
	Shiner surfperch	X	X		
	Silver surfperch	X	X		
	Spotfin surfperch	X	X		
	Striped seaperch	X	X		
	Walleye surfperch	X	X		
	White surfperch	X	X		

[a] FT = Federally listed as threatened.
ST = State listed as threatened.
FE = Federally listed as endangered.
SE = State listed as endangered.
FCT = Federal candidate for listing as threatened.
SOC = Species of concern.

B2-3 Life Histories of Primary Species Impinged and Entrained in California

Chinook salmon (*Oncorhynchus tshawytscha*)

Chinook salmon are anadromous members of the salmon and trout family (Salmonidae) (Moyle, 1976; Emmett et al., 1991; Boydstun et al., 1992). The San Francisco Bay-Delta is an important nursery area and migration route for chinook salmon (Kennish, 2000). Eggs, alevins (larvae), and young juveniles (fry and parr) use freshwater streams and rivers upstream of the delta, and juveniles migrate through the delta and use it as a nursery area (Emmett et al., 1991). Juveniles eventually migrate downstream to the Pacific Ocean as they transform into smolts, the ocean-dwelling stage. Chinook salmon spend from 1-8 years in the ocean before returning to their natal stream to spawn.

Four races of chinook salmon use the Sacramento-San Joaquin River system (Moyle, 1976; Yoshiyama et al., 2000). These include the fall run, late fall run, winter run, and spring run chinook salmon. In the Sacramento River, the winter run spawns from April to July, and the other runs spawn from July to December (Moyle, 1976). Spawning once occurred into the upper reaches of both the Sacramento and San Joaquin rivers, but dams have limited spawning to the lower reaches of these rivers and their tributaries (Moyle, 1976; Yoshiyama et al., 2000). The Central Valley late fall run was recently evaluated as a part of a proposed listing of the fall run under the Federal Endangered Species Act (ESA). Although it was decided that the combined Central Valley fall/late-fall run currently does not qualify for formal protection, both runs remain under consideration as candidate species (Yoshiyama et al., 2000). The Sacramento River winter run is listed as endangered under both the State and Federal ESA. The Central Valley spring run is listed as threatened under both statutes.

The four Central Valley runs of chinook salmon are vulnerable to I&E at the Pittsburg and Contra Costa power plants. Adults have been observed near the plants in October, and larvae (alevins) have been collected from inshore, shallow areas of Suisun Bay in January and February (Wang, 1986). Parr have been observed throughout the estuary in spring, with peak migration occurring in May and June (Wang, 1986).

CHINOOK SALMON
(Oncorhynchus tshawytscha)

Family: Salmonidae (salmon and trout).

Common names: Blackmouth, king salmon, quinnat salmon, spring, tyee.[a]

Similar species: Steelhead.

Geographic range: Arctic and Pacific from Point Hope, Alaska to Ventura River, California.[a]

Habitat: Oceans, streams and lakes.[a] Prefers gravel substrates for spawning.[b]

Lifespan: Can live up to 9 years.[a]

Fecundity: 2,000 to 14,000 eggs.[b]

Food sources:
- In streams, food is mainly terrestrial insects and small crustaceans.[a]
- In oceans, chinook salmon consume fish, crustaceans, and other invertebrates.[a]

Prey for:
- Striped bass, American shad, sculpins, Sacramento squawfish, sea gulls, mergansers, kingfishers.[a,b]

Life stage information:

***Eggs:* demersal**
- Eggs range from 6.0 to 8.5 mm (0.24 to 0.33 in).[b]
- Deposited and buried in gravel, and are bright orange-red in color.[b]

***Larvae:* demersal for 2-3 weeks, then free-swimming.[b]**
- Approximately 20 mm (0.79 in) at hatching.

Juveniles:
- Found in shallow and open waters of the Sacramento - San Joaquin Estuary.[b]
- Remain in freshwater for 1-2 years.[b]
- Drift feeders.[b]

***Adults*:**
- Return to natal streams from the sea for spawning.[a]
- Reach up to 147 cm (58 in).[a]

[a] Froese and Pauly, 2001.
[b] Wang, 1986.
Fish graphic from NEFSC, 2001.

Delta smelt (*Hypomesus transpacificus*)

The delta smelt is a pelagic member of the smelt family (Osmeridae). It is a small, short-lived species that is found only in the bay-delta estuary, in areas with low salinities (Moyle, 1976; Moyle et al., 1992; U.S. Fish and Wildlife Service, 1996b). It is the only smelt species endemic to California and the only true native estuarine species found in the delta (Moyle et al., 1992).

The spawning period of delta smelt is relatively long, and adults may spawn from December to May, although most spawning occurs in February and March (Moyle, 1976). Before spawning in the fall, delta smelt congregate in upper Suisun Bay and the lower reaches of the delta (Moyle, 1976). Spawning takes place in freshwater along river margins and adjoining dead-end sloughs of the western delta. Fecundity is low, ranging from only 1,247 to 2,590 eggs per female (Moyle, 1976). Adults apparently die shortly after spawning, at the end of their 1-year life span (Moyle et al., 1992).

Eggs are demersal and adhesive, sticking to aquatic plants and gravel, and are therefore unlikely to be drawn into cooling water intakes, although the larvae are vulnerable (Bruce Herbold, EPA Region 9, personal communication, September 1, 2000). After hatching, the buoyant larvae are carried downstream to the entrapment zone, the highly productive areas where freshwater and salt water mix. This zone is located in Suisun Bay in years of high freshwater inflow. Juveniles move downstream to San Pablo Bay and Carquinez Strait before turning back to Suisun Bay for spawning.

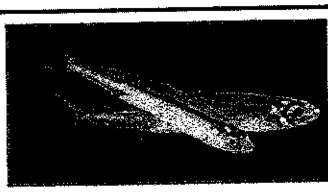
The delta smelt was once one of the most common fish species in the bay-delta estuary, but the species has declined nearly 90 percent over the last 20 years. A number of physical and biological factors have contributed to declines in recent years, including increased water exports, competition and predation from the accidentally introduced inland silverside (*Menidia beryllina*), drought conditions in the late 1980s and early 1990s, and changes in food availability (CDWR, 1994; U.S. Fish and Wildlife Service, 1996b). Another major factor is the seasonal location of the entrapment zone. The location of the entrapment zone is a function of the timing and magnitude of delta outflow. There is a significant positive relationship between delta smelt abundance and the number of days that the entrapment zone is located within Suisun Bay from February through June (Moyle et al., 1992). Habitat and prey availability for delta smelt are greater when the entrapment zone is in this area because Suisun Bay is broad and shallow, and therefore light penetrates most of its waters, promoting algal growth (U.S.

Fish and Wildlife Service, 1996b). Algal growth under these conditions provides an abundant food supply for zooplankton, which in turn provide food for plankton-eating fish like delta smelt.

Altered flow patterns caused primarily by agricultural water diversions during spawning also appear to contribute to delta smelt population losses by increasing the likelihood of entrainment of spawning adults and newly hatched larvae in diversion pumps (Moyle et al., 1992). In dry years, delta smelt are concentrated in upstream areas, whereas in wet years overall habitat conditions are more favorable and delta smelt are more widely distributed. When favorable conditions result in wider distribution, more delta smelt are affected by water diversion pumps (CDWR, 1994). The California Department of Water Resources (CDWR) estimated that entrainment losses of delta smelt at delta diversions reached 1.2 million in 1992 (CDWR, 1994).

Losses of delta smelt related to other water uses equal or exceed those at government water project pumps (CDWR, 1994). For example, because of their schooling behavior and preference for the region around Suisun Bay, delta smelt are highly vulnerable to the intakes of the Pittsburg and Contra Costa power plants. Monitoring of this species has not been required of the power plants, and the only estimates of I&E are based on incidental collection in striped bass monitoring samples in the late 1970's (Ecological Analysts, 1981b, 1981e). Nonetheless, the data indicate that in the late 1970's delta smelt were one of the most common fish species in the vicinity of the plants and experienced I&E in the millions each year.

Delta smelt is currently listed as a threatened species by both the USFWS and California. Historically, the delta smelt occurred from Suisun Bay upstream to the city of Sacramento on the Sacramento River and upstream to Mossdale on the San Joaquin River (Moyle et al., 1992). The size of the current population is uncertain, but in the early 1990's the population was estimated to be about 280,000 (Southern Energy Delta, LLC, 2000). Even at this population size, the delta smelt is considered highly vulnerable to environmental stressors because of its 1-year life cycle and low fecundity. Low fecundity and a short life span mean that even as few as 2 successive years of low reproductive success could decimate the population (Moyle, 1976).



DELTA SMELT
(Hypomesus transpacificus)

Family: Osmeridae (smelt).

Common names: none.

Similar species: Longfin smelt.

Geographic range: Sacramento - San Joaquin Delta.[a]

Habitat: Deadend sloughs, inshore areas of the delta and lower reaches of the Sacramento and San Joaquin rivers.[b]

Lifespan: Only live for one year.[c]

Fecundity: Fecundity is low, ranging from only 1,247 to 2,590 eggs per female.[d] Delta smelt die shortly after spawning.[c]

Food sources:
- Juveniles eat planktonic crustaceans, small insect larvae, and mysid shrimp.[b]

Prey for:

Life stage information:

***Eggs:* demersal**
- Eggs are adhesive and stick to aquatic plants and gravel.[e]
- Approximately 1mm (0.04 in) in diameter.[b]

***Larvae:* pelagic**
- Larvae are approximately 5.5 to 6.0 mm (0.22 to 0.24 in) at hatching.[b]
- Found near surface of water column.[b]

***Juveniles:* pelagic**
- Juveniles are concentrated in the Suisun Bay and the delta and in the lower reaches of the Sacramento and San Joaquin rivers.[b]

Adults:
- Reach 12 cm (4.7 in).[a]

[a] Froese and Pauly, 2001.
[b] Wang, 1986.
[c] Moyle et al., 1992.
[d] Moyle, 1976.
[e] Bruce Herbold, EPA Region 9, personal communication, September 1, 2000.
Fish graphic from California Department of Fish and Game, 2002b.

Green sturgeon (*Acipenser medirostris*)

The green sturgeon is a member of the sturgeon family Acipenseridae (Emmett et al., 1991; Southern Energy Delta, LLC, 2000). It is an anadromous species that is closely related to the white sturgeon (*A. transmontanus*), though it shows a greater preference for marine waters, spending little time in freshwater. It is not abundant in any Pacific Coast estuary, and therefore life history characteristics are poorly known (Emmett et al., 1991). Along the North America coast it is found from Mexico north to the Bering Sea (Southern Energy Delta, LLC, 2000).

Although not abundant in the bay-delta, in the Columbia River green sturgeon is caught commercially with the white sturgeon, but it is considered inferior eating and therefore less valuable (Emmett et al., 1991). Green sturgeon is also incidentally captured in the white sturgeon recreational fishery.

Females mature at 15 to 20 years of age (Southern Energy Delta, LLC, 2000). Spawning occurs in California in spring and early summer in deep, fast water in the lower reaches of the Sacramento and Klamath Rivers (Emmett et al., 1991; Southern Energy Delta, LLC, 2000). The green sturgeon is a broadcast spawner, with fecundity ranging from 60,000 to 140,000 eggs per female (Emmett et al., 1991). Juveniles are found in freshwater areas of the San Joaquin Delta in summer (Emmett et al., 1991). By age 2, juveniles move to the ocean. Adults move back into estuaries in spring and early summer to feed and spawn. Adults can reach up to 2.1 m (6.9 ft) in length and live up to 60 years (Emmett et al., 1991).

Green sturgeon are found near the Pittsburg and Contra Costa power plants as adults migrating to freshwater rivers to spawn in spring and as juveniles moving to the ocean (Southern Energy Delta, LLC, 2000). Green sturgeon has been identified as a species of concern in this area (Southern Energy Delta, LLC, 2000).

GREEN STURGEON
(Acipenser medirostris)

Family: Acipenseridae (sturgeon).

Common names: none.

Similar species: White sturgeon.

Geographic range: North America from the Aleutian Islands and the Gulf of Alaska to Ensenada, Mexico.[a]

Habitat: Spawn in freshwater rivers, found in estuaries in spring, and in oceans.[b,c]

Lifespan: Live up to 60 years.[c]

Fecundity: Females mature at 15 to 20 years.[b] Females produce 60,000 to 140,000 eggs.[c]

Food sources:
- Juveniles consume amphopods and mysid shrimp.[d]

Prey for:

Life stage information:

Eggs:
- Little known, difficult to differentiate from white sturgeon.[d]

Larvae:
- Little known, difficult to differentiate from white sturgeon.[d]

Juveniles:
- Found in freshwater areas of the San Joaquin Delta in summer.[c]

***Adults*: anadromous**
- Prefer marine environments.[c]

[a] Froese and Pauly, 2001.
[b] Southern Energy Delta, LLC, 2000.
[c] Emmett et al., 1991.
[d] Wang, 1986.
Fish graphic from California Department of Fish and Game, 2002a.

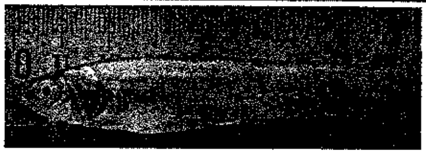
Longfin smelt (*Spirinchus thaleichthys*)

Longfin smelt is a member of the smelt family (Osmeridae) (Moyle, 1976). Longfin smelt is a native planktivore with a reproductive biology that is similar to delta smelt (Moyle, 1976; Wang, 1986; Herbold and Moyle, 1989; Emmett et al., 1991). It is an anadromous species that is abundant in many Pacific Coast estuaries from Monterey Bay, California, as far north as Prince William Sound, Alaska (Emmett et al., 1991). Longfin smelt have been sold seasonally in bay-delta fish markets (Wang, 1986). They also provide food for numerous predatory fishes, birds, and marine mammals (Emmett et al., 1991).

Adult longfin smelt are found in conditions ranging from seawater to freshwater during their upstream spawning migrations (Moyle, 1976; Wang, 1986; Herbold and Moyle, 1989; Emmett et al., 1991). Adults also show vertical migrations within the water column, concentrating in bottom waters during the day and surface waters at night. Spawning occurs in winter and spring in rivers (Kennish, 2000).

In California, longfin smelt are concentrated around San Pablo Bay, but the population also shows distinct seasonal movements (Moyle, 1976). Early summer is spent in San Francisco and San Pablo bays. In August, longfin smelt move into Suisun Bay, and in winter they congregate for spawning in upper Suisun Bay and the lower delta. In April and May, large schools of juveniles move back downstream, and concentrate in the Carquinez Strait, San Pablo Bay, and San Francisco Bay throughout spring and summer.

Most longfin smelt reach maturity at age 2 (Moyle, 1976; Wang, 1986; Herbold and Moyle, 1989; Emmett et al., 1991). Spawning takes place in freshwater at night from December to June, and is known to occur near both the Pittsburg and Contra Costa plants (Wang, 1986). The majority of adults die after spawning, but some females apparently live to spawn a second time (Moyle, 1976). The average female produces 18,000 to 24,000 eggs (Emmett et al., 1991). Eggs are demersal and adhesive and are deposited singly over rocks and submerged vegetation. Larvae are pelagic, and are found in surface waters from the Carquinez Strait to the lower reaches of the Sacramento and San Joaquin rivers. Schools of larvae often also include delta smelt (Wang, 1986), and it can be difficult to distinguish the two species in I&E samples. Juveniles range from 22 to 88 mm (0.9 to 3.5 in) in length, while adults average 100 mm (3.9 in) (Emmett et al., 1991). In the bay-delta estuary, abundance is positively correlated with the amount of freshwater inflow from February to September (Herbold and Moyle, 1989). Longfin smelt has been identified as a species of concern (Southern Energy Delta, LLC, 2000).



LONGFIN SMELT
(Spirinchus thaleichthys)

Family: Osmeridae (smelt).

Common names: Pacific smelt, Sacramento smelt.[a]

Similar species: Delta smelt.

Geographic range: Northern Pacific from Prince William Sound, Alaska to Monterey Bay, California.[a]

Habitat: Close to shore, in bays and estuaries.[a] Prefers rocky, hard or sandy substrates and aquatic vegetation for cover.[b]

Lifespan: Live up to 3 years.[a]

Fecundity: Females mature at 2 years and usually spawn only once, producing 18,000 to 24,000 eggs.[c]

Food sources:
- Diaphanosoma, Diaptomus, Epischura, mysid shrimp, and other small crustaceans.[b]

Prey for:
- Predatory fish, birds, and marine mammals.[b]

Life stage information:

***Eggs:* demersal**
- Eggs are approximately 1.2mm (0.04 in).[b]
- Eggs are deposited singly.[b]

***Larvae:* pelagic**
- Larvae are 6.9 to 8 mm (0.27 to 0.31 in) at hatching.[b]
- Larvae are found mostly on the surface of the water.[b]

Juveniles:
- Range from 22 to 28 mm (0.9 to 3.5 in) in length.[c]
- Juveniles are found in the middle to bottom of the water column.[b]

Adults:
- Adults average 100 mm (3.9 in).[c]

[a] Froese and Pauly, 2001.
[b] Wang, 1986.
[c] Emmett et al., 1991.
Fish graphic from California Department of Fish and Game, 2002b.

Sacramento splittail (*Pogonichthys macrolepidotus*)

Sacramento splittail is a member of the minnow family (Cyprinidae) and a freshwater native of California's Central Valley (Moyle, 1976; Daniels and Moyle, 1983; Wang, 1986). Splittail are bottom foragers that can reach up to 40.6 cm (16 in) in length. Juveniles provide forage for squawfish and striped bass.

Historically, splittail were abundant in the lakes and rivers of the Central Valley, including upstream reaches of the Sacramento and San Joaquin rivers and their tributaries. However, dams and diversions have restricted upstream access, and splittail are now limited in their distribution to freshwater and brackish conditions in the lower reaches of the Sacramento River, the delta, Suisun Marsh, San Pablo Bay, and Napa Marsh. Over the past 15 years, the species has declined by over 60 percent, primarily as a result of increasing water exports and the loss of shallow-water habitat (Meng and Moyle, 1995). Sacramento splittail was listed as threatened under the Federal Endangered Species Act by the USFWS effective March 1999.

Splittail spawn in the delta in spring over flooded vegetation in tidal freshwater and oligohaline areas (Wang, 1986; Kennish, 2000). The spawning season can extend from late January to July, but most spawning occurs from March through May as water levels and temperatures increase. Females mature at 1-2 years and produce up to 250,000 eggs (Daniels and Moyle, 1983). Eggs are demersal and adhesive and therefore unlikely to be entrained, but larvae and small juveniles are vulnerable. The delta and Suisun Bay are important nursery areas (Kennish, 2000). Larvae are known to concentrate near the Pittsburg plant at New York Slough (Wang, 1986). Juveniles are particularly abundant in Suisun Marsh and the Montezuma Slough of Suisun Bay (Meng and Moyle, 1995). Most splittail complete their life cycle in 5 years.

SACRAMENTO SPLITTAIL
(Pogonichthys macrolepidotus)

Family: Cyprinidae (minnow).

Common names: Splittail.[a]

Similar species:

Geographic range: Formerly throughout the Sacramento-San Joaquin River drainage, now restricted to the San Francisco Bay Delta and lower Sacramento River.[a]

Habitat: Backwaters and pools of rivers and lakes.[a]

Lifespan: Live for 5 years.[b]

Fecundity: Females mature at 1-2 years and produce up to 250,000 eggs.[c]

Food sources:
- Bottom foragers.[d]
- Juveniles prey on algae, pelecypods, and amphipods.[e]

Prey for:
- Juveniles are prey for squawfish and striped bass.[d]

Life stage information:

***Eggs:* demersal**
- Eggs are adhesive, and unlikely to be entrained.[f]
- Mature eggs are 1.3 to 1.6 mm (0.05 to 0.06 in).[e]

***Larvae:* planktonic**
- Hatch at less than 6.5 mm (0.26 in).[e]

Juveniles:
- Found in shallow and open water from the delta to San Pablo Bay.[e]

***Adults*:**
- Spawn in the delta in spring over flooded vegetation in tidal freshwater and oligohaline areas.[e,f]
- May reach 40.6 cm (16 in) in length.[d]

[a] Froese and Pauly, 2001.
[b] Meng and Moyle, 1995.
[c] Daniels and Moyle, 1983.
[d] Moyle, 1976.
[e] Wang, 1986.
[f] Kennish, 2000.
Fish graphic from California Department of Fish and Game, 2002b.

Steelhead (*Oncorhynchus mykiss*)

Steelhead is an anadromous form of rainbow trout and is part of the salmon and trout family (Salmonidae) (Moyle, 1976; Herbold and Moyle, 1989; Emmett et al., 1991). It is ecologically similar to chinook salmon.

There are at least two subspecies or races of steelhead in California, defined by when adult fish enter freshwater to spawn (Emmett et al., 1991). The winter run of steelhead that uses the Central Valley migrates upstream during fall, winter, and early spring and spawns from December to June, while the summer run migrates during spring, summer, and early fall and spawn the following spring.

Construction of Shasta Dam blocked access to half of the suitable spawning habitat for steelhead in the Sacramento River drainage, contributing to serious population declines (Herbold and Moyle, 1989). Other causes of decline include dewatered streams resulting from excessive water diversions, rapid flow fluctuations from water conveyance, high water temperatures in summer below reservoirs, and entrainment of juveniles into government water project pumps (McEwan, 1992). In March 1998, the winter run was listed as threatened by the NMFS. Much of the production of steelhead now occurs in hatcheries. Hatchery steelhead have lower survival and reproductive rates than wild steelhead and can reduce the genetic diversity of wild stocks by interbreeding (Emmett et al., 1991).

Steelhead eggs, larvae (alevins), and young juveniles (fry and parr) are riverine life stages that normally remain in freshwater for 1-4 years (Emmett et al., 1991). Alevins range from 14 mm (0.55 in.) at hatching to about 28 mm (1.1 in.). Eggs and alevins are benthic and infaunal. Fry and parr are found in areas with cover and move to deeper water as they grown. Parr transform into smolts as they move through rivers and estuaries on their migration to the ocean, where they remain for 1-5 years before returning to their natal river as adults to spawn. The average female produces 1,500 to 5,000 eggs (Emmett et al., 1991).

Juveniles are found in all habitats of the delta, but it is unknown how long the delta is used as a nursery area (Herbold and Moyle, 1989). Food sources in freshwater and estuarine areas include gammarid amphipods, crustaceans, and small fish (Moyle, 1976). Juveniles range from 28 mm (1.1 in.) to 400 mm (15.7 in.) (Emmett et al., 1991).

STEELHEAD
(Oncorhynchus mykiss)

Family: Salmonidae (salmon and trout).

Common names: Coast range trout, hardhead, rainbow trout, salmon trout.[a]

Similar species: Chinook salmon.

Geographic range: Eastern Pacific from Alaska to Baja California, Mexico.[a]

Habitat:

Lifespan: Adults may reach 11 years.[a]

Fecundity: Females produce from 1,500 to 5,000 eggs.[b]

Food sources:
- Gammarid amphipods, crustaceans, small fish.[c]

Prey for:

Life stage information:

***Eggs:* benthic**
- Spawned in riverine fresh water.

***Larvae:* benthic**
- Larvae range from 14 to 28 mm (0.55 to 1.1 in).[b]

Juveniles:
- Juveniles range from 28 to 400 mm (1.1 to 15.7 in).[b]
- Found in all habitats of the delta.[d]

***Adults*: Anadromous**
- Two subspecies or races of steelhead are defined by the timing of spawning (winter run & summer run).[b]
- May grow as large as 120 cm (47 in).[a]

[a] Froese and Pauly, 2001.
[b] Emmett et al., 1991.
[c] Moyle, 1976.
[d] Herbold and Moyle, 1989.
Fish graphic from Mason, 2002.

Striped bass (*Morone saxatilis*)

Striped bass was intentionally introduced to the Sacramento-San Joaquin River system during the 1870's (Moyle, 1976; Emmett et al., 1991; Stevens, 1992). Unlike some East Coast populations that make extensive coastal migrations, Sacramento-San Joaquin River populations appear to spend most of their lives in bays and estuaries. Adults move into bays (some into the delta) in the fall, overwinter in the bay and delta, and then after spawning in spring, move back to the ocean (Moyle, 1976).

Commercial fishing for striped bass in the San Francisco Bay system has been prohibited since 1935 because of demands by sport anglers (Stevens, 1992). The San Francisco striped bass recreational fishery is one of the most important recreational fisheries on the Pacific Coast. In 1985, it was valued at over $45 million annually (Stevens, 1992). However, the Sacramento-San Joaquin population has declined since the early 1960's. Poor recruitment of young striped bass is thought to be the primary reason for the decline in the adult stock (Stevens, 1992).

Striped bass spawn in schools at night (Stevens, 1992). Spawning occurs in freshwater, beginning in April in California and peaking in May and early June. Females mature at age 5, producing an average of 250,000 eggs per year. Striped bass can live up to 20 years, and exceed 22.7 kg (50 lb) in weight, thus showing high reproductive potential.

Larval striped bass feed on opossum shrimp in the delta and Suisun Bay, reaching about 3.8 cm (1.5 in) in length by late summer (Stevens, 1992). Large numbers of eggs and larvae are killed by the intakes of the Pittsburg and Contra Costa plants and government water projects, contributing to poor recruitment (Stevens, 1992; Southern Energy Delta, LLC, 2000). A number of restoration and management actions are in place to improve recruitment. However, striped bass are voracious predators on small fish, including several delta T&E species or species of concern such as delta smelt, longfin smelt, and Sacramento splittail, complicating management efforts.

STRIPED BASS
(Morone saxatilis)

Family: Moronidae (temperate basses).

Common names: Striper, rockfish, linesider, and sea bass.[a]

Similar species: White perch.

Geographic range: St. Lawrence River in Canada to the St. Johns River in Florida, and from the Suwannee River in western Florida to Lake Pontchartrain, Louisiana.[b] Intentionally introduced to Sacramento-San Joaquin River system.[c]

Habitat: Sacramento-San Joaquin River populations spend most of their lives in bays and estuaries.[c] Juveniles prefer shallow rocky to sandy areas. Adults in inshore areas use a variety of substrates, including rock, boulder, gravel, sand, detritus, grass, moss, and mussel beds.[b]

Lifespan: Adults may reach 30 years.[d]

Fecundity: Females mature at age 5 and produce an average of 250,000 eggs per year.[e]

Food sources:
- Larvae feed primarily on mobile planktonic invertebrates (beetle larvae, copepodids *Daphnia* spp.).[b]
- Juveniles eat larger aquatic invertebrates and small fishes.[b]
- Adults are piscivorous. Clupeid fish are the dominant prey and adults prefer soft-rayed fishes.[b]

Prey for: Any sympatric piscivorous fish.[b]

Life stage information:

Eggs: pelagic
- Eggs and newly hatched larvae require sufficient turbulence to remain suspended in the water column; otherwise, they can settle to the bottom and be smothered.[f]

Larvae: pelagic
- Larvae range from 5 to 30 mm (0.2 to 1.2 in).[b]

Juveniles:
- Most striped bass enter the juvenile stage at 30 mm (1.2 in) total length.[f]
- Juveniles school in larger groups after 2 years of age.[f]

***Adults*: Anadromous**
- Adults move into bays in the fall, overwinter in the bay and delta, and after spawning in the spring, return to the ocean.[c]
- May grow as large as 200 cm (79 in).[a]

[a] Froese and Pauly, 2001.
[b] Hill et al., 1989.
[c] Moyle, 1976.
[d] Atlantic States Marine Fisheries Commission, 2000d.
[e] Stevens, 1992.
[f] Bigelow and Schroeder, 1953.
Fish graphic from California Department of Fish and Game, 2002a.

B2-4 I&E Data Evaluated

Table B2-3 lists California facilities in scope of the Phase II rule and the facility I&E data evaluated by EPA. See Chapter A5 of Part A for a discussion of extrapolation methods.

Table B2-3: California Facilities In Scope of the Section 316(b) Phase II Rule and Facility I&E Data Evaluated

In Scope Facilities	I&E Data?	Years of Data
Contra Costa	Yes	1978, 1986-1992
Diablo Canyon Nuclear	Yes	1985, 1987-1988
El Segundo	Yes	1990-2001
Encina	Yes	1979
Harbor	Yes	1979
Haynes	Yes	1979, 2001
Humboldt Bay	Yes	1980
Hunter's Point	Yes	1978
Huntington Beach	Yes	1979-2001
Long Beach	No - extrapolated	
Mandalay	Yes	2001
Morro Bay	Yes	2000
Moss Landing	Yes	1979, 1999
Ormond Beach	Yes	1979, 1990-2001
Pittsburg	Yes	1978, 1986-1992
Potrero	Yes	1978, 2001
AES Redondo Beach	Yes	1979, 1991-2001
San Onofre Nuclear	Yes	1979, 1990-2001
Scattergood	Yes	1990-2002
South Bay	No - extrapolated	

B2-5 EPA's Estimate of Current I&E in California Expressed as Age 1 Equivalents, Foregone Yield, and Production Foregone

Table B2-4 provides EPA's estimate of the annual age 1 equivalents, foregone fishery yield, and production foregone resulting from the impingement of aquatic species at facilities located in California. Table B2-5 displays this information for entrainment.

Table B2-4: Current Annual Impingement in California Expressed as Age 1 Equivalents, Foregone Fishery Yield, and Production Foregone

Species Group	Age 1 Equivalents (#s)	Yield (lbs)	Production Foregone
American shad	14	3	8
Anchovies	2,397,761	3,756	10,009
Blennies	3,370	0	2
Cabezon	672	1,131	372
California halibut	4,633	17,439	2,173
California scorpionfish	1,964	1,334	264
Chinook salmon	63	0	198
Commercial crabs	102,662	20	1,058
Commercial sea basses	7	2	0
Commercial shrimp	49,058	1	3
Delta smelt	638	0	1
Drums and croakers	366,466	21,226	6,936
Dungeness crab	6,084	2,807	763
Flounders	69,439	5,690	5,188
Forage shrimp	1,747	0	0
Gobies	19,141	0	8
Herrings	371,810	0	15,335
Longfin smelt	6,774	0	28
Other (commercial)	922	179	118
Other (forage)	325,787	0	35
Other (commercial & recreational)	23,877	4,642	3,063
Other (recreational)	16,989	3,303	2,179
Recreational sea basses	8,351	2,058	194
Rockfishes	102,570	24,711	7,693
Sacramento splittail	911	0	93
Salmon	2	7	5
Sculpins	88,869	2,711	2,121
Silversides	635,963	0	27,502
Smelts	36,502	830	991
Steelhead	1	0	3
Striped bass	44,501	37,516	10,613
Surfperches	782,637	48,722	41,470

Table B2-5: Current Annual Entrainment in California Expressed as Age 1 Equivalents, Foregone Fishery Yield, and Production Foregone

Species Group	Age 1 Equivalents (#s)	Total Yield (lbs)	Production Foregone (lbs)
American shad	1	0	630
Anchovies	282,880	443	185,331
Blennies	80,359,464	0	395,364
Cabezon	500,110	842,357	743,502
California halibut	583,490	2,196,315	1,506
Chinook salmon	3	0	27
Commercial crabs	66,096,905	12,990	28,217,407
Commercial shrimp	5,305,810	138	13,165
Delta smelt	115	0	0
Drums and croakers	3,195,329	185,072	1,904,184
Dungeness crab	71,633	33,051	152,571
Flounders	147,615	12,096	170,697
Forage shrimp	16,808,030	0	25,841
Gobies	16,240,573	0	156,209
Herrings	2,728,452	0	350,759
Longfin smelt	51	0	1
Other (commercial)	44,341	8,621	101,838
Other (forage)	53,084,096	0	303,543
Other (recreational)	5,994	1,165	13,765
Recreational sea basses	4,548,657	1,121,173	129,024
Rockfishes	53,654,899	12,926,604	8,380,148
Sacramento splittail	1	0	1
Sculpins	3,684,908	112,404	424,884
Silversides	17,569	0	2,724
Smelts	1,695	39	2,198
Striped bass	102,238	86,189	1,810,779

B2-6 ASSUMPTIONS USED IN CALCULATING RECREATIONAL AND COMMERCIAL LOSSES

The lost yield estimates presented in Tables B2-4 and B2-5 are expressed as total pounds and include losses to both commercial and recreational catch. To estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table B2-6 presents the percentage impacts assumed for each species, as well as the value per pound for commercially harvested species.

Age-1 equivalent fish that are spared from I&E are not necessarily old enough or large enough to be attractive to anglers. It may take one more year for these fish to reach a harvestable age. For this reason, EPA discounts commercial and recreational benefits so that the cost and benefits estimates will be comparable. Tables B2-7 and B2-8 present the multiplicative discounting factors used in discounting benefits assuming a 3 percent real discount rate and a 7 percent real discount rate. For details on how these factors are developed, see Chapter A14.

Table B2-6: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries and Commercial Value per Pound for Species Impinged and Entrained at California Facilities

Species Group	Percent Impact to Recreational Fishery[a,b]	Percent Impact to Commercial Fishery[a,b]	Commercial Value per Pound (2002$)[c]
American shad	0.0%	100.0%	$1.36
Anchovies	0.0%	100.0%	$0.06
Cabezon	45.9%	54.1%	$3.70
California halibut	85.6%	14.4%	$2.66
California scorpionfish	83.7%	16.3%	$1.83
Commercial sea basses	0.0%	100.0%	$1.63
Commercial shrimp	0.0%	100.0%	$0.99
Drums and croakers	69.1%	30.9%	$1.01
Dungeness crab	0.0%	100.0%	$1.68
Flounders	1.0%	99.0%	$0.39
Other (commercial)	0.0%	100.0%	$0.05
Other (recreational)	100.0%	0.0%	na
Other (commercial & recreational)	54.0%	46.0%	$0.25
Northern anchovy	0.0%	100.0%	$0.06
Other commercial crabs	0.0%	100.0%	$1.16
Recreational sea basses	100.0%	0.0%	na
Rockfishes	23.6%	76.4%	$0.52
Salmon	100.0%	0.0%	na
Sculpins	85.0%	15.0%	$2.55
Smelts	6.2%	93.8%	$0.27
Striped bass	100.0%	0.0%	na
Surfperches	93.0%	7.0%	$1.60
Other (forage)[d]	50.0%	50.0%	$0.27

[a] Based on landings from 1993 to 2001.
[b] Calculated using recreational landings data from NMFS (2003c, http://www.st.nmfs.gov/recreational/queries/catch/snapshot.html) and commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).
[c] Calculated using commercial landings data from NMFS (2003a).
[d] Assumed equally likely to be caught by recreational or commercial fishermen. Commercial value calculated as overall average for region based on data from NMFS (2003a).

Species Group	Discount Factors for Entrainment		Discount Factors for Impingement	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Cabezon	0.865	0.723	0.891	0.774
California halibut	0.781	0.573	0.805	0.613
California scorpionfish	na	na	0.877	0.749
Drums and croakers	0.860	0.711	0.886	0.761
Flounders	0.945	0.878	0.973	0.940
Other recreational species	0.922	0.831	0.950	0.889
Other rec. and com. species	na	na	0.950	0.889
Recreational sea basses	0.817	0.632	0.842	0.677
Rockfishes	0.787	0.585	0.811	0.626
Sculpins	0.953	0.896	0.982	0.959
Smelts	0.954	0.899	0.983	0.962
Striped bass	0.864	0.717	0.879	0.749
Surfperches	na	na	0.935	0.859
Other unidentified fish (from forage losses)	0.919	0.829	0.919	0.829

Table B2-7: Factors Applied to Recreational Benefits to Implement Discounting in California

Table B2-8: Factors Applied to Commercial Benefits to Implement Discounting in California

Species Group	Discount Factors for Entrainment		Discount Factors for Impingement	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
American shad	na	na	0.893	0.773
Anchovies	0.933	0.856	0.961	0.916
Cabezon	0.832	0.663	0.857	0.710
California halibut	0.755	0.532	0.778	0.569
California scorpionfish	na	na	0.818	0.643
Commercial sea basses	na	na	0.819	0.637
Commercial shrimp	0.969	0.932	0.999	0.997
Drums and croakers	0.842	0.680	0.868	0.727
Dungeness crab	0.916	0.819	0.944	0.877
Flounders	0.930	0.847	0.958	0.907
Other commercial species	0.913	0.813	0.940	0.870
Other rec. and com. species	na	na	0.940	0.870
Northern anchovy	0.938	0.865	na	na
Other commercial crabs	0.882	0.750	0.908	0.803
Rockfishes	0.764	0.547	0.787	0.586
Sculpins	0.943	0.875	0.971	0.936
Smelts	0.922	0.832	0.950	0.890
Surfperches	na	na	0.926	0.840
Other unidentified fish (from forage losses)	0.900	0.792	0.900	0.792

Chapter B3: Commercial Fishing Valuation

INTRODUCTION

This chapter presents the results of the commercial fishing benefits analysis for the California region. Section B3-1 details the estimated losses under current, or baseline, conditions. Section B3-2 presents the expected benefits in the region attributable to the rule. Chapter A10 details the methods used in this analysis. All results are for Northern California and Southern California combined.

Note that all results have been sample weighted in this version. In the final revision results will be reported unweighted.

B3-1 BASELINE LOSSES

Table B3-1 provides EPA's estimate of the value of gross revenues lost in commercial fisheries resulting from the impingement of aquatic species at facilities in the California region. Table B3-2 displays this information for entrainment. Total annual revenue losses are approximately $6.1 million, assuming a 3 percent discount rate.

Table B3-1: Annual Commercial Fishing Gross Revenues Lost Due to Impingement at Facilities in the California Region

Species	Estimated Pounds of Harvest Lost	Estimated Value of Harvest Lost (in 2002 dollars)		
		Undiscounted	Discounted Using 3% Discount Rate	Discounted Using 7% Discount Rate
Anchovies	3,756	223	214	204
Cabezon	612	2,265	1,941	1,607
California halibut	2,515	6,700	5,213	3,814
Flounders	5,631	2,173	2,082	1,971
Rockfishes	18,877	9,882	7,778	5,787
Sculpins	406	1,037	1,007	971
Smelts	778	209	198	186
Surfperches	3,412	5,475	5,071	4,602
American shad	3	5	4	4
Crabs (commercial)	20	23	21	19
Drums and croakers	6,553	6,621	5,745	4,815
Dungeness crab	2,807	4,711	4,446	4,129
Other (commercial)	179	9	9	8
Shrimp (commercial)	1	1	1	1
California scorpionfish	217	397	325	256
Other (rec. and com.)	2,136	541	509	471
Sea basses (commercial)	2	3	2	2
Other unidentified species (from forage losses)	4,342	1,177	1,059	932
TOTAL	52,248	41,453	35,627	29,778

Table B3-2: Annual Commercial Fishing Gross Revenues Lost Due to Entrainment at Facilities in the California Region

Species	Estimated Pounds of Harvest Lost	Estimated Value of Harvest Lost (in 2002 dollars)		
		Undiscounted	Discounted Using 3% Discount Rate	Discounted Using 7% Discount Rate
Anchovies	442	26	24	22
Cabezon	456,096	1,686,720	1,403,524	1,118,679
California halibut	316,710	843,802	637,356	448,884
Flounders	11,970	4,620	4,297	3,915
Rockfishes	9,874,518	5,169,293	3,950,073	2,829,210
Sculpins	16,828	42,994	40,552	37,627
Smelts	36	10	9	8
Crabs (commercial)	12,990	15,009	13,235	11,257
Drums and croakers	57,141	57,733	48,636	39,239
Dungeness crab	33,051	55,465	50,821	45,439
Other (commercial)	8,621	436	399	355
Northern anchovy	128	7	7	6
Shrimp (commercial)	138	137	133	128
Other unidentified species (from forage losses)	614,088	166,453	149,827	131,852
TOTAL	11,402,757	8,042,706	6,298,892	4,666,621

B3-2 BENEFITS

As described in Chapter A10, EPA estimates that 0 to 40 percent of the gross revenue losses represent surplus losses to producers, assuming no change in prices or fishing costs. The 0 percent estimate, of course, results in loss estimates of $0. The 40 percent estimates, as presented in the Table B3-3, total approximately $2.5 million when a 3 percent discount rate is assumed.

The expected reductions in I&E attributable to changes at facilities required by the rule are 30.9 percent for impingement and 21.0 percent for entrainment. Total annual benefits are estimated by applying these estimated reductions to the annual producer surplus loss. As presented in Table B3-3, this results in total annual benefits of $0.5 million, assuming a 3 percent discount rate.

Table B3-3: Annual Commercial Fishing Benefits Attributable to Phase II Rule at Facilities in the California Region (million 2002$), Assumes Compliance in 2005

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$0.04	$8.04	$8.08
3% discount rate	$0.03	$6.11	$6.14
7% discount rate	$0.03	$4.34	$4.37
Producer Surplus Lost - Low	**$0.0**	**$0.0**	**$0.0**
Producer Surplus Lost - High (gross revenue * 0.4)			
Undiscounted	$0.02	$3.22	$3.23
3% discount rate	$0.01	$2.44	$2.46
7% discount rate	$0.01	$1.74	$1.75
Expected reduction due to rule[a]	30.9%	21.0%	---
Benefits attributable to rule - Low	**$0.0**	**$0.0**	**$0.0**
Benefits attributable to rule - High			
Undiscounted	$0.01	$0.68	$0.68
3% discount rate	$0.00	$0.51	$0.52
7% discount rate	$0.00	$0.37	$0.37

[a] Estimated based on EPA's assumptions. EPA's assumption about the amount of electricity that will be produced in the future differs very slightly from DOE's. Using DOE's assumptions, the expected reductions would be 31.4 percent for impingement and 22.9 percent for entrainment.

Chapter B4: RUM Analysis

Introduction

This case study uses a random utility model (RUM) approach to estimate the benefits of improved fishing opportunities due to reduced impingement and entrainment (I&E) in the Northern and Southern California regions. The Northern and Southern California regions are defined based on National Marine Fisheries Service (NMFS) regional boundaries. Northern California includes all northern counties to, and including, San Luis Obispo County. Southern California includes all southern counties to, and including, Santa Barbara County.

EPA included anglers intercepted at sites in both the Northern California region and the Southern California region in the RUM model. Thus, the model allows for substitution of sites across the two regions. When constructing each angler's choice set, EPA included all sites within 140 miles of the angler's home zip code. Thus, sites from the Southern California region were included for some Northern California anglers, and vice versa, to allow anglers to travel to all substitute sites located within a one day travel distance limit.

Chapter Contents

Cooling Water Intake Structures (CWIS) withdrawing water from California coastal waters and estuaries impinge and entrain many of the species sought by recreational anglers. These species include halibut, other flatfish, striped bass, sea basses, various bottom fish species, and other less prominent species. Accordingly, EPA included the following species and species groups in the model: flatfish, striped bass, sea basses, bottom fish, small game fish, salmon, sturgeon, other small fish, and other species. Some of these species inhabit a wide range of coastal waters, which can span the entire coast of California.

The study's main assumption is that, all else being equal, anglers will get greater satisfaction, and thus greater economic value, from sites with a higher catch rate. This benefit may occur in two ways: first, an angler may get greater enjoyment from a given fishing trip with higher catch rates, yielding a greater value per trip; second, anglers may take more fishing trips when catch rates are higher, resulting in greater overall value for fishing in the region.

The following sections focus on the data set used in the analysis and the analytic results. Chapter A-11 provides a detailed description of the RUM methodology used in this analysis.

B4-1 Data Summary

EPA's analysis of improvements in recreational fishing opportunities in California relies on data collected by the NMFS' Marine Recreational Fishery Statistics Survey (MRFSS) (NMFS, 2003b).[1] The model of recreational fishing behavior relies on a subset of the data that includes only single-day trips to sites located in California. In addition, the sample excludes respondents missing data on key variables (e.g., home town), and includes only private/rental boat and shore mode anglers. The Agency did not include charter boat anglers in the model. As explained below, the welfare gain to charter boat anglers from improved catch rates is approximated based on the regression coefficients developed for the boat anglers. Additionally,

[1] For general discussion of the MRFSS, see Chapter A11 of the Regional Study Report or Marine Recreational Fisheries Statistics: Data User's Manual, http://www.st.nmfs.gov/st1/recreational/pubs/data_users/index.html (NMFS, 1999a).

values for single-day trips were used to value each day of a multi-day trip. The final sample used to estimate the RUM model includes 11,367 boat and shore anglers.

B4-1.1 Summary of Anglers' Characteristics

a. Fishing modes and targeted species

Fifty-one percent of the anglers in the sample fish from either a private or a rental boat (see Table B4-1). Approximately 24 percent fish from the shore, and 24 percent fish from a party or charter boat. In Northern California, most anglers (61 percent) fish from a private or rental boat; 28 percent fish from shore, and only 11 percent fish from party or charter boats. In Southern California, 44 percent fish from private or rental boats, 34 percent fish from party or charter boats, and 22 percent fish from shore.

Table B4-1: Fishing Mode Choice, Northern and Southern California

Fishing Mode	All California		Northern California		Southern California	
	Frequency	Percent	Frequency	Percent by Mode	Frequency	Percent by Mode
Shore	4,007	24.48%	1,892	27.79%	2,115	22.12%
Private/Rental Boat	8,383	51.21%	4,158	61.07%	4,225	44.19%
Party/Charter Boat	3,979	24.31%	759	11.15%	3,220	33.68%
All Modes	16,369	100.00%	6,809	100.00%	9,560	100.00%

Source: NMFS, 2003b.

In addition to the mode of fishing, the MRFSS contains information on the specific species targeted on the current trip (see Tables B4-2 and B4-3). In Northern California, approximately 26 percent of anglers did not have a designated target species. The most popular targeted species, targeted by 25 percent of anglers, is salmon. The second most popular species group, targeted by 20 percent of anglers, is bottom fish. Of the remaining anglers, 9 percent target striped bass, 9 percent target flatfish (primarily California halibut), 6 percent target sturgeon, 2 percent target other species, 2 percent target small game fish, one percent target big game fish, and 0.5 percent target other small fish.[2]

In Southern California, 45 percent of anglers do not target a particular species. The most popular targeted species, targeted by 13 percent of anglers, is jacks. The second most popular species group, targeted by 12 percent of anglers, is flatfish (mostly California halibut). Of the remaining anglers, 10 percent target sea basses, 9 percent target bottom fish, 5 percent target small game, 4 percent target big game fish, and less than one percent target each of the following species/species groups: other species, salmon, other small fish, and striped bass.[3]

The distribution of target species is not uniform by fishing mode. In Northern California, for example, 34 percent of private/rental boat anglers and 28 percent of charter anglers target salmon, while less than 2 percent of shore anglers target salmon. Forty-six percent of shore anglers do not target a particular species, while only 20 percent of private/rental boat anglers and 13 percent of charter boat anglers do not target a particular species. Almost 58 percent of charter boat anglers target bottom fish species, while only 12 percent of private/rental boat anglers and 22 percent of shore anglers target bottom fish. Fourteen percent of private/rental boat anglers target flatfish (primarily halibut), while no charter anglers and less than two percent of shore anglers target flatfish. Twenty-two percent of shore anglers target striped bass, while only 6 percent of private/rental boat anglers and no charter boat anglers target striped bass.

[2] Bottom fish species include surfperches, seaperches, sheephead, croakers, rockfishes, scorpionfish, drums, hake, tomcod, opaleye, sargo, mullet, and queenfish. Small game fish include Pacific bonito, Pacific barracuda, and small tunas and mackerels. Flatfish include California halibut, sanddabs, starry flounder, and other flounders. Big game fish include sharks, dolphins, and tunas. Other small fish include the anchovy family, silverside family, pacific sardine, herrings, jacksmelt, and other smelts.

[3] Jacks include jack mackerel and yellowtail. Sea basses include kelp bass and sandbasses.

Table B4-2: Species Group Choice by Mode of Fishing, Northern California								
Species Group	All Modes		Private/Rental Boat		Party/Charter Boat		Shore	
	Frequency	Percent	Frequency	Percent by Mode	Frequency	Percent by Mode	Frequency	Percent by Mode
Small Game	114	1.67%	102	2.45%	10	1.32%	2	0.11%
Striped Bass	641	9.41%	229	5.51%	0	0.00%	412	21.78%
Bottom Fish	1337	19.64%	490	11.78%	440	57.97%	407	21.51%
Flatfish	602	8.84%	566	13.61%	0	0.00%	36	1.90%
Big Game	95	1.40%	82	1.97%	0	0.00%	13	0.69%
Salmon	1669	24.51%	1,433	34.46%	209	27.54%	27	1.43%
Sturgeon	395	5.80%	371	8.92%	0	0.00%	24	1.27%
Other Species	130	1.91%	68	1.64%	0	0.00%	62	3.28%
Other Small Fish	34	0.50%	1	0.02%	0	0.00%	33	1.74%
No Target	1792	26.32%	816	19.62%	100	13.18%	876	46.30%
All Species	6,809	100.00%	4,158	100.00%	759	100.00%	1,892	100.00%

Source: NMFS, 2003b.

Table B4-3: Species Group Choice by Mode of Fishing, Southern California								
Species Group	All Modes		Private/Rental Boat		Party/Charter Boat		Shore	
	Frequency	Percent	Frequency	Percent by Mode	Frequency	Percent by Mode	Frequency	Percent by Mode
Small Game	509	5.32%	251	5.94%	134	4.16%	124	5.86%
Other Small Fish	16	0.17%	0	0.00%	0	0.00%	16	0.76%
Striped Bass	1	0.01%	1	0.02%	0	0.00%	0	0.00%
Jacks	1,283	13.42%	748	17.70%	535	16.61%	0	0.00%
Sea Basses	964	10.08%	662	15.67%	204	6.34%	98	4.63%
Bottom Fish	852	8.91%	340	8.05%	369	11.46%	143	6.76%
Flatfish	1,153	12.06%	775	18.34%	176	5.47%	202	9.55%
Big Game	423	4.42%	247	5.85%	135	4.19%	41	1.94%
Salmon	24	0.25%	24	0.57%	0	0.00%	0	0.00%
Other	73	0.76%	21	0.50%	34	1.06%	18	0.85%
No Target	4,262	44.58%	1,156	27.36%	1,633	50.71%	1,473	69.65%
All Species	9,560	100.00%	4,225	100.00%	3220	100.00%	2,115	100.00%

Source: NMFS, 2003b.

In Southern California, no shore anglers target jacks, while 18 percent of private/rental boat anglers and 17 percent of charter anglers target jacks. Sixteen percent of private/rental boat anglers target sea basses, while only 6 percent of charter anglers and 5 percent of shore anglers target sea basses. Eighteen percent of private/rental boat anglers target flatfish, while 10 percent of shore anglers and 5 percent of charter anglers target flatfish. Seventy percent of shore anglers do not target a particular species, and 51 percent of charter anglers and 27 percent of boat anglers do not target a particular species.

b. Anglers' characteristics

This section presents a summary of angler characteristics for California, using the data included in the RUM model, i.e., only data for private/rental boat anglers and shore anglers. This data set includes 11,367 observations: 7,809 boat anglers and 3,558 shore anglers. Table B4-4 summarizes information on fishing trips and anglers.

The average income of the respondent anglers was $52,021. Because income was not reported by intercept survey respondents, EPA used median household income data by zip code, from the U.S. Census Bureau in 2000, to approximate income data for survey respondents.[4] Ninety-two percent of the anglers are male. The average angler spent 27 days fishing during the past year. The average trip cost for surveyed trips is $16 (2000$),[5] and the average one way travel time to the site was about 40 minutes.[6] The average duration of a fishing trip was four and a half hours. The California data did not include additional demographic statistics.

[4] Census data for median income by zip code are in census Summary File 3 (U.S. Census Bureau, 2002).

[5] All costs are in 2000$, which represent the MRFSS survey year. All costs/benefits will be updated to 2002$ later in this analysis (e.g., for welfare estimation).

[6] Calculation of trip cost and travel time is explained in section B4-1.4.

Table B4-4: Data Summary for California Anglers

Variable	All Modes			Private/Rental Boat			Shore		
	N	Mean[a]	Std Dev	N	Mean[a]	Std Dev	N	Mean[a]	Std Dev
Travel Cost (2002$)	11,367	15.66	16.14	7,809	17.25	16.78	3,558	12.17	14.01
One Way Travel Time (hours)	11,367	0.60	0.62	7,809	0.66	0.65	3,558	0.47	0.54
Male	16,300	0.92	0.27	8,336	0.94	0.24	3,987	0.89	0.31
Annual Trips	16,117	27.13	41.34	8,261	26.36	33.67	3,918	36.80	57.24
Income	11,367	$52.021	$17.115	7,809	$53,353	$17,011	3,558	$49,096	$16,982
Average Trip Length (hours)	16,343	4.38	2.10	8,367	5.09	1.98	3,999	3.27	1.74

[a] For dummy variables such as "Male" that take the value of 0 or 1, the reported value represents a portion of the survey respondents possessing the relevant characteristic. For example, 92 percent of the surveyed anglers are males.

Sources: NMFS, 2003b; and U.S. Census Bureau, 2002.

B4-1.2 Recreational Fishing Choice Sets

The NMFS survey intercept sites included in the analysis are depicted in Figure B1-1 in Chapter B1 of this report. There are 126 fishing sites in the Northern California region total choice set, and 122 sites in the Southern California region choice set. Choice sets for individual anglers were generated based on NMFS sites located within 140 miles of the respondent's home zip code.[7] Distances from unique zip codes to each of the 248 NMFS sites located in California were estimated using ArcView 3.2a software. A maximum of 37 sites defines the choice set, inclusive of the site actually visited at the time of the survey. In cases where more than 37 additional sites per mode are within the 140 mile distance limit, 37 sites are randomly drawn from the available sites. Table B4-5 summarizes the number of sites available, and anglers intercepted, for each county in California.

Table B4-5: Number of California Sites and Anglers by County

County	Number of Sites	Number of Intercepted Anglers[a]
Northern CA		
Alameda	12	650
Contra Costa	5	409
Del Norte	6	119
Humboldt	11	379
Marin	11	388
Mendocino	10	233
Monterey	12	409
San Francisco	12	326
San Luis Obispo	10	239
San Mateo	15	602
Santa Clara	1	0
Santa Cruz	10	745
Solano	2	530
Sonoma	9	256
Total Northern CA	126	5,285
Southern CA		
Los Angeles	32	1,968
Orange	17	863
San Diego	35	2,595
Santa Barbara	18	166
Ventura	20	486
Total Southern CA	122	6,078

[a] Includes intercepted private/rental boat and shore mode anglers only. Charter boat anglers are not included as no specific charter boat model of site choice was estimated.

Source: NMFS, 2003b.

[7] The distance limit was based on the 99th percentile for the distance traveled to a fishing site.

B4-1.3 Site Attributes

This analysis assumes that the angler chooses between site alternatives by comparing his/her utility for each alternative and choosing the one that maximizes his/her utility. Following McConnell and Strand (1994), we assume that the individual first chooses a mode and species and then, conditional on this choice, chooses the recreational site (Hicks et al., 1999).

To measure site quality, this analysis uses catch rates for the fish species of concern, as well as the presence of marinas and/or docks at each site, and the presence of piers or jetties at each site. Catch rate is the most important attribute of a fishing site from the angler's perspective (McConnell and Strand, 1994; Haab et al., 2000). This attribute is also a policy variable of concern because catch rate is a function of fish abundance, which is affected by fish mortality due to I&E. The catch rate variable in the RUM therefore provides the means to measure baseline losses in I&E and changes in anglers' welfare attributed to changes in I&E resulting from the final section 316(b) rule.

To specify the fishing quality of the case study sites, EPA calculated historic catch rate based on the NMFS catch rates from 1996 to 2000. Seven species or species groups were included in the model: sturgeon, salmon, flatfish, small game fish, big game fish, bottom fish, and other species. No-target anglers in California caught fish in all species groups included in the model. Thus, for no-target anglers, EPA calculated average catch for all species caught by anglers who did not target a specific species.

The catch rates represent the number of fish caught on a fishing trip divided by the number of hours spent fishing (i.e., the number of fish caught per hour per angler). The estimated catch rates are averages across all anglers by mode, target species, and site over the five-year period (1996-2000).

The catch rate variables include total catch, including fish caught and kept and fish released. Some NMFS studies use the catch-and-keep measure as the relevant catch rate. Although a greater error may be associated with the measured number of fish not kept, the total catch measure is most appropriate because a large number of anglers catch and release fish. The total catch rate variables include both targeted fish catch and incidental catch. For example, small game catch rates include fish caught by small game anglers, anglers targeting another species group but who actually caught a small game fish, and anglers who don't target any particular species. Anglers who target particular species generally catch more fish in the targeted category than anglers who do not target these species because of specialized equipment and skills. EPA considered using targeted species catch rates for this analysis, but discovered that this approach did not provide a sufficient number of observations to allow estimation of catch rates for all fishing sites included in the analysis. Tables B4-6 and B4-7 summarize average catch rates by species for Northern and Southern California sites.

- <u>Northern California sites</u>. Of the boat mode anglers who target particular species, bottom fish anglers catch the largest number of fish per hour (1.15), followed by anglers who target other small fish (0.71), those who target small game (0.62), those who target other species (0.56), those who target big game (0.45), those who target flatfish (0.40), those who target striped bass (0.36), those who target salmon (0.34), and those who target sturgeon (0.21). Of the shore mode anglers who target particular species, anglers who target other small fish catch the largest number of fish per hour (1.88), followed by anglers who target bottom fish (1.01), those who target small game (0.78), those who target flatfish (0.63), those who target other species (0.53), those who target sturgeon (0.52), those who target striped bass (0.47), and those who target salmon (0.28).

- <u>Southern California sites</u>. Of the boat mode anglers who target particular species, small game anglers catch the largest number of fish per hour (0.84), followed by anglers who target sea basses (0.76), those who target bottom fish (0.65), those who target other small fish (0.58), those who target salmon (0.52), those who target flatfish (0.45), those who target other species (0.44), those who target jacks (0.42), those who target big game (0.41), and those who target striped bass (0.20). Of the shore anglers who target particular species, anglers who target other small fish catch the largest number of fish per hour (1.50), followed by anglers who target small game (1.11), those who target bottom fish (1.05), those who target sea basses (0.65), those who target flatfish (0.55), and those who target other species (0.48).

Some RUM studies use predicted, rather than actual, catch rates (Haab et al., 2000; Hicks et al., 1999; McConnell and Strand, 1994). This practice allows for individual characteristics to affect catch rates; for example, anglers with different levels of experience may have different catch rates. Haab et al. (2000) compared historic catch-and-keep rates to predicted catch-and-keep rates and found that historic catch-and-keep rates were a better measure of site quality. Hicks et al. (1999) found that using historic catch rates resulted in more conservative welfare estimates than predicted catch rate models. Consequently, EPA favored this more conservative approach.

Table B4-6: Average Catch Rate by Species/Species Group for Northern California Sites by Mode of Fishing

Species/Species Group	Average Catch Rate (fish per angler per hour)			
	All Sites		Sites with Non Zero Catch Rates	
	Private/Rental Boat	Shore	Private/Rental Boat	Shore
Small Game	0.078	0.080	0.615	0.776
Striped Bass	0.060	0.160	0.360	0.469
Bottom Fish	0.420	0.697	1.152	1.009
Flatfish	0.116	0.140	0.404	0.628
Big Game	0.111	N/A	0.449	N/A
Salmon	0.085	0.020	0.336	0.280
Sturgeon	0.023	0.025	0.206	0.520
Other Species	0.186	0.248	0.557	0.530
Other Small Fish	0.107	0.731	0.713	1.880
No Target	0.294	0.645	0.881	0.992

Source: NMFS, 2002e.

Table B4-7: Average Catch Rate by Species/Species Group for Southern California Sites by Mode of Fishing

Species/Species Group	Average Catch Rate (fish per angler per hour)			
	All Sites		Sites with Non Zero Catch Rates	
	Private/Rental Boat	Shore	Private/Rental Boat	Shore
Small Game	0.192	0.418	0.837	1.109
Striped Bass	0.002	N/A	0.200	N/A
Bottom Fish	0.145	0.730	0.654	1.047
Flatfish	0.096	0.227	0.451	0.553
Big Game	0.057	N/A	0.408	N/A
Salmon	0.009	N/A	0.522	N/A
Sea Basses	0.231	0.353	0.761	0.652
Other Species	0.104	0.267	0.440	0.478
Other Small Fish	0.080	0.615	0.575	1.501
No Target	0.238	0.569	1.003	0.857
Jacks	0.065	N/A	0.415	N/A

Source: NMFS, 2002e.

B4-1.4 Travel Cost

EPA used ArcView 3.2a software to estimate distances from the household zip code to each NMFS fishing site in the individual opportunity sets. The Agency obtained fishing site locations from the Master Site Register supplied by NMFS. The Master Site Register includes both a unique identifier that corresponds to the visited site identifier used in the angler survey, and latitude and longitude coordinates. For some sites, the latitude and longitude coordinates were missing or demonstrably incorrect, in which case the town point, as identified in the U.S. Geological Survey (USGS) Geographic Names Information System, was used as the site location if a town was reported in the site address. The program measured the distance in miles of the shortest route, using state and U.S. highways, from the household zip code to each fishing site, then added the distances from the zip code location to the closest highway and from the site location to the closest highway. The average one-way distance to the visited site for all modes is 24.08 miles. Private/rental boat anglers traveled farther, on average, to the chosen site than shore anglers, going 26.53 miles versus 18.72 miles.

EPA estimated trip "price" as the sum of travel costs plus the opportunity cost of time following the procedure described in Haab et al. (2000). Based on Parsons and Kealy (1992), this study assumed that time spent "on-site" is constant across sites and can be ignored in the price calculation. To estimate anglers' travel costs, EPA multiplied round trip distance by average motor vehicle cost per mile ($0.325, 2000 dollars).[8] To estimate the opportunity cost of travel time, EPA first divided round trip distance by 40 miles per hour to estimate trip time, and used one-third of the household's wage to yield the opportunity cost of time. EPA estimated household wage by dividing household income by 2,080 (i.e., the number of full time hours potentially worked).

EPA calculated visit price as:

$$Visit\ Price = (Round\ Trip\ Distance \times \$.325) + \left[\frac{Round\ Trip\ Distance}{40\ mph} \times (Wage) \times 0.33 \right] \qquad \text{(B4-1)}$$

B4-2 Site Choice Models

The nature of the MRFSS data leads to the RUM as a means of examining anglers' preferences (Haab et al., 2000). Anglers arrive at each NMFS site by choosing among a set of feasible sites. The RUM assumes that the individual angler makes a choice among mutually exclusive site alternatives based on the attributes of those alternatives (McFadden, 1981). The number of feasible choices (J) in each angler's choice set was set to 37 sites within 140 miles of the angler's home.

An angler's choice of sites relies on utility maximization. An angler will choose site j if the utility (u_j) from visiting site j is greater than that from vising other sites (h), such that:

$$u_j > u_h \ for\ h = 1, ..., J\ and\ h \neq j \qquad \text{(B4-2)}$$

Anglers choose the species to seek and the mode of fishing in addition to choosing a fishing site. Available fishing modes include shore fishing, fishing from charter boats, or fishing from private or rental boats. The target species or group of species include small game, striped bass, jacks, sea basses, bottom fish, flatfish, big game fish, salmon, sturgeon, and other fish. Anglers may also choose not to target any particular species.

Recreational fishing models generally assume that anglers first choose a mode and species, and then a site. The nested logit model is generally used for recreational demand models, as it avoids the independence of relevant alternatives (IIA) problem, in which sites with similar characteristics that are not included in the model have correlated error terms. However, the nested model did not work well for the California region, indicating that nesting may not be appropriate for the data. Consequently, EPA estimated separate logit models for boat and shore anglers. The Agency did not include the angler's choice of fishing

[8] EPA used the 2000 government rate ($0.325) for travel reimbursement to estimate travel costs per mile traveled. This estimate includes vehicle operating cost only.

mode and target species in the model, instead assuming that the mode/species choice is exogenous to the model and that the angler simply chooses the site. EPA used the following general model to specify the deterministic part of the utility function:[9]

$$v\ (site\ j) = f\,(TC_j,\ SITE\text{-}ATTRIBUTES_j,\ SQRT(Q_{js}) \times Flag(s)) \qquad \text{(B4-3)}$$

where:

v	=	the expected utility for site j (j=1,...37);
TC_j	=	travel cost for site j;
$SITE\text{-}ATTRIBUTES_j$	=	presence of marinas or docks; or piers or jetties at site j;
$SQRT(Q_{js})$	=	square root of the historic catch rate for species s at site j;[10] and
$Flag(s)$	=	1 if an angler is targeting this species; 0 otherwise.

The analysis assumes that each angler in the estimated model considers site quality based on the catch rate for the targeted species and site amenities such as the presence of marinas and/or docks and piers or jetties at each site. Theoretically, an angler may catch any of the available species at a given site (McFadden, 1981). If, however, an angler truly has a species preference, then including the catch variable for all species available at the site would inappropriately attribute utility to the angler for a species not pursued (Haab et al., 2000). To avoid this problem, the Agency used an interaction variable $SQRT(Q_{js}) \times Flag(s)$, such that the catch rate variable for a given species is turned on only if the angler targets a particular species [$Flag(s) = 1$]. The Agency calculated a separate catch rate for no-target anglers, using the average of all species caught by no-target anglers. The final model presented here is a site choice model that includes all fish species. The analysis therefore assumes that each angler has chosen a mode/species combination followed by a site based on the catch rates for that site and species. EPA estimated all RUM models with LIMDEP™ software (Greene, 1995). Table B4-8 gives the parameter estimates for the boat and shore models.

One disadvantage of the specified model is that the model looks at site choice without regard to mode or species, whereas mode and species selection may be integral parts of the nested RUM. In the model presented here, once an angler chooses a target species and mode, no substitution is allowed across species or mode (i.e., the value of catching, or potentially catching, a different species, or fishing by a different mode, is not included in the calculation). Therefore, improvements in fishing circumstances related to species other than the target species will have no effect on angler's choices.

Table B4-8 shows that most coefficients have the expected signs and are statistically significant at the 95th percentile or better. The exceptions are the coefficients on sea basses and other small fish in the shore model. Trip cost has a negative effect on the probability of selecting a site, indicating that anglers prefer to visit sites closer to their homes (other things being equal). In the boat model, the positive coefficient on the marina/dock variable for Northern California and the negative coefficient on the pier/jetty variable indicates that anglers fishing from boats in Northern California are more likely to choose sites with marinas or docks, and less likely to choose sites with piers or jetties. The signs on these variables are reversed for shore anglers, for both Northern and Southern California, indicating that shore anglers prefer sites with piers or jetties, and are less likely to fish from marinas or docks. For the boat model, the Southern region has a negative coefficient on the marina/dock variable. This result is counter-intuitive, and is likely a result of insufficient data on site amenities in the Southern California region.

For all species, the probability of a site visit increases as the historic catch rate for fish species increases. EPA used historic catch rates averaged over all species caught by no-target anglers to characterize fishing site quality for no-target anglers. Many species can contribute to sites' perceived quality for no-target anglers because they catch whatever bites. In general, no-target anglers select sites with higher historic catch rates.

---

[9] See Chapter A-11 for details on model specification.

[10] The analysis used the square root of the catch rate to allow for decreasing marginal utility of catching fish (McConnell and Strand, 1994).

Table B4-8: Estimated Coefficients for the Conditional Site Choice				
Variable	Private/Rental Boat Model		Shore Model	
	Estimated Coefficient	t-statistic	Estimated Coefficient	t-statistic
Travel Cost	-0.0524	-73.39	-0.0827	-49.67
SQRT ($Q_{small\ game}$)	1.5578	12.10	1.9067	7.33
SQRT ($Q_{striped\ bass\ -\ North}$)	3.3437	7.82	1.9558	9.89
SQRT ($Q_{jacks\ -\ South}$)	11.9676	25.00	N/A	N/A
SQRT ($Q_{sea\ basses\ -\ South}$)	0.5443	5.51	0.1873	0.57
SQRT (Q_{bottom})	1.8420	15.58	0.7824	5.24
SQRT ($Q_{flatfish\ -\ North}$)	2.7179	12.71	2.4743	5.00
SQRT ($Q_{flatfish\ -\ South}$)	4.4960	21.81	1.6156	6.98
SQRT ($Q_{big\ game\ -\ North}$)	2.9221	5.51	N/A	N/A
SQRT ($Q_{big\ game\ -\ South}$)	1.5820	10.27	N/A	N/A
SQRT ($Q_{salmon\ -\ North}$)	5.5201	23.88	N/A	N/A
SQRT ($Q_{salmon\ -\ South}$)	4.2645	5.63	N/A	N/A
SQRT ($Q_{sturgeon\ -\ North}$)	17.3385	10.21	N/A	N/A
SQRT ($Q_{other\ -\ North}$)	N/A	N/A	3.0937	5.28
SQRT ($Q_{other\ -\ South}$)	1.4604	2.30	1.7437	1.50
SQRT ($Q_{other\ small\ fish}$)	N/A	N/A	1.1416	6.63
SQRT ($Q_{no\ target}$)	0.4074	10.22	0.5255	8.23
Marina/Dock	N/A	N/A	-0.2206	-3.86
Marina/Dock - North	0.4235	10.17	N/A	N/A
Marina/Dock - South	-1.1688	-17.40	N/A	N/A
Pier/Jetty	-0.7106	-23.30	0.4777	12.81

Source: U.S. EPA analysis for this report.

B4-3 WELFARE ESTIMATES

This section presents estimates of welfare losses to recreational anglers from fish mortality due to I&E, and potential welfare gains from improvements in fishing opportunities due to reduced fish mortality stemming from the final section 316(b) rule.

B4-3.1 Estimating Changes in the Quality of Fishing Sites

To estimate changes in the quality of fishing sites under different policy scenarios, EPA relied on the recreational fishery landings data by state and the estimates of recreational losses from I&E corresponding to different technology options. The NMFS provided recreational fishery landings data for the Northern and Southern California regions. EPA estimated the losses to recreational fisheries using the physical impacts of I&E on the relevant fish species, and the percentage of total fishery landings attributed to recreational fishing, as described in Chapter B2 of this document. I&E affects recreational species in two ways: by directly killing recreational species, and by killing forage species, thus indirectly affecting recreational species through the food chain. The indirect effects on recreational species were calculated in two steps. First, EPA estimated the total number of fish lost due to forage fish losses. Second, EPA allocated this total number of fish among recreational species according to each species' percent of total recreational landings.

The Agency estimated changes in the quality of recreational fishing sites under different policy scenarios in terms of the percentage change in the historic catch rate. EPA estimated changes in catch rates for each NMFS region, Northern and Southern California, separately. The Agency assumed that catch rates will change uniformly across all marine fishing sites in each NMFS region (i.e., Northern and Southern California), because species considered in the analysis inhabit the entire coast of each NMFS region.[11] For each species included in the model, EPA used five-year recreational landing data (1996 through 2000) for state waters to calculate an average landing per year for a given NMFS region in California.[12] EPA then divided losses to the recreational fishery from I&E by the total recreational landings for a given NMFS region to calculate the percent change in historic catch rate from eliminating I&E completely. Table B4-9 presents results of this analysis for Northern California, and Table B4-10 presents results for Southern California. EPA estimated that compliance with the Phase II rule would reduce impingement by 32.1 percent in Northern California and 30 percent in Southern California, and would reduce entrainment by 35.93 percent in Northern California and 9.5 percent in Southern California (see Chapter B2 for details). Tables B4-11 and B4-12 present estimated improvements in catch rates, over baseline losses, for the final section 316(b) rule in each region.

Table B4-9: Estimated Changes in Catch Rates from Eliminating All I&E of Affected Species in Northern California

Estimated Fishery I&E		Total Recreational Landings for Northern California (fish per year)[a]	Percent Increase in Recreational Catch from Elimination of I&E
Species by Species Group	**Total I&E**		
Flatfish	135,092	238,394	56.67%
Striped Bass	50,023	220,345	22.70%
Bottom Fish	3,093,249	3,245,932	95.23%
Small Game Fish	40,723	250,634[b]	16.25%
Other Fish	875,665	691,382	126.65%
Other Small Fish	234,466	1,442,356	16.26%
Total for All Species[c]	**4,429,218**	**6,089,043**	**72.71%**

[a] Total recreational Landings are calculated as a five year average (1996-2000) for state waters.
[b] Small game fish landings include landings of jacks and all other small game fish except striped bass.
[c] The "all species" totals are used to calculate I&E losses for no-target anglers.

Source: NMFS, 2002e; and U.S. EPA analysis for this report.

[11] Fish lost to I&E are most often very small fish, which are too small to catch. Because of the migratory nature of most affected species, by the time these fish have grown to catchable size, they may have traveled some distance from the facility where I&E occurs. Without collecting extensive data on migratory patterns of all affected fish, it is not possible to evaluate whether catch rates will change uniformly or in some other pattern. Thus, EPA assumed that catch rates will change uniformly across the entire region.

[12] State waters include sounds, inlets, tidal portions of rivers, bay, estuaries, and other areas of salt or brackish water, plus ocean waters to three nautical miles from shore, http://www.st.nmfs.gov/st1/recreational/queries/catch/snapshot.html (NMFS, 2003b).

Table B4-10: Estimated Changes in Catch Rates from Eliminating All I&E of Affected Species in Southern California			
Estimated Fishery I&E		Total Recreational Landings for Southern California (fish per year)[a]	Percent Increase in Recreational Catch from Elimination of I&E
Species by Species Group	Total I&E		
Flatfish	3,487	730,812	0.48%
Sea Basses	835,299	3,298,540	25.32%
Bottom Fish	466,316	2,089,320	22.32%
Small Game Fish	11,766	3,541,997[b]	0.33%
Other Fish	39,995	1,461,775	2.74%
Other Small Fish	1,580	475,689	0.33%
Total for All Species[c]	**1,358,442**	**8,056,136**	**11.71%**

[a] Total recreational landings are calculated as a five year average (1996-2000) for state waters.
[b] Small game fish landings include landings of jacks, striped bass, and all other small game fish.
[c] The "all species" totals are used to calculate I&E losses for no-target anglers.

Source: NMFS, 2002e; and U.S. EPA analysis for this report.

Table B4-11: Estimated Changes in Catch Rates from Reducing I&E of Affected Species in Northern California Under the Final Section 316(b) Rule			
Estimated Fishery I&E		Total Recreational Landings for Northern California (fish per year)[a]	Percent Increase in Recreational Catch from Reduction of I&E
Species by Species Group	Total Reduced I&E		
Flatfish	48,524	238,394	20.35%
Striped Bass	17,802	220,345	8.08%
Bottom Fish	1,105,461	3,245,932	34.03%
Small Game Fish	14,626	250,634[b]	5.84%
Other Fish	313,921	691,382	45.40%
Other Small Fish	84,204	1,442,356	5.84%
Total for All Species[c]	**1,584,538**	**6,089,043**	**26.01%**

[a] Total recreational landings are calculated as a five year average (1996-2000) for state waters.
[b] Small game fish landings include landings of jacks and all other small game fish except striped bass.
[c] The "all species" totals are used to calculate I&E losses for no-target anglers.

Source: NMFS, 2002e; and U.S. EPA analysis for this report.

Table B4-12: Estimated Changes in Catch Rates from Reducing I&E of Affected Species in Southern California Under the Final Section 316(b) Rule

Estimated Fishery I&E		Total Recreational Landings for Southern California (fish per year)[a]	Percent Increase in Recreational Catch from Reduction of I&E
Species by Species Group	Total Reduced I&E		
Flatfish	648	730,812	0.09%
Sea Basses	80,258	3,298,540	2.43%
Bottom Fish	63,934	2,089,320	3.06%
Small Game Fish	1,878	3,541,997[b]	0.05%
Other Fish	4,159	1,461,775	0.28%
Other Small Fish	252	475,689	0.05%
Total for All Species[c]	**151,129**	**11,598,133**	**1.30%**

[a] Total recreational landings are calculated as a five year average (1996-2000) for state waters.
[b] Small game fish landings include landings of jacks, striped bass, and all other small game fish.
[c] The "all species" totals are used to calculate I&E losses for no-target anglers.

Source: NMFS, 2002e.

B4-3.2 Estimating Losses from I&E in Northern and Southern California

The recreational behavior model described in the preceding sections provides a means for estimating the economic effects of changes in recreational fishery losses from I&E in California. First, EPA estimated welfare gain to recreational anglers from eliminating fishery losses due to I&E. This estimate represents economic damages to recreational anglers from I&E of recreational fish species in California under the baseline scenario. EPA then estimated benefits to recreational anglers from implementing the preferred CWIS technologies.

EPA estimated anglers' willingness-to-pay (WTP) for improvements in the quality of recreational fishing due to I&E elimination by first calculating an average per-day welfare gain based on the expected changes in catch rates from eliminating I&E. Table B4-13 presents the compensating variation per fishing day (averaged over all anglers in the sample) associated with reduced fish mortality from eliminating I&E for each fish species group of concern. Table B4-13 also shows the per-day welfare gain attributable to reduced I&E resulting from the final section 316(b) rule.[13,14]

Table B4-13 shows that shore anglers in Northern California targeting species in the "other" category have the largest per-day gain ($15.51) from eliminating I&E, followed by boat anglers targeting bottom fish in Northern California ($13.04). Anglers in Northern California targeting flatfish also have a relatively high per-day welfare gain of $6.98 for boat anglers and $6.66 for shore anglers. The high value for "other" species is due to the large predicted change in catch rates for these species.

Table B4-13 also reports the willingness-to-pay for a one-unit increase in historic catch rate by species. The value of increasing the historic catch rate varies significantly by species and by fishing mode. For boat anglers in Northern California who target specific species, sturgeon are the most highly valued fish, followed by salmon, striped bass, big game fish, flatfish, bottom fish, and small game fish. For boat anglers in Southern California who target specific species, jacks are the most highly valued fish, followed by flatfish, salmon, bottom fish, small game fish, other fish, big game fish, and sea basses. For shore anglers in Northern California who target specific species, other fish are the most highly valued, followed by flatfish, striped bass, small game fish, bottom fish, and other small fish. For shore anglers in Southern California who target specific species, other fish (includes unidentified sharks, greenling, and sculpins) are the most highly valued, followed by flatfish, small game fish, bottom fish, other small fish, and sea basses. Boat anglers have higher values than shore anglers for flatfish, striped bass, and bottom fish.

[13] A compensating variation equates the expected value of realized utility under the baseline and post-compliance conditions.

[14] As the RUM model estimated values for single-day trips, the per-day value is equal to a per-trip value.

Table B4-13: Per-Day Welfare Gain from Eliminating I&E and From I&E Reductions with the Preferred Technology in Northern and Southern California						
Targeted Species Group	Per-Day Welfare Gain (2002$)				WTP for an Additional Fish per Trip (2002$)	
	Eliminating I&E		Reduced I&E with Preferred Technology		Boat Anglers	Shore Anglers
	Boat Anglers	Shore Anglers	Boat Anglers	Shore Anglers		
Flatfish - N. CA	$6.98	$6.66	$2.59	$2.47	$6.21	$4.41
Flatfish - S. CA	$0.13	$0.03	$0.02	$0.01	$10.83	$3.12
Sea Basses - S. CA	$0.69	$0.20	$0.07	$0.02	$0.71	$0.35
Striped Bass - N. CA	$3.87	$1.70	$1.40	$0.62	$8.23	$4.22
Bottom Fish - N. CA	$13.04	$3.35	$4.90	$1.30	$2.70	$1.35
Bottom Fish - S. CA	$2.00	$1.06	$0.28	$0.17	$2.70	$1.35
Small Game Fish - N. CA	$0.98	$1.25	$0.35	$0.46	$2.21	$3.02
Small Game Fish - S. CA	$0.04	$0.04	$0.01	$0.01	$2.21	$3.02
Other Fish - N. CA[a]	N/A	$15.51	N/A	$6.11	N/A	$6.54
Other Fish - S. CA	$0.14	$0.31	$0.02	$0.06	$2.11	$4.21
Other Small Fish-N. CA[a]	N/A	$2.16	N/A	$0.78	N/A	$1.18
Other Small Fish - S. CA[a]	N/A	$0.13	N/A	$0.04	N/A	$1.18
No Target - N. CA [b]	$0.93	$1.79	$0.36	$0.46	$0.45	$0.92
No Target - S. CA [b]	$0.22	$0.34	$0.03	$0.05	$0.45	$0.92
Jacks - S. CA[c,d]	N/A	N/A	N/A	N/A	$28.54	N/A
Salmon - N. CA[c,d]	N/A	N/A	N/A	N/A	$15.23	N/A
Salmon - S. CA [c]	N/A	N/A	N/A	N/A	$8.28	N/A
Sturgeon - N. CA	N/A	N/A	N/A	N/A	$60.14	N/A
Big Game Fish - N. CA[d,e]	N/A	N/A	N/A	N/A	$6.33	N/A
Big Game Fish - S. CA[d,e]	N/A	N/A	N/A	N/A	$2.10	N/A

[a] Not targeted by boat anglers in the sample.
[b] The value is based on all species caught by no-target anglers.
[c] Not targeted by shore anglers in the sample.
[d] Values for jacks are included in small game values.

Source: U.S. EPA analysis for this report.

EPA calculated the total economic value of eliminating I&E in Northern California by combining the estimated per-day welfare gain with the total number of fishing days in the Northern California region. NMFS provided information on the total number of fishing trips by state and by fishing mode; this total number of fishing days includes both single- and multiple-day trips. Table B4-14 presents the NMFS number of fishing days by fishing mode.

The Agency assumed that the welfare gain per day of fishing is independent of the number of days fished per trip and therefore equivalent for both single- and multiple-day trips. Each day of a multiple-day trip is valued the same as a single-day trip.[15] Per-day welfare gain differs across recreational species and fishing mode.[16] EPA therefore estimated the number of fishing days associated with each species of concern and the number of days fished by no-target anglers. EPA used the MRFSS sample to calculate the proportion of recreational fishing trips taken by no-target anglers and anglers targeting each species of concern and applied these percentages to the total number of trips to estimate species-specific participation. Tables B4-15 and B4-16 show the calculation results.

[15] See section B4-4.1 for limitations and uncertainties associated with ths assumption.

[16] EPA used the per-day values for private/rental boat anglers to estimate welfare gains for charter boat anglers.

Table B4-14: Recreational Fishing Participation in 2001 by Fishing Mode for Northern and Southern California		
Fishing Mode	Total Number of Fishing Days per Year, Northern CA[a]	Total Number of Fishing Days per Year, Southern CA[a]
Private Rental Boat	1,065,009	1,742,369
Shore	864,178	1,315,430
Charter Boat	278,447	994,353
Total	2,207,634	4,052,152

[a] Total days includes each day of a multiple-day fishing trip.

Source: *http://www.st.nmfs.gov/recreational/queries/participation/par_time_series.html (NMFS, 2002d).*

Table B4-15: Recreational Fishing Participation by Species and Fishing Mode, Northern California				
Species	Mode: Private Rental Boats Number of Fishing Days	Mode: Shore Number of Fishing Days	Mode: Charter Boat Number of Fishing Days	Total for All Modes[a]
Flatfish	144,948	16,419	0	161,367
Striped Bass	58,682	188,218	0	246,900
Bottom Fish	125,458	185,885	161,416	472,759
Other Small Fish	0	15,037	0	15,037
No Target	208,955	400,114	36,699	645,768
Total[a]	538,043	805,673	198,115	1,541,831

[a] Sum of individual values may not add up to totals due to rounding error.

Source: U.S. EPA analysis for this report.

Table B4-16: Recreational Fishing Participation by Species and Fishing Mode, Southern California				
Species	Mode: Private Rental Boats Number of Fishing Days	Mode: Shore Number of Fishing Days	Mode: Charter Boat Number of Fishing Days	Total for All Modes[a]
Flatfish	319,550	125,624	54,391	499,565
Sea Basses	273,029	60,904	63,042	396,975
Bottom Fish	140,261	88,923	113,953	343,137
Other Small Fish	0	9,997	0	9,997
No Target	476,712	916,197	504,236	1,897,145
Total[a]	1,209,552	1,201,645	735,622	3,146,819

[a] Sum of individual values may not add up to totals due to rounding error.

Source: U.S. EPA analysis for this report.

In Northern California, no-target anglers account for the largest number of fishing days, followed by anglers targeting bottom fish, striped bass, flatfish, and other small fish. In Southern California, no-target anglers account for the largest number of fishing days, followed by anglers targeting flatfish, sea basses, bottom fish, and other small fish.

The estimated number of fishing days represents the baseline level of participation. Anglers may fish more when recreational fishing circumstances improve. However, EPA was unable to estimate a trip participation model for California, because the required data were not available. Therefore, the welfare estimates presented here do not account for likely increases in the number of trips due to elimination or reduction of I&E, and thus understate total welfare effects.

Tables B4-17 and B4-18 provide total annual welfare estimates for two policy scenarios. These values were discounted, to reflect the fact that fish must grow to a certain size before they will be caught by recreational anglers. EPA calculated discount factors separately for I&E of each species. To estimate discounted total benefits, EPA calculated weighted averages of these discount factors for each species group, and applied them to estimated willingness-to-pay values. Discount factors were calculated for both a three percent discount rate and a seven percent discount rate. For the final section 316(b) rule, an additional discount factor was applied to account for the one-year lag between the date when installation costs are incurred and the installation of the required cooling water technology is completed.

Table B4-17 presents annual losses to recreational anglers from baseline I&E effects in California. Total recreational losses from I&E to California anglers, before discounting, are $8.9 million per year (2002$). Total discounted baseline losses are $7.5 million, discounted using a three percent discount rate; and $6.1 million, discounted using a seven percent discount rate.

Table B4-18 presents the annual welfare gain to recreational anglers resulting from the final section 316(b) rule. Total gain to recreational anglers before discounting is $3 million under the final section 316(b) rule. Total discounted gain is $2.5 million and $1.9 million using a three and seven percent discount rate, respectively.

Table B4-17: Total Estimated Annual Baseline Losses From I&E for California Anglers (2002$)

Species	Total Losses Before Discounting				Total Losses with 3% Discounting				Total Losses with 7% Discounting			
	Boat	Shore	Charter	Totals	Boat	Shore	Charter	Totals	Boat	Shore	Charter	Totals
Flatfish	$1,052,504	$113,509	$6,968	$1,172,981	$867,417	$93,509	$6,279	$967,205	$687,022	$74,021	$5,546	$766,589
Striped Bass	$226,994	$320,117	$0	$547,111	$205,350	$289,593	$0	$494,943	$181,660	$256,184	$0	$437,844
Sea Basses	$187,937	$11,886	$43,367	$243,190	$153,850	$9,730	$35,501	$199,081	$119,395	$7,551	$27,551	$154,497
Bottom Fish	$1,916,883	$716,181	$2,332,755	$4,965,819	$1,580,960	$590,084	$1,917,757	$4,088,801	$1,252,856	$467,074	$1,514,014	$3,233,944
Small Game Fish	$40,914	$4,461	$11,261	$56,636	$37,707	$4,123	$10,403	$52,233	$34,141	$3,745	$9,444	$47,330
Other Fish	$1,244	$442,515	$1,508	$445,267	$1,181	$417,450	$1,432	$420,063	$1,107	$388,231	$1,342	$390,680
Other Small	$0	$33,850	$0	$33,850	$0	$31,119	$0	$31,119	$0	$28,095	$0	$28,095
No Target	$297,670	$1,028,627	$143,603	$1,469,900	$252,037	$871,272	$121,150	$1,244,459	$206,319	$713,934	$98,253	$1,018,506
Total Recreational Use Losses	$3,724,146	$2,671,146	$2,539,462	$8,934,754	$3,098,502	$2,306,880	$2,092,522	$7,497,904	$2,482,500	$1,938,835	$1,656,150	$6,077,485

Source: U.S. EPA analysis for this report.

Table B4-18: Total Estimated Annual Welfare Gain to California Anglers Under the Final Section 316(b) Rule (2002$)

Species	Total Gain Before Discounting				Total Gain with 3% Discounting				Total Gain with 7% Discounting			
	Boat	Shore	Charter	Totals	Boat	Shore	Charter	Totals	Boat	Shore	Charter	Totals
Flatfish	$382,876	$41,435	$1,310	$425,621	$305,687	$33,075	$1,129	$339,891	$232,373	$25,137	$944	$258,454
Striped Bass	$82,398	$116,617	$0	$199,015	$72,388	$102,450	$0	$174,838	$61,663	$87,271	$0	$148,934
Sea Basses	$18,755	$1,201	$4,328	$24,284	$14,928	$956	$3,445	$19,329	$11,175	$715	$2,579	$14,469
Bottom Fish	$653,649	$256,811	$822,157	$1,732,617	$520,528	$204,473	$653,566	$1,378,567	$394,583	$154,965	$494,348	$1,043,896
Small Game Fish	$11,551	$948	$2,499	$14,998	$10,337	$852	$2,245	$13,434	$9,012	$747	$1,966	$11,725
Other Fish	$130	$173,668	$157	$173,955	$120	$159,040	$145	$159,305	$108	$142,358	$131	$142,597
Other Small	$0	$12,212	$0	$12,212	$0	$10,902	$0	$10,902	$0	$9,476	$0	$9,476
No Target	$86,253	$318,265	$25,444	$429,962	$71,128	$262,456	$21,014	$354,598	$56,416	$208,167	$16,639	$281,222
Total Recreational Use Gain	$1,235,612	$921,157	$855,895	$3,012,664	$995,116	$774,204	$681,544	$2,450,864	$765,330	$628,836	$516,607	$1,910,773

Source: U.S. EPA analysis for this report.

B4-4 Limitations and Uncertainties

B4-4.1 Extrapolating Single-Day Trip Results to Estimate Benefits from Multiple-Day Trips

Use of per-day welfare gain estimated for single-day trips to estimate per-day welfare gain associated with multiple-day trips can either understate or overstate benefits to anglers taking multiple-day trips. Inclusion of multi-day trips in the model of recreational anglers' behavior can be problematic because multi-day trips are frequently multi-activity trips. An individual might travel a substantial distance and participate in several recreational activities such as shopping and sightseeing, all as part of one trip. Recreational benefits from improved recreational opportunities for the primary activity are overstated if all travel costs are treated as though they apply to the one recreational activity of interest. EPA therefore limited the recreational behavior model to single-day trips only and then extrapolated single-day trip results to estimate benefits to anglers taking multiple-day trips.

There is evidence that multi-day trips are more valuable than single-day trips. McConnell and Strand (1994) estimated a RUM using the NMFS data for New England and the Mid-Atlantic. Their study was intended to supplement the RUM study of single-day trips for the same region conducted by Hicks et al. (1999). The reported values for a catch rate increase of one fish are consistently higher for overnight trips than for single-day trips. Lupi and Hoehn (1998) compared values for single- and multi-day fishing trips. Their comparison is based on a RUM for the Great Lakes, with single and multiple-day trips treated as distinct alternatives in the choice set, with separate parameters for different length trips. They found that multiple-day trips are less responsive to changes in travel cost, and thus relatively more valuable than single-day trips. Their case study results found that "over half the value of an across the board marginal change in catch rates was due to multiple-day trips even though multiple-day trips represent less than one fourth of the trips in the sample" (p. 45).

B4-4.2 Considering Only Recreational Values

This study understates the total benefits of improvements in fishing site quality because estimates are limited to recreational use benefits. Many other forms of benefits, such as habitat values for a variety of species (in addition to recreational fish), non-use values, etc., are also likely to be important.

B4-4.3 Species and Mode Substitution

EPA's estimated RUM model does not allow for anglers to substitute between modes or species. The analysis therefore assumes that each angler has chosen a mode/species combination followed by a site based on the catch rates for that site and species. One disadvantage of the specified model is that the model looks at site choice without regard to mode or species. Once an angler chooses a target species and mode, no substitution is allowed across species or mode (i.e., the value of catching, or potentially catching, a different species or fishing using a different mode is not included in the calculation). Therefore, improvements in fishing circumstances related to other species or modes will have no effect on anglers' choices, and thus will not be accounted for in the welfare estimates.

B4-4.4 Charter Anglers

EPA's model does not include charter boat anglers. Instead, the Agency used values for private/rental boat anglers to estimate values for charter anglers. It is not clear whether this will result in an overestimate or underestimate of per-day values for charter boat anglers.

B4-4.5 Potential Sources of Survey Bias

The survey results could suffer from bias, such as recall bias and sampling effects.

a. Recall bias

Recall bias can occur when respondents are asked, such as in the MRFSS, the number of their recreation days over the previous season. Some researchers believe that recall bias tends to lead to an overstatement of the number of recreation days, particularly by more avid participants. Avid participants tend to overstate the number of recreation days because they count days in a "typical" week and then multiply them by the number of weeks in the recreation season. They often neglect to consider days missed due to bad weather, illness, travel, or when fulfilling "atypical" obligations. Some studies also found that the more salient the activity, the more "optimistic" the respondent tends to be in estimating the number of recreation days.

Individuals also have a tendency to overstate the number of days they participate in activities that they enjoy and value. Taken together, these sources of recall bias may result in an overstatement of the actual number of recreation days.

b. Sampling effects

Recreational demand studies frequently face observations that do not fit general recreation patterns, such as observations of avid participants. These participants can be problematic because they claim to participate in an activity an inordinate number of times. This reported level of activity is sometimes correct but often overstated, perhaps due to recall bias. Even where the reports are correct, these observations tend to be overly influential (Thomson, 1991).

Chapter B5: Non-Use Benefits

INTRODUCTION

CHAPTER CONTENTS

Aquatic species without any direct uses account for the majority of losses due to impingement and entrainment (I&E) at cooling water intake structures (CWIS). However, EPA's analysis of direct use benefits includes values only for organisms with direct uses, which comprise a very small percentage of total losses (approximately two percent). Because the other 98 percent of losses, consisting of organisms without direct uses, are not without value, the potential exists for significant non-use values that have not been addressed under EPA's estimation of use benefits. For this reason it is important to consider non-use benefits to the human population, produced by the increased numbers of organisms without direct use values, under the final section 316(b) rule.

One way to consider the impact of the section 316(b) rule is to estimate the non-use value of baseline I&E losses and I&E reductions due to the final rule for each case study region using the non-use meta-analysis results. The non-use meta-analysis is presented in detail in Chapter A12, Non-Use Meta-Analysis Methodology, which includes discussions of the literature review process, the estimated regression models and results, and the general methodology used to estimate household and aggregate non-use benefits based on regression results. Total regional non-use benefits can be estimated using the following three steps:

1. Estimate annual changes in non-use value of the affected fishery resources per household due to the baseline impingement and entrainment (I&E) losses and the post-compliance reduction in impingement and entrainment;

2. Estimate the population of households in the California region holding non-use value for the affected resources; and

3. Estimate the total non-use value to the affected California populations for completely eliminating baseline I&E losses, and for reducing I&E losses from the baseline to post-compliance levels.

EPA explored this approach for the California region. However, EPA did not include the results of this approach in the benefit analysis because of limitations and uncertainties associated with estimation of non-use benefits on a regional scale. For further discussion of the limitations and uncertainties of this method, refer to Chapter A12.

B5-1 QUALITATIVE ASSESSMENT OF ECOLOGICAL BENEFITS FOR THE CALIFORNIA REGION

Changes in CWIS design or operations resulting from the section 316(b) regulations for existing facilities are expected to reduce I&E losses of fish, shellfish, and other aquatic organisms and, as a result, are expected to increase the numbers of individuals present, increase local and regional fishery populations, and ultimately contribute to the enhanced environmental functioning of affected waterbodies (rivers, lakes, estuaries, and oceans) and associated ecosystems. The economic welfare of human populations is expected to increase as a consequence of the improvements in fisheries and associated aquatic ecosystem functioning.

The aquatic resources affected by cooling water intake structures provide a wide range of services. Ecosystem services are the physical, chemical, and biological functions performed by natural resources and the human benefits derived from those functions, including both ecological and human use services (Daily, 1997; Daily et al., 1997). Scientific and public interest in protecting ecosystem services is increasing with the recognition that these services are vulnerable to a wide range of human activities and are difficult, if not impossible, to replace with human technologies (Meffe, 1992).

In addition to their importance in providing food and other goods of direct use to humans, the organisms lost to I&E are critical to the continued functioning of the ecosystems of which they are a part. Fish are essential for energy transfer in aquatic food webs, regulation of food web structure, nutrient cycling, maintenance of sediment processes, redistribution of bottom substrates, the regulation of carbon fluxes from water to the atmosphere, and the maintenance of aquatic biodiversity (Peterson and Lubchenco, 1997; Postel and Carpenter, 1997; Holmund and Hammer, 1999; Wilson and Carpenter, 1999). Examples of ecological and public services disrupted by I&E include:

- decreased numbers of ecological keystone, rare, or sensitive species;
- decreased numbers of popular species that are not fished, perhaps because the fishery is closed;
- decreased numbers of special status (e.g., threatened or endangered) species;
- increased numbers of exotic or disruptive species that compete well in the absence of species lost to I&E;
- disruption of ecological niches and ecological strategies used by aquatic species;
- disruption of organic carbon and nutrient transfer through the food web;
- disruption of energy transfer through the food web;
- decreased local biodiversity;
- disruption of predator-prey relationships;
- disruption of age class structures of species;
- disruption of natural succession processes;
- disruption of public uses other than fishing, such as diving, boating, and nature viewing; and
- disruption of public satisfaction with a healthy ecosystem.

Many of these services can only be maintained by the continued presence of all life stages of fish and other aquatic species in their natural habitats.

The traditional approach of EPA and other natural resource agencies to quantifying the environmental benefits of proposed regulations has focused on active use values, particularly direct use values such as recreational or commercial fishing. Nonconsumptive uses (such as the importance of fish for aquatic food webs), and passive use or non-use values (including the value of protecting a resource for its own sake), are seldom considered because they are difficult to monetize with available economic methods. However, even though economists debate methods for indirect and non-use valuation, there is general agreement that these values exist and can be important. The potential magnitude of non-use values remains an empirical matter. EPA believes that non-use values are applicable for the section 316(b)-related I&E and that these values are likely to be appreciable for the California region.

Chapter B6: Threatened and Endangered Species Analysis

INTRODUCTION

CHAPTER CONTENTS

This chapter develops potential methods for the estimation of non-use values for special status species in California.[1] Non-use value estimates are particularly relevant for these species. Their populations have been depleted to the point where active use values based on previous studies would be misleading because of fishing restrictions or decreased effort or participation due to low catch rates.

Regulation-specific stated preference surveys are the preferred way to directly estimate total values (including use and non-use) for special status species. Such a survey has not been undertaken because it could not be completed within the time frame for the rulemaking process. Despite potential difficulties associated with benefit transfer approaches, if properly done they can constitute a second-best alternative to original stated preference studies to value improved protection of special status species. Chapter A13 of this report provides a detailed description of the benefits transfer approach used in this analysis. Section B6-2 describes the benefit transfer studies used in the analysis and presents analytic results.

B6-1 A POTENTIAL METHOD FOR VALUING SPECIAL STATUS SPECIES

B6-1.1 Overview of Method

This method is based on the premise that under specific circumstances it is possible to infer how much value society places on a program or activity by observing how much society is willing to forego (in out-of-pocket expenses and opportunity costs) to implement the program. For example, the costs borne by society to implement programs that preserve and restore special status species can, under select conditions, be interpreted as a measure of how much society values the outcomes it anticipates receiving. This is analogous to the broadly accepted revealed preference method of inferring values for private goods and services based on observed individual behavior.

In the case of observed individual behavior, when a person willingly bears a cost (pays a price) to receive a good or service, it is deduced that the person's value for that acquired good or service must be at least as great as the price paid. This observation is, based on the presumption that individual behavior reflects the economic rationality of seeking to maximize utility (well-being), the person's willingness-to-pay (WTP) must exceed the observed price paid, otherwise they would not have purchased that unit of the commodity. The approach described in this section uses the same premise, but applies it to societal choices rather than to a single individual's choices.

A critical issue with the approach is determining when it is likely that a specific public sector activity (or other form of collective action) does indeed reflect a "societal choice." EPA recognizes clearly that not every policy enacted by a public sector entity can rightfully be interpreted as an indication of social choice. Hence, the costs imposed in such instances may

[1] Consistent with the discussion in Chapter A13, "special status species" is the term used to refer to species that have been specifically identified as "threatened and endangered" (i.e., T&E) or that have been given a special status designation at the State or Federal level.

not reveal social values. For example, some regulatory actions may have social costs that outweigh the social benefits, but may be implemented anyway because of legal requirements or other considerations. In such a case, asserting that the costs imposed reflect a lower bound estimate of the "value" of the action would not be accurate (the values may be less than the imposed costs). Alternatively, there are some regulatory programs for which the benefits greatly exceed costs, and in such instances using costs as a reflection of value would greatly understate social benefits.

There are some public policy actions that can be suitably interpreted as expressions of societal preferences and values. In these instances, the incurred costs may be viewed as an indication of social values. The criteria to help identify when such situations arise include whether the actions taken are voluntary, or whether the actions reflect an open and broadly inclusive policy-making process that enables and encourages active participation by a broad spectrum of stakeholders. This is especially relevant where (1) plans and actions are developed in an inclusive, consensus-building manner; (2) implementation steps are pursued in an adaptive management framework that enables continuous feedback and refinement; or (3) the actions are ultimately supported by some positive indication of broad community support, such as voter approval of a referendum. In such instances, the policy choices made are the product of a broad-based, collective decision-making process, and such programs should be viewed as an expression of societal preferences. When programs or activities stem from such open collective processes, the actions (and costs incurred) reflect the revealed preference of society.

This approach incorporates the basic economic principle that holds a resource's value is defined in terms of its opportunity costs. The method builds on this principle by recognizing that public agencies and private individuals voluntarily and/or through a broad-based collective decision-making process undertake a range of actions intended to maintain or increase the populations of fish stocks, and that often these actions are directed to improve the stocks of special status species. As a result, the costs involved with implementing these actions, combined with the value of any foregone opportunities that need to be committed to the action to ensure its success (even if they may not involve a direct expenditure, e.g., maintaining instream water flows), can provide an estimate of the value of the intended improvement in the species population.

A key criterion for a project to be considered an expression of public values is that the project be voluntarily undertaken so that any costs and foregone opportunities provide a true indication of an opportunity cost of the action being realized. For projects undertaken by private individuals and organizations, it is assumed that this criterion is satisfied unless there is evidence that the action is undertaken to satisfy a strict regulatory compliance requirement or a mandated court requirement. For actions of public agencies to be considered, this criterion is assumed to be satisfied when the action is taken in response to legislative mandates that have been widely supported by lawmakers and/or the public (e.g., as evidenced by broad stakeholder involvement, especially in a consensus-oriented decision-making context, and/or where funding is supported by voters through referenda, such as evident in the CALFED process), or where the action has been approved through an internal project screening and selection process designed to allocate limited resources. In the second case, while subtle, the criterion is assumed satisfied if there were alternative projects/actions that could have been pursued but were not, as this provides evidence that an opportunity cost was involved with the selections that were made.

A second criterion that needs to be satisfied for a project to be considered in the analysis is that the project objectives and actions have a clear link to the resource being valued. In some cases the actions may be directed at a targeted group of resources (e.g., California condor population support programs clearly are targeting California condors). However, in other cases a project may benefit a number of resources outside of the scope of the valuation analysis. In these cases, it is necessary to determine whether the full scope of the activity was required to benefit the resources of concern or whether there were additional benefits. For example, if a certain level of instream flow may be required by a special status species, actions taken to maintain flows at this level because of the species would be appropriate for consideration in the analysis. However, if flows were increased above the level required by the species to provide additional benefits (e.g., improved downstream kayaking), only the share of actual costs or foregone value associated with the portion of the release required for the special status species should be considered.

The economic foundations for using this approach to value T&E species are firmly established through the widespread recognition and acceptance of revealed preference data as a source of nonmarket information that is acceptable for the valuation of resources. In EPA's approach, valuation estimates rely on the costs of actions or the value of foregone opportunities that are *voluntarily* undertaken or that have been approved through extensive public input and review (and developed in a consensus-oriented approach). With these sources of data, the method avoids the well-established problems associated with using "costs" as a measure of "value" — a problem that can arise when the cost is realized involuntarily (e.g., avoided cost-based measures of value). Specifically, because of the available evidence of the public's acceptance and willingness to incur the opportunity costs associated with the actions that are selected for evaluation, the fundamental criteria for defining the value of any resource are satisfied.

It is important to note that one issue that arises with the use of this method is that it is not clear that the resulting values can be distinctly categorized as direct use or non-use values because the underlying actions benefitting the T&E species could reflect an expressed mix of non-use values (e.g., preservation and existence) and discounted future use values (e.g., the actions are seen as an "investment" that could return the species to levels at which direct use would be permitted).

The principle source of information that can be used to determine expenditures for special status species in the San Francisco Estuary comes from actions being undertaken by the CALFED program to protect and enhance their populations. Other potentially relevant information includes the value of foregone water diversions used to maintain instream flows critical to special status species. These programs are discussed in the following section.

B6-1.2 CALFED

The CALFED program represents a cooperative effort on the part of more than 20 Federal and State agencies that work collaboratively with local communities to implement projects that address specific goals within the four main objective areas of the program: ecosystem restoration, water quality, water supply and reliability, and levee system integrity.[2] CALFED has an adaptive management process that provides the various participating agencies and private citizens/organizations with extensive opportunities to review and comment on materials presented for the purposes of determining policy. The commitment of financial resources to the program through State and Federal sources — through a combination of general fund allocations, revenues from approved State bonds and department allocations, and with funds and resources provided by local/private sources — satisfies the first criterion that the project is undertaken voluntarily.

In addition to State and Federal agencies that serve on the Policy Group (as listed in footnote 2), many environmental and resource conservation groups, unions, Tribal governments, and municipalities serve on the CALFED Public Advisory Committee, as listed in Table B6-1.

Table B6-1: Organizations Represented on CALFED Public Advisory Committee

▸ The Bay Institute	▸ United Farm Workers of America, AFL-CIO
▸ Ducks Unlimited	▸ Association of California Water Agencies
▸ Glenn County	▸ California Strategies, LLC
▸ City Of West Sacramento	▸ Paskenta Band of Nomlaki Indians
▸ Kern County Water Agency	▸ Plumas County
▸ City of Rio Vista	▸ Planning and Conservation League
▸ Inland Empire Utilities Agency	▸ Natural Resources Defense Council
▸ Northern California Power Agency	▸ San Luis & Delta-Mendota Water Authority
▸ Friant Water Users Authority	▸ Pacific Coast Federation of Fishermen's Association
▸ Contra Costa Water District	▸ California Farm Bureau Federation
▸ Northern California Water Association	▸ Metropolitan Water District of Southern California

Source: CALFED website (accessed 11/27/02): http://calfed.ca.gov/BDPAC/BDPAC_Members.shtml (CALFED, 2001d).

The goal of the Public Advisory Committee is to provide assistance and recommendations to the Secretary of the Interior, the Governor of California, the California Legislature, and other interested entities through the CALFED Policy Group. The Committee also serves as a liaison between the program's workgroups, subcommittees, State and Federal agencies, and the general public.[3]

Numerous additional stakeholders are also represented at the subcommittee level. For example, the Ecosystem Restoration Subcommittee membership includes representatives from the organizations listed in Table B6-2.

---

[2] Participating Federal agencies include the Bureau of Reclamation, the Fish and Wildlife Service, the U.S. Geological Survey, the Bureau of Land Management, the Environmental Protection Agency, the Army Corps of Engineers, the Natural Resource Conservation Service, the U.S. Forest Service, the National Marine Fisheries Service, and the Western Area Power Administration. Participating State agencies include the Department of Water Resources, the California Department of Fish and Game (CDFG), The Reclamation Board, the Delta Protection Commission, the Department of Conservation, the San Francisco Bay Conservation and Development Commission, the State Water Resources Control Board, the Department of Health Services, and the Department of Food and Agriculture.

[3] CALFED website (accessed 11/27/02): http://calfed.ca.gov/BDPAC/US_Dept_of_Interior_Charter.pdf (CALFED, 2001a).

Table B6-2: Stakeholder Organizations Represented on Ecosystem Restoration Subcommittee

▸ Central Valley Project Water Association	▸ Northern California Water Association
▸ Supervisor, District 4 Glenn County	▸ The Trust for Public Land
▸ Natural Heritage Institute	▸ MWD of Southern California
▸ Kern County Water Agency	▸ Save the Bay
▸ Mayor, City of Rio Vista	▸ Tribal Environmental Coordinator
▸ California Trout	▸ California Farm Bureau
▸ Friends of the River	▸ Environmental Defense Fund
▸ Friant Water Users Authority	▸ Matlock, Charles, Rowe & Co.
▸ Contra Costa Water District	

Source: CALFED website (accessed 11/29/02): http://calfed.ca.gov/BDPAC/Subcommittees/EcosystemSubcommitteeMembers.shtml (CALFED, 2001b).

With feedback from the general public, an independent science advisory board, and various government agencies, this subcommittee developed the plan for habitat restoration in the San Francisco Bay-Delta.

In addition to stakeholder organizations represented on the various committees and subcommittees, there also is broad involvement of the general public. According to CALFED director Patrick Wright: "Public involvement has been one of the hallmarks of the program."[4] To ensure a thoroughly collective process, the general public is also strongly encouraged to participate through numerous subcommittees, workshops, and informational publications. The CALFED program was created to ensure that all interested parties were included in a collective process aimed at improving the water supply and restoring the Bay-Delta ecosystem.

The Sacramento River Conservation Area Forum (SRCAF) is another representative example of this inclusive process. Although not a government agency and having no regulatory power, the SRCAF was created over a decade ago to guide riparian habitat management along the river. The forum is convened monthly to facilitate discussion between landowners, government agencies, conservation groups, and the general public. The six non-voting members of the SRCAF board represent interested government agencies to share information on the progress of their restoration activities.[5] Based on information presented to the board, only the voting members, which include landowners and other interested members of the public, make recommendations and issue opinions about whether these restoration activities are conducted according to the inclusive principles of the CALFED program and SRCAF mission.

This example, along with the overall structure of the CALFED process, is representative of a restoration program that reflects an attempt to form and implement a broad-based societal consensus. The program is based on the cooperative participation of government agencies and the inclusion of a broad cross section of stakeholders and the general public in the decision and funding process. Accordingly, restoration efforts developed under this collective decision-making process can be considered as expressions of revealed social preferences.

A second criterion to be satisfied for considering specific actions requires demonstration that the action was intended to benefit the resource in question. With respect to CALFED, it is clear that certain program elements, the categories of activity defined by CALFED, are focused on special status species. Specifically, the Ecosystem Restoration Program Plan (ERPP) has identified the following specific goals:[6]

- Recover 19 at-risk native species and contribute to the recovery of 25 additional species;[7]
- Protect and restore functional habitats, including aquatic, upland, and riparian, to allow species to thrive;

---

[4] CALFED website (accessed 11/29/02): http://calfed.ca.gov/Newsroom/NewsReleases_2001/Newsrelease_10-22-01.shtml (CALFED, 2001c).

[5] SRCAF website (accessed 12/8/02): http://www.sacramentoriver.ca.gov/publications/questions_to_date.pdf (SRCAF, 2002).

[6] Source http://calwater.ca.gov/Programs/EcosystemRestoration/Ecosystem.shtml, accessed 6/23/03 (CALFED, 2003).

[7] Among the species in this combined group are the following: delta smelt, longfin smelt, green sturgeon, Sacramento splittail, Sacramento winter-run chinook salmon, Central Valley spring-run chinook salmon, late-fall-run chinook salmon, fall-run chinook salmon, and Central Valley steelhead (see CALFED Ecosystem Restoration Plan) (CALFED, 2000).

- Maintain and enhance fish populations critical to commercial sport and recreational fisheries;
- Improve and maintain water and sediment quality to better support ecosystem health and allow species to flourish;
- Rehabilitate natural processes related to hydrology, stream channels, sediment, floodplains, and ecosystem water quality; and
- Reduce the negative impacts of invasive species and prevent additional introductions that compete with and destroy native species.

It is clear that the goals of the ERPP are focused, at least in part, on special status species. The Environmental Water Account program element within CALFED also includes actions undertaken to protect fish and habitats in addition to the regulatory actions required for project operations.

B6-1.3 Values for Water in California

"Restoration" programs need not be relied on exclusively to infer societal revealed WTP to preserve special status species. In many instances, other programs or restrictions are used in lieu of (or in conjunction with) restoration programs, and the costs associated with the nonrestoration components also reveal a WTP. For example, efforts to preserve fish species in the San Francisco Estuary also include water use restrictions that reduce the amount of fresh water diverted from the upstream portion of the Sacramento River to highly valued water uses in the central and southern parts of California. The foregone use values of these waters in agricultural and municipal applications are an important component of the cost society bears to protect and preserve special status fish species.

Several actions have been taken in northern California to increase stream flows to improve fish habitat. The most significant reduction in water use to meet these increases in stream flows has been experienced by urban and agricultural water users who obtain their supplies from the Bureau of Reclamation. The Bureau has had to cut back on supply to its Central Valley Project (CVP) customers to comply with the various water needs and restrictions of the Federal Endangered Species Act (FESA) and California Endangered Species Act (CESA), the CVP Improvement Act (CVPIA), and the new Bay-Delta water quality standards issued in 1995 by the State Water Resources Control Board. For these purposes, the Bureau has reduced by 40 to 60 percent its usual 7 million AF per year delivered to water users without water rights (personal communication, Earl Cummings, California Division of Water Resources, Environmental Services Office, March 2000; personal communication, Jeff Sandberg, Central Valley Project, March 2000). Thus, the Bureau has foregone 3 to 4 million AF per year for environmental water use intended for the Sacramento and San Joaquin rivers to protect special status species. EPA estimated that this represents a range of value to California water users from $155 to $425 per AF (the calculation is explained in Appendix B2), and is a weighted average reflecting agricultural and municipal uses. Using this estimate, the value to California water users of the water the Bureau has foregone ranges from $484 million to $1.8 billion annually in 2002 dollars.

EPA contacted the Bureau of Reclamation to verify the amount of water being diverted for special status species under the context of the CVPIA and bay delta water quality standards. Although the Bureau could not estimate the amount of water diversion cut back specifically for special status species, they estimated that approximately 50 percent of the water diverted for the CVPIA and the Bay-Delta water quality standards is to preserve or enhance the targeted fish populations through water quality or other habitat improvements (personal communication, Jeff McCracken, Public Information Office, Bureau of Reclamation, June 2003).

B6-1.4 Conclusions

EPA did not use the method described in this section in its benefits analysis for the final section 316(b) Phase 2 rule because of uncertainties about the percent of program funding assigned to the protection of special status species. Nonetheless, EPA believes this method holds promise.

B6-2 An Exploration of Benefits Transfer to Estimate Non-use Benefits of Reduced I&E in Northern California

This section presents a benefits-transfer methodology explored by EPA to estimate public WTP for protection of special status fish species from I&E at the Pittsburg and Contra Costa power plants. The analysis focuses on four special status species affected by I&E: delta smelt, longfin smelt, Sacramento splittail, and chinook salmon.

B6-2.1 Benefit Transfer Approach

Case-specific estimates of non-use values for the protection of special status species can only be derived by primary research using stated preference techniques (e.g., the contingent valuation method). However, the cost, administrative burden, and time required to develop primary research estimates is beyond the schedule and resources available to EPA for the section 316(b) rulemaking. As an alternative, EPA explored a benefit transfer approach that relies on information from existing studies (U.S. EPA, 2000). Boyle and Bergstrom (1992) define benefit transfer as "the transfer of existing estimates of nonmarket values to a new study which is different from the study for which the values were originally estimated."

There are four types of benefit transfer studies: point estimate, benefit function, meta-analysis, and Bayesian techniques (U.S. EPA, 2000). The point estimate approach involves taking the mean value (or range of values) from the study case and applying it directly to the policy case (U.S. EPA, 2000). This approach may be used to transfer estimates of values for preserving certain endangered species in one region to another region or to another species. A conceptually preferred benefits transfer approach is to use the benefit function transfer approach, which is more refined but also more complex than the point estimate approach. If the study case provides a WTP function, valuation estimates can be updated by substituting applicable values of key variables, such as baseline risk and population characteristics (e.g., mean or median income, racial or age distribution) from the policy case into the benefit function (U.S. EPA, 2000).

Ideally, transfer studies would be available that value special status species that are identical to the species affected in the San Francisco Estuary. EPA, however, was unable to identify such studies. Thus, the Agency selected benefits transfer studies that valued aquatic species that have attributes similar to the affected species. One of the most important attributes to consider is whether the affected species have any use values. As shown in Table B6-3, the majority of I&E losses of special status species are associated with forage species that do not have direct use values.

Table B6-3: Comparison of Special Status Species Losses to I&E with Target Abundance in Bay-Delta Region

Special Status Fish Species	Type of Value	Current Population[a]	Total Baseline I&E Losses		I&E Losses as % of Current Population
			Number of Fish	Species Loss as % of Total I&E Loss of Special Status Species	
Delta smelt	Non-use	334,855	753	8.8%	0.2%
Longfin smelt	Primarily non-use	636,225	6,824	79.8%	1.1%
Sacramento splittail	Primarily non-use	7,973	911	10.6%	11.4%
Chinook salmon (all runs)	Use and non-use	301,877	67	0.8%	0.0%
Total	-	1,280,930	8,555	100.0%	0.7%

[a] Current abundance is equal to the median value for the period 1990-2000 or the median of the most recent values available from 1990 onward. See Appendix B3 for details.

Of the four special status species only one, chinook salmon, has high direct use values. The remaining three species — delta smelt, longfin smelt, and Sacramento splittail — have primarily non-use values. There are no known recreational or consumptive uses for the delta smelt. The longfin smelt is fished occasionally and it has also been sold seasonally at fish markets, but neither use appears to be widespread. Before the Sacramento splittail was listed as a threatened species it was used as bait for striped bass anglers, but not to a large extent (Federal Register, 1999). Given that I&E losses of chinook salmon represent only 0.8 percent of total I&E losses of special status species in the San Francisco Estuary, EPA focused on economic studies valuing preservation of obscure forage species in identifying benefit transfer candidates.

The Agency identified two studies that valued special status species that match closely characteristics of the species affected by I&E in the San Francisco Estuary. Boyle and Bishop (1987) found that citizens of Wisconsin are willing to pay $7.52 (2002$) to preserve the striped shiner, a small minnow of the Milwaukee River (which is listed by the State of Wisconsin as endangered, but is not listed as a Federally threatened or endangered species).[8] A study by Berrens et al. (1996) found that preservation of the endangered silvery minnow in New Mexico would be worth an average of $8.32 (2002$) per household per year.[9]

EPA considered using the point estimate approach to derive a range of WTP values for improving protection of the four special status species in the San Francisco Estuary. Neither the Boyle and Bishop (1987) nor the Berrens (1996) study contained sufficient or relevant information for applying any of the more elaborate benefits transfer techniques. Boyle and Bishop (1987) did not estimate a function which itself may be transferable to other regions. They obtained WTP values by asking citizens if they would accept or reject fixed membership fees to join a foundation that would conduct the necessary activities to preserve the species in question and reported the estimated results but not a regression function. Therefore, the benefit function transfer approach is not a feasible alternative using the Boyle and Bishop (1987) study. The Berrens et al. (1996) study also does not lend itself to benefits function transfer.

Using the two studies described in the preceding section and applying a range of the per taxpayer WTP to protect the striped shiner and silvery minnow to the 2000 population of California, it is possible to estimate WTP to prevent extinction of the delta smelt and other Federally-listed special status fish species in California.

Because I&E at the Pittsburgh and Contra Costa plants is only one of several factors that cause decline of the delta smelt, longfin smelt, Sacrament splittail, and chinook salmon populations, the societal benefit achieved from preventing all I&E losses at these two plants is lower than the benefit of reducing the risk of species extinction to zero. Thus, one would assign a fraction of the non-use estimates for species preservation programs based on the percent of the estimated standing stock that is adversely impacted under the baseline level of I&E losses. As shown in Table B6-3, the estimated impact of I&E amounts to 0.7 percent of the estimated current population of the special status species in the Bay-Delta area.

EPA notes, that although the Agency explored this approach to estimate non-use values of improved protection of the four special status species in the San Francisco Estuary, benefits based on this method were not included in the final section 316(b) rule benefit cost analysis due to the uncertainty and limitations discussed in Section A13-6.1 of this report.

EPA would like to further note the encouraging point that the valuation results are highly consistent across the relevant T&E studies available in the literature. As more studies become available, it may be possible to obtain insights into the effects of various variables (e.g., population and resource characteristics) and develop welfare estimates that may be adjusted for the attributes of the policy or region under consideration. For example, researchers and policy makers have placed increasing focus on meta-analysis and similar empirical approaches to improve the performance of benefit transfer in policy analysis.

---

[8] The original WTP amount was converted to 2002$ using the Consumer Price Index (CPI) obtained from U.S. Department of Labor Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2003).

[9] Berrens estimated a $28/year per household (1995$) WTP for a 5-year program. To place it on an equivalent basis to Boyle and Bishop, the 5-year payment needs to be converted to an equivalent annual payment over a longer time frame. Using a 25-year payment period and a 3 percent discount rate to convert the Berrens 5-year result to 25 years, and using the CPI to update from 1995$ to 2002$, the result of $8.32 (2002$) per household per year is derived. The 25-year period is used by EPA as a reasonable proxy for a longer-term indefinite period as implied by the other studies, because typical median aged household heads probably would not envision paying appreciable taxes or contributions after 25 or 30 years (i.e., past age 70).

Appendix B1: Life History Parameter Values Used to Evaluate I&E in the Northern and Southern California Regions

The tables in this appendix present the life history parameter values used by EPA to calculate age 1 equivalents, fishery yields, and production foregone from I&E data for the California region. Because of differences in the number of life stages represented in the loss data, there are cases where more than one life stage sequence was needed for a given species or species group. Alternative parameter sets were developed for this purpose and are indicated with a number following the species or species group name (i.e., Anchovies 1, Anchovies 2).

Table B1-1: American Shad Life History Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.496	0	0	0.000000716
Larvae	3.01	0	0	0.000000728
Juvenile	7.40	0	0	0.000746
Age 1+	0.300	0	0	0.309
Age 2+	0.300	0	0	1.17
Age 3+	0.300	0	0	2.32
Age 4+	0.540	0.21	0.45	3.51
Age 5+	1.02	0.21	0.90	4.56
Age 6+	1.50	0.21	1.0	5.47
Age 7+	1.50	0.21	1.0	6.20
Age 8+	1.50	0.21	1.0	6.77

Sources: Able and Fahay, 1998; PSE&G, 1999; and U.S. Fish and Wildlife Service, 1978.

Table B1-2: Anchovies Life History Parameters 1[a,b]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000138
Larvae	7.99	0	0	0.00000151
Juvenile	2.12	0	0	0.0132
Age 1+	0.700	0.03	0.50	0.0408
Age 2+	0.700	0.03	1.00	0.0529
Age 3+	0.700	0.03	1.00	0.0609
Age 4+	0.700	0.03	1.00	0.0684
Age 5+	0.700	0.03	1.00	0.0763
Age 6+	0.700	0.03	1.00	0.0789

[a] Includes northern anchovy, deepbody anchovy, slough anchovy and other anchovies not identified to species.
[b] Life history parameters applied to losses from Contra Costa, Diablo, Encina, Harbor, Haynes, Humboldt, Hunter's Point, Huntington, Mandalay, Morro Bay, Moss Landing, Ormond, Pittsburg, Redondo Beach, Scattergood, Segundo, and San Onofre.

Sources: Ecological Analysts Inc., 1981b; Froese and Pauly, 2002; Pacific Fishery Management Council, 1998; Tenera Environmental Services, 2000a; Virginia Tech, 1998; and Wang, 1986.

Table B1-3: Anchovies Life History Parameters 2[a,b]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000138
Larvae 3 mm	0.172	0	0	0.00000151
Larvae 4 mm	0.172	0	0	0.00000173
Larvae 5 mm	0.172	0	0	0.00000334
Larvae 6 mm	0.172	0	0	0.00000572
Larvae 7 mm	0.172	0	0	0.00000901
Larvae 8 mm	0.172	0	0	0.0000134
Larvae 9 mm	0.172	0	0	0.0000189
Larvae 10 mm	0.172	0	0	0.0000258
Larvae 11 mm	0.172	0	0	0.0000342
Larvae 12 mm	0.172	0	0	0.0000442
Larvae 13 mm	0.172	0	0	0.0000559
Larvae 14 mm	0.172	0	0	0.0000696
Larvae 15 mm	0.172	0	0	0.0000853
Larvae 16 mm	0.172	0	0	0.000103
Larvae 17 mm	0.172	0	0	0.000123
Larvae 18 mm	0.172	0	0	0.000146
Larvae 19 mm	0.172	0	0	0.000171
Larvae 20 mm	0.172	0	0	0.000199
Larvae 21 mm	0.172	0	0	0.000230
Larvae 22 mm	0.172	0	0	0.000264

Table B1-3: Anchovies Life History Parameters 2[a,b]				
Stage Name	**Natural Mortality (per stage)**	**Fishing Mortality (per stage)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Larvae 23 mm	0.172	0	0	0.000301
Larvae 24 mm	0.172	0	0	0.000341
Larvae 25 mm	0.172	0	0	0.000385
Larvae 26 mm	0.172	0	0	0.000432
Larvae 27 mm	0.172	0	0	0.000483
Larvae 28 mm	0.172	0	0	0.000538
Larvae 29 mm	0.172	0	0	0.000597
Larvae 30 mm	0.172	0	0	0.000659
Larvae 31 mm	0.172	0	0	0.000726
Larvae 32 mm	0.172	0	0	0.000798
Larvae 33 mm	0.172	0	0	0.000873
Larvae 34 mm	0.172	0	0	0.000954
Larvae 35 mm	0.172	0	0	0.00104
Larvae 36 mm	0.172	0	0	0.00113
Larvae 37 mm	0.172	0	0	0.00122
Larvae 38 mm	0.172	0	0	0.00132
Larvae 39 mm	0.172	0	0	0.00143
Larvae 40 mm	0.172	0	0	0.00154
Larvae 41 mm	1.249	0	0	0.00166
Larvae 59 mm	0.208	0	0	0.00485
Juvenile	2.12	0	0	0.0132
Age 1+	0.700	0.03	0.50	0.0408
Age 2+	0.700	0.03	1.0	0.0529
Age 3+	0.700	0.03	1.0	0.0609
Age 4+	0.700	0.03	1.0	0.0684
Age 5+	0.700	0.03	1.0	0.0763
Age 6+	0.700	0.03	1.0	0.0789

[a] Includes northern anchovy.
[b] Life history parameters applied to losses from Potrero.

Sources: Ecological Analysts Inc., 1980b, 1981b; Froese and Pauly, 2002; Pacific Fishery Management Council, 1998; Tenera Environmental Services, 2000a; and Wang, 1986.

Table B1-4: Anchovies Life History Parameters 3[a,b]				
Stage Name	**Natural Mortality (per stage)**	**Fishing Mortality (per stage)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	0.669	0	0	0.00000138
Larvae 6 mm	0.104	0	0	0.00000572
Larvae 7 mm	0.207	0	0	0.00000901
Larvae 9 mm	0.104	0	0	0.0000189
Larvae 10 mm	0.104	0	0	0.0000258
Larvae 11 mm	0.104	0	0	0.0000342
Larvae 12 mm	0.104	0	0	0.0000442
Larvae 13 mm	0.104	0	0	0.0000559
Larvae 14 mm	0.104	0	0	0.0000696
Larvae 15 mm	0.207	0	0	0.0000853
Larvae 17 mm	0.207	0	0	0.000123
Larvae 19 mm	0.104	0	0	0.000171
Larvae 20 mm	0.104	0	0	0.000199
Larvae 21 mm	0.207	0	0	0.000230
Larvae 23 mm	0.311	0	0	0.000301
Larvae 26 mm	0.207	0	0	0.000432
Larvae 28 mm	0.104	0	0	0.000538
Larvae 29 mm	0.104	0	0	0.000597
Larvae 30 mm	0.104	0	0	0.000659
Larvae 31 mm	0.104	0	0	0.000726
Larvae 32 mm	0.622	0	0	0.000798
Larvae 38 mm	1.97	0	0	0.00132
Larvae 57 mm	0.519	0	0	0.00438
Larvae 62 mm	0.207	0	0	0.00561
Larvae 64 mm	0.104	0	0	0.00616
Larvae 65 mm	0.104	0	0	0.00645
Larvae 66 mm	0.104	0	0	0.00675
Larvae 67 mm	0.311	0	0	0.00706
Larvae 70 mm	0.519	0	0	0.00803
Larvae 75 mm	0.622	0	0	0.00984
Larvae 81 mm	0.104	0	0	0.0123
Larvae 82 mm	0.104	0	0	0.0128
Juvenile	2.12	0	0	0.0132
Age 1+	0.700	0.03	0.50	0.0408
Age 2+	0.700	0.03	1.0	0.0529
Age 3+	0.700	0.03	1.0	0.0609
Age 4+	0.700	0.03	1.0	0.0684
Age 5+	0.700	0.03	1.0	0.0763
Age 6+	0.700	0.03	1.0	0.0789

[a] Includes northern anchovy.
[b] Life history parameters applied to losses from Hunter's Point.

Sources: Ecological Analysts Inc., 1980b, 1981b, 1982a; Froese and Pauly, 2002; Pacific Fishery Management Council, 1998; Tenera Environmental Services, 2000a; and Wang, 1986.

Table B1-5: Blennies Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.105	0	0	0.00000176
Larvae	3.98	0	0	0.00000193
Juvenile	0.916	0	0	0.000501
Age 1+	1.34	0	0	0.00314
Age 2+	1.34	0	0	0.00745
Age 3+	1.34	0	0	0.0101
Age 4+	1.34	0	0	0.0113
Age 5+	1.34	0	0	0.0119
Age 6+	1.34	0	0	0.0122
Age 7+	1.34	0	0	0.0123
Age 8+	1.34	0	0	0.0123
Age 9+	1.34	0	0	0.0124

[a] Includes bay blenny, combtooth blenny, mussel blenny, orangethroat pikeblenny, rockpool blenny, tube blenny, and other blennies not identified to species.

Sources: Froese and Binohlan, 2000; Froese and Pauly, 2003; and Tenera Environmental Services, 2000b.

Table B1-6: Cabezon Life History Parameters				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000430
Larvae	3.79	0	0	0.000605
Juvenile	0.916	0	0	0.00825
Age 1+	0.288	0	0	0.169
Age 2+	0.144	0.14	0.50	1.06
Age 3+	0.144	0.14	1.0	3.26
Age 4+	0.144	0.14	1.0	4.72
Age 5+	0.144	0.14	1.0	5.30
Age 6+	0.144	0.14	1.0	6.13
Age 7+	0.144	0.14	1.0	6.78
Age 8+	0.144	0.14	1.0	7.37
Age 9+	0.144	0.14	1.0	8.76
Age 10+	0.144	0.14	1.0	9.23
Age 11+	0.144	0.14	1.0	10.5
Age 12+	0.144	0.14	1.0	12.0
Age 13+	0.144	0.14	1.0	13.7

Sources: Cailliet, 2000; Leet et al., 2001; O'Connell, 1953; Tenera Environmental Services, 1988; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table B1-7: California Halibut Life History Parameters				
Stage Name	**Natural Mortality (per stage)**	**Fishing Mortality (per stage)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	0.223	0	0	0.000000548
Larvae	2.86	0	0	0.00000444
Juvenile	0.555	0	0	0.0170
Age 1+	0.160	0	0	0.130
Age 2+	0.160	0	0	0.739
Age 3+	0.160	0	0	1.94
Age 4+	0.160	0	0	3.87
Age 5+	0.160	0	0	6.21
Age 6+	0.160	0.16	1.0	8.89
Age 7+	0.160	0.16	1.0	12.2
Age 8+	0.160	0.16	1.0	15.3
Age 9+	0.160	0.16	1.0	18.9
Age 10+	0.160	0.16	1.0	21.3
Age 11+	0.160	0.16	1.0	23.8
Age 12+	0.160	0.16	1.0	26.6
Age 13+	0.160	0.16	1.0	28.6
Age 14+	0.160	0.16	1.0	30.7
Age 15+	0.160	0.16	1.0	33.0
Age 16+	0.160	0.16	1.0	35.3
Age 17+	0.160	0.16	1.0	37.7
Age 18+	0.160	0.16	1.0	40.2
Age 19+	0.160	0.16	1.0	42.9
Age 20+	0.160	0.16	1.0	45.7
Age 21+	0.160	0.16	1.0	48.5
Age 22+	0.160	0.16	1.0	51.5
Age 23+	0.160	0.16	1.0	54.7
Age 24+	0.160	0.16	1.0	57.9
Age 25+	0.160	0.16	1.0	61.3
Age 26+	0.160	0.16	1.0	64.8
Age 27+	0.160	0.16	1.0	68.4
Age 28+	0.160	0.16	1.0	72.2
Age 29+	0.160	0.16	1.0	76.1
Age 30+	0.160	0.16	1.0	80.1

Sources: Cailliet, 2000; Froese and Pauly, 2002; Kucas and Hassler, 1986; Leet et al., 2001; Tenera Environmental Services, 2000a; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table B1-8: California Scorpionfish Life History Parameters[a]				
Stage Name	**Natural Mortality (per stage)**	**Fishing Mortality (per stage)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.00000200
Larvae	1.00	0	0	0.00000219
Juvenile	1.00	0	0	0.000712
Age 1+	0.130	0	0	0.281
Age 2+	0.130	0.13	0.50	0.445
Age 3+	0.130	0.13	1.0	0.662
Age 4+	0.130	0.13	1.0	0.940
Age 5+	0.130	0.13	1.0	1.42
Age 6+	0.130	0.13	1.0	1.80
Age 7+	0.130	0.13	1.0	2.19
Age 8+	0.130	0.13	1.0	2.58
Age 9+	0.130	0.13	1.0	2.95
Age 10+	0.130	0.13	1.0	3.31
Age 11+	0.130	0.13	1.0	3.65
Age 12+	0.130	0.13	1.0	3.96
Age 13+	0.130	0.13	1.0	4.25
Age 14+	0.130	0.13	1.0	4.51
Age 15+	0.130	0.13	1.0	4.75
Age 16+	0.130	0.13	1.0	4.97
Age 17+	0.130	0.13	1.0	5.17
Age 18+	0.130	0.13	1.0	5.35
Age 19+	0.130	0.13	1.0	5.51
Age 20+	0.130	0.13	1.0	5.65
Age 21+	0.130	0.13	1.0	6.18

[a] Includes California scorpionfish and spotted scorpionfish.

Sources: Cailliet, 2000; Froese and Binohlan, 2000; and Leet et al., 2001.

Table B1-9: Chinook Salmon Life History Parameters				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000317
Larvae	5.04	0	0	0.000349
Juvenile	0.916	0	0	0.199
Age 1+	0.160	0	0	0.397
Age 2+	0.160	0	0	4.50
Age 3+	0.160	0	0	12.2
Age 4+	0.160	0	0	23.8
Age 5+	0.160	0	0	33.8

Sources: Allen and Hassler, 1986; Beauchamp et al., 1983; Froese and Pauly, 2001; and Wang, 1986.

Table B1-10: Commercial Sea Basses/Recreational Sea Basses Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.00000101
Larvae	1.00	0	0	0.0000216
Juvenile	0.190	0	0	0.000138
Age 1+	0.190	0	0	0.0313
Age 2+	0.190	0	0	0.0625
Age 3+	0.190	0	0	0.125
Age 4+	0.190	0	0	0.312
Age 5+	0.190	0.26	0.50	0.531
Age 6+	0.190	0.26	1.0	0.813
Age 7+	0.287	0.26	1.0	1.13
Age 8+	0.287	0.26	1.0	1.50
Age 9+	0.287	0.26	1.0	1.88
Age 10+	0.287	0.26	1.0	2.19
Age 11+	0.287	0.26	1.0	2.30
Age 12+	0.287	0.26	1.0	2.41
Age 13+	0.287	0.26	1.0	2.67
Age 14+	0.287	0.26	1.0	2.93
Age 15+	0.287	0.26	1.0	3.19
Age 16+	0.287	0.26	1.0	3.44
Age 17+	0.287	0.26	1.0	3.69
Age 18+	0.287	0.26	1.0	3.94
Age 19+	0.287	0.26	1.0	4.19
Age 20+	0.287	0.26	1.0	4.42
Age 21+	0.287	0.26	1.0	4.66
Age 22+	0.287	0.26	1.0	4.88

Table B1-10: Commercial Sea Basses/Recreational Sea Basses Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Age 23+	0.287	0.26	1.0	5.10
Age 24+	0.287	0.26	1.0	5.31
Age 25+	0.287	0.26	1.0	5.51
Age 26+	0.287	0.26	1.0	5.71
Age 27+	0.287	0.26	1.0	5.90
Age 28+	0.287	0.26	1.0	6.08
Age 29+	0.287	0.26	1.0	6.25
Age 30+	0.287	0.26	1.0	6.42
Age 31+	0.287	0.26	1.0	6.58
Age 32+	0.287	0.26	1.0	6.73
Age 33+	0.287	0.26	1.0	6.88

[a] Commercial sea bass species includes giant sea bass; recreational sea bass species includes barred sand bass, paralabrax species, broomtail grouper, kelp bass, spotted bass, and spotted sand bass.

Sources: Cailliet, 2000; California Department of Fish and Game, 2000a; Froese and Binohlan, 2000; Froese and Pauly, 2002; and Leet et al., 2001.

Table B1-11: Commercial Shrimp Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.693	0	0	0.000000249
Larvae	3.00	0	0	0.000000736
Juvenile	2.16	0.14	1.0	0.0000865
Age 1+	2.16	0.14	1.0	0.000452
Age 2+	2.16	0.14	1.0	0.00236

[a] Includes Alaskan bay shrimp, bay shrimp, black tailed bay shrimp, blackspotted shrimp, Franscican bay shrimp, ghost shrimp, smooth bay shrimp, spot shrimp, and spotted bay shrimp.

Sources: Bielsa et al., 1983; Leet et al., 2001; Siegfried, 1989; Tenera Environmental Services, 2001; and Virginia Tech, 1998.

Table B1-12: Delta Smelt Life History Parameters				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.90	0	0	0.00000115
Larvae	4.89	0	0	0.00000120
Juvenile	0.916	0	0	0.0000462
Age 1+	1.28	0	0	0.00418

Sources: Brown and Kimmerer, 2002; Buckley, 1989a; Froese and Pauly, 2001, 2003; Moyle et al., 1992; and Wang, 1986.

Table B1-13: Drums/Croakers Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.500	0	0	0.000000722
Larvae	4.61	0	0	0.00000464
Juvenile	3.38	0	0	0.000212
Age 1+	0.420	0	0	0.120
Age 2+	0.420	0	0	0.156
Age 3+	0.210	0.21	0.50	0.195
Age 4+	0.210	0.21	1.0	0.239
Age 5+	0.210	0.21	1.0	0.287
Age 6+	0.210	0.21	1.0	0.340
Age 7+	0.210	0.21	1.0	0.398
Age 8+	0.210	0.21	1.0	0.458
Age 9+	0.210	0.21	1.0	0.519
Age 10+	0.210	0.21	1.0	0.584
Age 11+	0.210	0.21	1.0	0.648
Age 12+	0.210	0.21	1.0	0.723

[a] Includes black croaker, California corbina, queenfish, spotfin croaker, white croaker, white seabass, yellowfin croaker, and other drums or croakers not identified to species.

Sources: Cailliet, 2000; Isaacson, 1964; and Tenera Environmental Services, 1988, 2000b, 2001.

Table B1-14: Dungeness Crab Life History Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.223	0	0	0.000000153
Zoea/Larvae[a]	1.20	0	0	0.000134
Megalopae	1.20	0	0	0.590
Age 1+	0.500	0	0	1.10
Age 2+	0.500	0.50	0.50	1.37
Age 3+	0.500	0.50	1.0	2.48
Age 4+	1.71	0.50	1.0	4.04
Age 5+	1.71	0.50	1.0	4.41
Age 6+	1.71	0.50	1.0	4.79
Age 7+	1.71	0.50	1.0	5.20
Age 8+	1.71	0.50	1.0	5.63
Age 9+	1.71	0.50	1.0	6.08
Age 10+	1.71	0.50	1.0	6.56

[a] Life stages reported as larvae and zoea were assigned the same life history parameters.

Sources: Carroll, 1982; Leet et al., 2001; Pauley et al., 1989; Tenera Environmental Services, 2000a; University of Washington, 2000; Virginia Tech, 1998; and Wild and Tasto, 1983.

Table B1-15: Flounders Life History Parameters[a]

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.223	0	0	0.000000303
Larvae	6.28	0	0	0.00121
Juvenile	1.14	0	0	0.00882
Age 1+	0.363	0.24	0.50	0.0672
Age 2+	0.649	0.43	1.0	0.226
Age 3+	0.752	0.50	1.0	0.553
Age 4+	0.752	0.50	1.0	1.13

[a] Includes bigmouth sole, CO turbot, California halibut, curlfin sole, diamond turbot, dover sole, english sole, fantail sole, hornyhead turbot, longfin sanddab, pacific sanddab, petrale sole, rock sole, sand sole, slender sole, speckled sanddab, spotted turbot, starry flounder, and other flounders not identified to species.

Sources: Cailliet, 2000; ENSR and Marine Research Inc., 2000; Leet et al., 2001; Tenera Environmental Services, 2000a, 2001; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table B1-16: Forage Shrimp Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.693	0	0	0.000000249
Larvae	3.00	0	0	0.000000736
Juvenile	2.30	0	0	0.0000865
Age 1+	2.30	0	0	0.000131
Age 2+	2.30	0	0	0.00236

[a] Includes anemone shrimp, blue mud shrimp, broken back shrimp, brown shrimp, California green shrimp, dock shrimp, mysids, opossum shrimp, oriental shrimp, pistol shrimp, sidestriped shrimp, skeleton shrimp, stout bodied shrimp, striped shrimp, tidepool shrimp, twistclaw pistol shrimp, and other shrimp not identified to species.

Sources: Siegfried, 1989; Tenera Environmental Services, 2001; and Virginia Tech, 1998.

Table B1-17: Gobies Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0	0	0	0.0000115
Larvae	5.77	0	0	0.0000190
Juvenile	0.871	0	0	0.000169
Age 1+	1.10	0	0	0.00194
Age 2+	1.10	0	0	0.00414
Age 3+	1.10	0	0	0.00763
Age 4+	1.10	0	0	0.0310
Age 5+	1.10	0	0	0.0810

[a] Includes arrow goby, bay goby, blackeye goby, blind goby, chameleon goby, cheekspot goby, longjaw mudsucker shadow goby, yellowfin goby, and other gobies not identified to species.

Sources: Froese and Pauly, 2000, 2002; NMFS, 2003a; Tenera Environmental Services, 2000a; and Wang, 1986.

Table B1-18: Herrings Life History Parameters 1[a,b]				
Stage Name	**Natural Mortality (per stage)**	**Fishing Mortality (per stage)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.00000164
Larvae	4.61	0	0	0.00000180
Juvenile	0.693	0	0	0.00161
Age 1+	0.473	0	0	0.0408
Age 2+	0.474	0	0	0.128
Age 3+	0.474	0	0	0.167
Age 4+	0.474	0	0	0.211
Age 5+	0.474	0	0	0.258
Age 6+	0.474	0	0	0.288
Age 7+	0.474	0	0	0.330
Age 8+	0.474	0	0	0.345
Age 9+	0.474	0	0	0.353
Age 10+	0.474	0	0	0.364
Age 11+	0.474	0	0	0.375

[a] Includes middle thread herring, pacific herring, pacific sardine, round herring, threadfin shad, and other herrings not identified to species.
[b] Life history parameters applied to losses from Contra Costa, Diablo, Encina, Humboldt Bay, Hunter's Point, Huntington, Morro Bay, Moss Landing, Ormond, Pittsburg, Redondo Beach, Scattergood, Segundo, and San Onofre.

Sources: Ecological Analysts Inc., 1981b, 1982a; Froese and Pauly, 2002; Lassuy, 1989; NMFS, 2003a; and Tenera Environmental Services, 2001.

Table B1-19: Herrings Life History Parameters 2[a,b]

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000164
Larvae 6 mm	0.140	0	0	0.00000182
Larvae 7 mm	0.121	0	0	0.00000299
Larvae 8 mm	0.107	0	0	0.00000461
Larvae 9 mm	0.096	0	0	0.00000675
Larvae 10 mm	0.087	0	0	0.00000948
Larvae 11 mm	0.079	0	0	0.0000129
Larvae 12 mm	0.221	0	0	0.0000171
Larvae 13 mm	0.221	0	0	0.0000221
Larvae 14 mm	0.221	0	0	0.0000281
Larvae 15 mm	0.221	0	0	0.0000352
Larvae 16 mm	0.221	0	0	0.0000433
Larvae 17 mm	0.221	0	0	0.0000527
Larvae 18 mm	0.221	0	0	0.0000634
Larvae 19 mm	0.221	0	0	0.0000755
Larvae 20 mm	0.221	0	0	0.0000891
Larvae 22 mm	0.221	0	0	0.000121
Larvae 23 mm	0.221	0	0	0.000140
Larvae 24 mm	0.221	0	0	0.000161
Larvae 25 mm	0.221	0	0	0.000183
Larvae 26 mm	0.221	0	0	0.000208
Larvae 27 mm	0.221	0	0	0.000235
Larvae 28 mm	0.221	0	0	0.000264
Larvae 29 mm	0.221	0	0	0.000296
Larvae 30 mm	0.221	0	0	0.000330
Juvenile	0.693	0	0	0.00161
Age 1+	0.473	0	0	0.0408
Age 2+	0.474	0	0	0.128
Age 3+	0.474	0	0	0.167
Age 4+	0.474	0	0	0.211
Age 5+	0.474	0	0	0.258
Age 6+	0.474	0	0	0.288
Age 7+	0.474	0	0	0.330
Age 8+	0.474	0	0	0.345
Age 9+	0.474	0	0	0.353
Age 10+	0.474	0	0	0.364
Age 11+	0.474	0	0	0.375

[a] Includes pacific herring and other herrings not identified to species.
[b] Life history parameters applied to losses from Potrero.

Sources: Ecological Analysts Inc., 1981b; Froese and Pauly, 2002; Lassuy, 1989; NMFS, 2003a; Tenera Environmental Services, 2001; and Wang, 1986.

Table B1-20: Herrings Life History Parameters 3[a,b]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000164
Larvae 6 mm	0.107	0	0	0.00000182
Larvae 7 mm	0.107	0	0	0.00000299
Larvae 8 mm	0.107	0	0	0.00000461
Larvae 9 mm	0.107	0	0	0.00000675
Larvae 10 mm	0.107	0	0	0.00000948
Larvae 11 mm	0.107	0	0	0.0000129
Larvae 12 mm	0.107	0	0	0.0000171
Larvae 13 mm	0.214	0	0	0.0000221
Larvae 15 mm	0.107	0	0	0.0000352
Larvae 16 mm	0.107	0	0	0.0000433
Larvae 17 mm	0.107	0	0	0.0000527
Larvae 18 mm	0.107	0	0	0.0000634
Larvae 19 mm	0.107	0	0	0.0000755
Larvae 20 mm	0.107	0	0	0.0000891
Larvae 21 mm	0.107	0	0	0.000104
Larvae 22 mm	0.107	0	0	0.000121
Larvae 23 mm	0.107	0	0	0.000140
Larvae 24 mm	0.107	0	0	0.000161
Larvae 25 mm	2.36	0	0	0.000183
Larvae 47 mm	0.107	0	0	0.00141
Larvae 48 mm	0.107	0	0	0.00151
Juvenile	0.693	0	0	0.00161
Age 1+	0.473	0	0	0.0408
Age 2+	0.474	0	0	0.128
Age 3+	0.474	0	0	0.167
Age 4+	0.474	0	0	0.211
Age 5+	0.474	0	0	0.258
Age 6+	0.474	0	0	0.288
Age 7+	0.474	0	0	0.330
Age 8+	0.474	0	0	0.345
Age 9+	0.474	0	0	0.353
Age 10+	0.474	0	0	0.364
Age 11+	0.474	0	0	0.375

[a] Includes pacific herring.
[b] Life history parameters applied to losses from Hunter's Point.

Sources: Ecological Analysts Inc., 1981b, 1982a; Froese and Pauly, 2002; Lassuy, 1989; NMFS, 2003a; Tenera Environmental Services, 2001; and Wang, 1986.

Table B1-21: Longfin Smelt Life History Parameters				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.90	0	0	0.00000115
Larvae	6.38	0	0	0.00000186
Juvenile	0.916	0	0	0.000213
Age 1+	0.670	0	1.0	0.00355
Age 2+	0.670	0	1.0	0.0157
Age 3+	0.670	0	1.0	0.0434

Sources: Buckley, 1989a; Froese and Pauly, 2001; U.S. Fish and Wildlife Service, 1996b; and Wang, 1986.

Table B1-22: Northern Anchovy Life History Parameters				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000138
Larvae 5 mm	1.71	0	0	0.00000334
Larvae 6 mm	0.196	0	0	0.00000572
Larvae 7 mm	0.196	0	0	0.00000901
Larvae 8 mm	0.196	0	0	0.0000134
Larvae 9 mm	0.196	0	0	0.0000189
Larvae 10 mm	0.196	0	0	0.0000258
Larvae 11 mm	0.196	0	0	0.0000342
Larvae 12 mm	0.196	0	0	0.0000442
Larvae 13 mm	0.196	0	0	0.0000559
Larvae 14 mm	0.196	0	0	0.0000696
Larvae 15 mm	0.196	0	0	0.0000853
Larvae 16 mm	0.196	0	0	0.000103
Larvae 17 mm	0.196	0	0	0.000123
Larvae 18 mm	0.196	0	0	0.000146
Larvae 19 mm	0.196	0	0	0.000171
Larvae 20 mm	0.196	0	0	0.000199
Larvae 21 mm	0.196	0	0	0.000230
Larvae 22 mm	0.196	0	0	0.000264
Larvae 23 mm	0.196	0	0	0.000301
Larvae 24 mm	0.196	0	0	0.000341
Larvae 25 mm	0.196	0	0	0.000385
Larvae 26 mm	0.196	0	0	0.000432
Larvae 27 mm	0.196	0	0	0.000483
Larvae 28 mm	0.196	0	0	0.000538
Larvae 29 mm	0.196	0	0	0.000597
Larvae 30 mm	0.196	0	0	0.000659
Larvae 31 mm	0.196	0	0	0.000726

Table B1-22: Northern Anchovy Life History Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Larvae 32 mm	0.196	0	0	0.000798
Larvae 33 mm	0.196	0	0	0.000873
Larvae 34 mm	0.196	0	0	0.000954
Larvae 35 mm	0.196	0	0	0.00104
Larvae 36 mm	0.196	0	0	0.00113
Larvae 37 mm	0.196	0	0	0.00122
Juvenile	2.12	0	0	0.0132
Age 1+	0.700	0.03	0.50	0.0408
Age 2+	0.700	0.03	1.0	0.0529
Age 3+	0.700	0.03	1.0	0.0609
Age 4+	0.700	0.03	1.0	0.0684
Age 5+	0.700	0.03	1.0	0.0763
Age 6+	0.700	0.03	1.0	0.0789

Sources: Ecological Analysts Inc., 1980b; Froese and Pauly, 2002; Virginia Tech, 1998; Tenera Environmental Services, 2000a; and Wang, 1986.

Table B1-23: Other Commercial Crabs Life History Parameters 1[a,b]

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0	0	0	0.000000153
Zoea 1	1.58	0	0	0.00000195
Zoea 2	0.948	0	0	0.00000726
Zoea 3	0.948	0	0	0.0000177
Zoea 4	0.948	0	0	0.0000347
Zoea 5	1.26	0	0	0.0000598
Megalopae	2.31	0	0	0.000134
Age 1+	2.43	0	0	0.289
Age 2+	2.43	0	0	0.654
Age 3+	2.43	0	0	1.26
Age 4+	1.82	0.61	0.50	1.97
Age 5+	1.82	0.61	1.0	2.55
Age 6+	1.82	0.61	1.0	3.00

[a] Includes Anthony's rock crab, black clawed crab, brown rock crab, common rock crab, cryptic kelp crab, dwarf crab, elbow crab, graceful kelp crab, hairy crab, hairy rock crab, kelp crab, lined shore crab, lumpy crab, majid crab, masking crab, mole crab, moss crab, northern kelp crab, porcelain crab, purple shore crab, red crab, red rock crab, sharp nosed crab, shore crab family, slender crab, southern kelp crab, spider crab, striped shore crab, thickclaw porcelain crab, yellow crab, yellow shore crab, and other commercial crabs not identified to species.
[b] Life history parameters applied to losses from Diablo, Encina, Morro Bay, and Moss Landing.

Sources: Carroll, 1982; Leets et al., 2001; Tenera Environmental Services, 2000a; and University of Washington, 2000.

Table B1-24: Other Commercial Crabs Life History Parameters 2[a,b]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0	0	0	0.000000153
Larvae	7.99	0	0	0.0000192
Megalopae	2.31	0	0	0.000134
Age 1+	2.43	0	0	0.289
Age 2+	2.43	0	0	0.654
Age 3+	2.43	0	0	1.26
Age 4+	1.82	0.61	0.50	1.97
Age 5+	1.82	0.61	1.0	2.55
Age 6+	1.82	0.61	1.0	3.00

[a] Includes brown rock crab, European green crab, hairy rock crab, hermit crab, lined shore crab, mud crab, pacific sand crab, pea crab, pebble crab, porcelain crab, red crab, red rock crab, shore crab, slender crab, slender rock crab, spider crab, stone crab, yellow crab, yellow rock crab, yellow shore crab, and other commercial crabs not identified to species.
[b] Life history parameters applied to losses from Humboldt Bay, Hunter's Point, Morro Bay, Moss Landing, and Potrero.

Sources: Carroll, 1982; Leets et al., 2001; Tenera Environmental Services, 2000a, 2001; and University of Washington, 2000.

Table B1-25: Pacific Herring Life History Parameters				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000164
Larvae 6 mm	1.44	0	0	0.00000182
Larvae 7 mm	0.703	0	0	0.00000299
Larvae 8 mm	0.609	0	0	0.00000461
Larvae 9 mm	0.537	0	0	0.00000675
Larvae 10 mm	0.481	0	0	0.00000948
Larvae 11 mm	0.435	0	0	0.0000129
Larvae 12 mm	0.397	0	0	0.0000171
Juvenile	0.693	0	0	0.00161
Age 1+	0.473	0	0	0.243
Age 2+	0.474	0	0	0.351
Age 3+	0.474	0	0	0.388
Age 4+	0.474	0	0	0.410
Age 5+	0.474	0	0	0.434
Age 6+	0.474	0	0	0.450
Age 7+	0.474	0	0	0.472
Age 8+	0.474	0	0	0.485

Sources: Ecological Analysts Inc., 1981b; Froese and Pauly, 2002, 2003; Lassuy, 1989; NMFS, 2003a; Tenera Environmental Services, 2001; and Washington Dept. of Fish and Wildlife, 1997.

Table B1-26: Rockfish Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Larvae	1.00	0	0	0.000181
Juvenile	1.00	0	0	0.00760
Age 1+	0.215	0	0	0.0444
Age 2+	0.215	0	0	0.150
Age 3+	0.261	0	0	0.308
Age 4+	0.131	0.13	0.25	0.458
Age 5+	0.131	0.13	0.50	0.689
Age 6+	0.131	0.13	0.75	0.878
Age 7+	0.131	0.13	1.0	1.05
Age 8+	0.131	0.13	1.0	1.21
Age 9+	0.131	0.13	1.0	1.34
Age 10+	0.131	0.13	1.0	1.46
Age 11+	0.131	0.13	1.0	1.55
Age 12+	0.131	0.13	1.0	1.63
Age 13+	0.131	0.13	1.0	1.70
Age 14+	0.131	0.13	1.0	1.75
Age 15+	0.131	0.13	1.0	1.80
Age 16+	0.131	0.13	1.0	1.83
Age 17+	0.131	0.13	1.0	1.86
Age 18+	0.131	0.13	1.0	1.88
Age 19+	0.131	0.13	1.0	1.90
Age 20+	0.131	0.13	1.0	1.92
Age 21+	0.131	0.13	1.0	1.93
Age 22+	0.131	0.13	1.0	1.94
Age 23+	0.131	0.13	1.0	1.95
Age 24+	0.131	0.13	1.0	1.95

[a] Includes aurora rockfish, black and yellow rockfish, black rockfish, blue rockfish, bocaccio, brown rockfish, calico rockfish, chilipepper, copper rockfish, flag rockfish, gopher rockfish, grass rockfish, kelp rockfish, olive rockfish, shortbelly rockfish, treefish, vermilion rockfish, yellowtail rockfish, and other rockfish not identified to species.

Sources: Cailliet, 2000; Leet et al., 2001; Froese and Binohlan, 2000; Russell and Hanson, 1990; and Tenera Environmental Services, 2001.

Table B1-27: Sacramento Splittail Life History Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000352
Larvae	11.3	0	0	0.0000140
Juvenile	0.916	0	0	0.00103
Age 1+	0.370	0	1.0	0.0683
Age 2+	0.370	0	1.0	0.252
Age 3+	0.370	0	1.0	0.480
Age 4+	0.370	0	1.0	0.704
Age 5+	0.370	0	1.0	1.05

Sources: California Department of Water Resources and U.S. Bureau of Reclamation, 1994; Daniels and Moyle, 1983; and Froese and Pauly, 2001.

Table B1-28: Salmon Life History Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000317
Larvae	5.04	0	0	0.000349
Juvenile	0.916	0	0	0.199
Age 1+	0.160	0.16	0.50	0.397
Age 2+	0.160	0.16	1.0	4.50
Age 3+	0.160	0.16	1.0	12.2
Age 4+	0.160	0.16	1.0	23.8
Age 5+	0.160	0.16	1.0	33.8

Sources: Allen and Hassler, 1986; Beauchamp et al., 1983; California Dept. of Fish and Game, 2003; Froese and Pauly, 2001; and Wang, 1986.

Table B1-29: Sculpins Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000338
Larvae	3.79	0	0	0.00000371
Juvenile	0.916	0	0	0.0120
Age 1+	0.420	0.50	0.50	0.0400
Age 2+	0.420	0.50	1.0	0.104
Age 3+	0.420	0.50	1.0	0.219

[a] Includes bonehead sculpin, brown Irish lord, buffalo sculpin, coralline sculpin, fluffy sculpin, manacled sculpin, pacific staghorn sculpin, prickly sculpin, rosy sculpin, roughcheek sculpin, roughneck sculpin, smoothhead sculpin, snubnose sculpin, spotted scorpionfish, staghorn sculpin, tidepool sculpin, woolly sculpin, and other sculpins not identified to species.

Sources: Cailliet, 2000; Froese and Pauly, 2002; Leet et al., 2001; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table B1-30: Silversides Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000924
Larvae	7.99	0	0	0.0000528
Juvenile	0.420	0	0	0.000472
Age 1+	0.420	0	0	0.0207
Age 2+	0.420	0	0	0.106
Age 3+	0.420	0	0	0.166
Age 4+	0.420	0	0	0.246
Age 5+	0.420	0	0	0.349
Age 6+	0.420	0	0	0.476
Age 7+	0.420	0	0	0.632
Age 8+	0.420	0	0	0.818
Age 9+	0.420	0	0	1.04
Age 10+	0.420	0	0	1.30
Age 11+	0.420	0	0	1.59

[a] Includes California grunion, jacksmelt, topsmelt, and other silversides not identified to species.

Sources: Cailliet, 2000; Froese and Pauly, 2002; Leet et al., 2001; NMFS, 2003a; and Wang, 1986.

Table B1-31: Smelts Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.90	0	0	0.00000154
Larvae	7.99	0	0	0.000389
Juvenile	0.740	0.15	0.50	0.00520
Age 1+	0.740	0.15	1.0	0.0364
Age 2+	0.740	0.15	1.0	0.147
Age 3+	0.740	0.15	1.0	0.393
Age 4+	0.740	0.15	1.0	0.738
Age 5+	0.740	0.15	1.0	1.25

[a] Includes night smelt, popeye smelt, surf smelt, and other smelts not identified to species.

Sources: Buckley, 1989a; Cailliet, 2000; Dryfoos, 1965; Froese and Pauly, 2002; and Leet et al., 2001.

Table B1-32: Steelhead Life History Parameters				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000317
Larvae	5.04	0	0	0.000349
Juvenile	0.916	0	0	0.199
Age 1+	0.160	0	0	0.397
Age 2+	0.160	0	0.50	4.50
Age 3+	0.160	0	1.0	12.2
Age 4+	0.160	0	1.0	23.8
Age 5+	0.160	0	1.0	33.8
Age 6+	0.160	0	1.0	37.9
Age 7+	0.160	0	1.0	40.1
Age 8+	0.160	0	1.0	41.9
Age 9+	0.160	0	1.0	43.0

Sources: Beauchamp et al., 1983; Froese and Pauly, 2001; and Wang, 1986.

Table B1-33: Striped Bass Life History Parameters 1[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.50	0	0	0.0000416
Larvae 5 to 6 mm	1.00	0	0	0.0000457
Larvae 7 to 10 mm	2.01	0	0	0.0000503
Larvae 11 to 14 mm	0.939	0	0	0.0000553
Larvae 15 to 18 mm	0.651	0	0	0.0000898
Larvae 19 mm	0.0610	0	0	0.000135
Larvae 20 to 24 mm	0.312	0	0	0.000207
Larvae 25 to 29 mm	0.286	0	0	0.000397
Larvae 30 to 34 mm	0.334	0	0	0.000616
Larvae 35 to 39 mm	0.375	0	0	0.000977
Larvae 40 to 44 mm	0.441	0	0	0.00136
Larvae 45 to 49 mm	0.904	0	0	0.00194
Larvae 51 to 75 mm	0.700	0	0	0.00421
Larvae 76 to 100 mm	0.350	0	0	0.0105
Juvenile	0.916	0	0	0.0174
Age 1+	0.320	0	0	0.100
Age 2+	0.320	0.18	0.06	0.500
Age 3+	0.320	0.18	0.20	2.30
Age 4+	0.320	0.18	0.63	4.30
Age 5+	0.320	0.18	0.94	6.00
Age 6+	0.320	0.18	1.0	8.50
Age 7+	0.320	0.18	1.0	11.8
Age 8+	0.320	0.18	1.0	13.8
Age 9+	0.320	0.18	1.0	16.0

[a] Life history parameters applied to losses from Contra Costa and Pittsburg.

Sources: California Dept. of Fish and Game, 2000a; Ecological Analysts Inc., 1981b; Froese and Pauly, 2001; Leet et al., 2001; PSE&G, 1999; Setzler et al., 1980.

Table B1-34: Striped Bass Life History Parameters 2[a]				
Stage Name	**Natural Mortality (per stage)**	**Fishing Mortality (per stage)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	1.50	0	0	0.0000416
Larvae	7.44	0	0	0.0000457
Juvenile	0.916	0	0	0.0174
Age 1+	0.320	0	0	0.100
Age 2+	0.320	0.18	0.06	0.500
Age 3+	0.320	0.18	0.20	2.30
Age 4+	0.320	0.18	0.63	4.30
Age 5+	0.320	0.18	0.94	6.00
Age 6+	0.320	0.18	1.0	8.50
Age 7+	0.320	0.18	1.0	11.8
Age 8+	0.320	0.18	1.0	13.8
Age 9+	0.320	0.18	1.0	16.0

[a] Life history parameters applied to losses from Hunter's Point.

Sources: California Dept. of Fish and Game, 2000a; Ecological Analysts Inc., 1981b; Froese and Pauly, 2001; Leet et al., 2001; PSE&G, 1999; and Setzler et al., 1980.

Table B1-35: Surfperches Life History Parameters[a]				
Stage Name	**Natural Mortality (per stage)**	**Fishing Mortality (per stage)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Juvenile	0.560	0	0	0.00443
Age 1+	0.280	0	0	0.0429
Age 2+	0.280	0.28	0.50	0.125
Age 3+	0.280	0.28	1.0	0.203
Age 4+	0.280	0.28	1.0	0.261
Age 5+	0.280	0.28	1.0	0.300
Age 6+	0.280	0.28	1.0	0.324

[a] Includes barred surfperch, black surfperch, calico surfperch, dwarf surfperch, island surfperch, kelp surfperch, pile surfperch, pink seaperch, rainbow surfperch, rubberlip surfperch, shiner surfperch, silver surfperch, spotfin surfperch, striped surfperch, walleye surfperch, white seaperch, and other surfperches not identified to species.

Sources: Cailliet, 2000; Froese and Binohlan, 2000; Froese and Pauly, 2002; and Leet et al., 2001.

Table B1-36: Other Commercial Species Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per Stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] See Table B1-40 for a list of species.

Sources: Able and Fahay, 1998; ASMFC, 2001b; Durbin et al., 1983; Entergy Nuclear Generation Company, 2000; PSE&G, 1999; Ruppert et al., 1985; and U.S. Fish and Wildlife Service, 1978.

Table B1-37: Other Recreational Species Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per Stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] See Table B1-41 for a list of species.

Sources: Able and Fahay, 1998; ASMFC, 2001b; Durbin et al., 1983; Entergy Nuclear Generation Company, 2000; PSE&G, 1999; Ruppert et al., 1985; and U.S. Fish and Wildlife Service, 1978.

Table B1-38: Other Rec/Com Species Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Yolk-sac larvae	2.85	0	0	0.000000728
Post yolk-sac larvae	2.85	0	0	0.00000335
Juvenile 1	1.43	0	0	0.000746
Juvenile 2	1.43	0	0	0.0472
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes barracuda, California sheephead, jack mackerel, lingcod, piked dogfish, and spiny dogfish.

Sources: Able and Fahay, 1998; ASMFC, 2001b; Durbin et al., 1983; Entergy Nuclear Generation Company, 2000; PSE&G, 1999; Ruppert et al., 1985; and U.S. Fish and Wildlife Service, 1978.

Table B1-39: Other Forage Species Life History Parameters[a]				
Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] See Table B1-42 for a list of species.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Table B1-40: Other Commercial Species[a]			
Basketweave cusk-eel	Monkeyface eel	Pacific hake	Spotted cusk-eel
California moray	Monkeyface prickleback	Pricklebreast poacher	Yellow snake-eel
Catalina conger	Moray eel	Ribbon prickleback	
Leopard shark	Pacific hagfish	Rock prickleback	

[a] Includes other organisms not identified to species.

Table B1-41: Other Recreational Species[a]

Angel shark	Chub mackerel	Pacific angel shark	Round stingray
Bat ray	Diamond stingray	Pacific bonito	Senorita
Big skate	Gray smoothhound	Pacific bumper	Sevengill shark
Black skate	Halfmoon	Pacific electric ray	Soupfin shark
Broadnose sevengill shark	Horn shark	Pacific mackerel	Striped mullet
Brown smoothhound	Kelp greenling	Pacific moonfish	Swell shark
California butterfly ray	Mexican scad	Pacific pompano	Thornback ray
California electric ray	Monterey Spanish mackerel	Painted greenling	
California ray	Opaleye	Rock wrasse	

[a] Includes other organisms not identified to species.

Table B1-42: Other Forage Species[a]

Barcheek pipefish	Finescale triggerfish	Ocean sunfish	Sea porcupine
Bay pipefish	Flathead mullet	Ocean whitefish	Sharksucker
Bigscale goatfish	Fringehead	Onespot fringehead	Shovelnose guitarfish
Bigscale logperch	Garibaldi	Pacific butterfish	Slimy snailfish
Black bullhead	Giant kelpfish	Pacific cornetfish	Smalleye squaretail
Blacksmith	Grunt	Pacific cutlassfish	Snailfishes
Blue lanternfish	Gunnels	Pacific lamprey	Snubnose pipefish
Broadfin lampfish	Hatchet fish	Pacific sand lance	Southern poacher
Bullseye puffer	High cockscomb	Penpoint gunnel	Southern spearnose poacher
California clingfish	Hitch	Pipefishes	Specklefin midshipman
California flyingfish	Island kelpfish	Plainfin midshipman	Spotted kelpfish
California killifish	Kelp gunnel	Pygmy poacher	Spotted ratfish
California lizardfish	Kelp pipefish	Ratfish	Squid
California needlefish	Kelpfish	Red brotula	Stickleback
California tonguefish	Lampfish	Reef finspot	Striped kelpfish
Californian needlefish	Lanternfish	Ribbonfish	Sunfish family
Catfish family	Longfin lanternfish	Rockweed gunnel	Thornback
Clingfishes	Longspine combfish	Ronquils	Threespine stickleback
Clinids	Medusafish	Saddleback gunnel	Tubesnout
Codfishes	Mexican lampfish	Salema	White catfish
Combfish	Northern clingfish	Sarcastic fringehead	Zebra perch
Cortez angelfish	Northern lampfish	Sargo	
Crevice kelpfish	Northern spearnose poacher	Scarlet kelpfish	

[a] Includes other organisms not identified to species.

Appendix B2: Valuing Water Use Foregone

INTRODUCTION

APPENDIX CONTENTS

It is difficult to identify the precise value of the water lost to municipal and agricultural users as a result of programs that increase freshwater flows to the San Francisco Bay-Delta. Water is not an actively traded commodity, such as a farm crop or gasoline, where market transactions provide clear market prices. Information is available, however, that can be used to approximate water values. This appendix discusses available evidence and makes an estimate of expected water values.

Identifying water value translates into answering the question, "How much would water agencies be willing to pay today to secure permanent water supplies of delta surface waters?" To answer this question EPA investigated both what water users are currently paying for delta surface waters delivered by the California State Water Project (SWP) and recent California water market transactions.

B2-1 STATE WATER PROJECT

The SWP is the largest state-built, multipurpose water project in the nation. Its main purpose is water supply — to store surplus water during wet periods and distribute it to areas of need throughout California. Construction began after passage of a $1.75 billion public bond issue in 1960. The main storage reservoir is Lake Oroville in northern California. Water is transported through the Feather and Sacramento rivers and a system of canals, pipelines, pumping plants, and power plants for use by agricultural and urban users (29 water agencies). It is likely that SWP water deliveries will be lowered to increase delta flows, in the same manner that Central Valley Project (CVP) diversions already have been reduced.

Table B2-1 shows what SWP water customers currently pay for SWP water. Water costs vary widely by geographic region largely because of differences in conveyance costs. SWP water is least expensive in the San Joaquin and Feather River areas, between $65 and $69 per acre foot (AF) of entitlement, or between $83 and $88 per AF for water delivered (assuming 78 percent of entitlement is delivered in an average year). The delivered price of SWP water to coastal areas (e.g., Santa Barbara) is as great as $986/per AF.[1] The average weighted cost of delivered SWP water is $182/AF.

These costs provide information on the lower bound of water value. The 29 purchasing water agencies value the water by at least the amount they pay for the water, or else they would dispose or sell their interest in the SWP. The $83/AF cost estimate provides a firm lower bound of the value of water to its current buyers (users). Most of the water used in the San Joaquin area is used for agriculture. Hence, the $83/AF estimate provides a firm lower bound for agricultural water. In other words, if CALFED offered to buy SWP users' entitlement rights at $83/AF of delivered water ($65/AF of entitlement water), there would be very few, if any, sellers. Thus, EPA applied a range of from $100 to $200 per AF as the value of water to agricultural users, given that it costs these users at least $83/AF to obtain the water.

[1] This is only the SWP cost. Many users pay additional costs to transport water from SWP facilities to their location. For example, Santa Barbara pays the Central Coast Water Authority to move water to their service area. Additional costs are also associated with treating water.

Table B2-1: State Water Project Costs

Service Area	Cost of Entitlement ($/AF)[a]	Effective Cost for Water Delivered ($/AF)[b]	Entitlement (AF/yr)[a]	% Entitlement
San Joaquin	$65	$83	1,178,937	50.2%
Feather River	$69	$88	1,421	0.1%
South Bay Area	$113	$145	147,186	6.3%
North Bay Area	$180	$231	37,871	1.6%
Southern California	$233	$299	973,254	41.5%
Coastal Area	$769	$986	8,538	0.4%
Average/Total	$142	$182	2,347,207	100.0%

[a] Information from Davis et al., 1999. Excludes other deliveries.
[b] Adjusted to reflect actual delivery of entitlement averages of 78 percent (e.g., $65/0.78 = $83).

The SWP water costs also indicate that an offered water price would have to be high for municipal users to surrender their SWP water entitlements. In the central coast counties of San Luis Obispo and Santa Barbara, the offer would need to exceed $986/AF, the effective price that this area is currently willing to pay for SWP water. That is, municipal users in some portions of California are paying nearly $1,000/AF for water from the SWP. The value of water is high in this area because of the limited and expensive alternative water supply options (e.g., desalination). The acceptance price might be lower for other municipal agencies that have other, less expensive alternative water supplies.

B2-2 WATER MARKET TRANSACTIONS

Another approach that can be used to estimate the value of water is to review recent California water transactions. EPA identified 20 transactions in California from January 1998 to March 2000 (see Table B2-2). Most of the transactions (14) involved municipal agencies purchasing water supplies to serve growing populations. The water price associated with these municipal transactions ranged from $90 to $412/AF, averaging $267/AF. Every transaction had unique circumstances and conditions that may affect the transaction price (e.g., reliability of water yield, water quality, duration of the purchase agreement). The water transactions involving groundwater in West Coast Basin, Central Basin, and the Main San Gabriel Basin showed municipal users selling water in the $300 to $320/AF range.

Four transactions involved municipal users purchasing SWP water. These transactions included a one-time payment of $1,000/AF entitlement (1,000 AF per year, indefinitely), plus assumption of SWP expenses. This translates into an average price of $290/AF on an annual AF basis.

From this information, EPA estimated the approximate value of water for municipal agencies to be at least $300/AF. The SWP deliveries to southern California cost about $299/AF delivered. Given expected future water shortages, EPA surmises that not many municipal customers (e.g., Metropolitan Water District of Southern California) would sell their interests in SWP water for $300. Hence, the value is most likely much higher.

Table B2-2: Recent California Water Transactions

No.	$/AF[a]	AF/yr	Use[b]	Source	Transaction	Date	Acquirer	Supplier	Comments
1	$45	1,000	I	Surface	Lease	1998	Garfield WD	Madera Irrigation District	Ag transfer of surplus water supplies
2	$90	5,000	M	Surface	Lease	1998	Alameda County FCWCD#7	Byron Bethany ID	15-year lease near S.F.
3	$177	8,000	M	Surface	Purchase	1998	Western Hills WD	Berrenda Mesa Water District	Transfer of SWP entitlement; $1,000/AF + SWP costs
4	$300	4,531	M	Ground	Purchase	7/98 - 6/99	Various	Various	2 adjudicated basins in Southern CA
5	$150	10,000	M	Ground	Lease	Feb-99	Orange County	San Bernardino Valley	1-year lease Bunker Hill Basin near L.A.
6	$320	2,748	M	Ground	Purchase	7/98 - 6/99	Various	Various	Main San Gabriel Basin near L.A.
7	$241	15,000	M	Surface	Purchase	Oct-99	Alameda County FCWCD#7	Lost Hills Water District (Ag)	Transfer of SWP entitlement; $1,000/AF + SWP costs
8	$164	54,352	M	Ground	Lease	7/98 - 6/99	Various	Various	2 adjudicated basins in Southern CA
9	$200	5,950	M	Surface	Lease	1998	City of Inglewood	Western Water Company	5-year lease near L.A.
10	$240	23,416	M	Ground	Lease	7/98 - 6/99	Various	Various	1-year lease; Main San Gabriel Basin near L.A.
11	$361	4,000	M	Surface	Purchase	Jun-99	Palmdale WD	Belridge WD	Transfer of SWP entitlement; $1,000/AF + SWP costs
12	$297	13,697	M	Surface	Lease	1998	Mojave Water Agency	CA Dept of Water Resources	Reduce aquifer overdraft in Southern CA
13	$380	41,000	M	Surface	Purchase	May-99	Castaic Lake WA	Wheeler Ridge WD	Transfer of SWP entitlement; $1,150/AF + SWP costs
14	$409	20,000	M	Surface	Lease	Oct-99	City of San Diego	Western Water Company	1-year lease in Southern CA
15	$412	10,000	M	Surface	Lease	Jun-99	Santa Margarita WD	Western Water Company	1-year lease in Southern CA
16	$55	30,000	M & I	Surface	Lease	Nov-99	Stockton East Water District	Oakdale & South San Joaquin Ids	10-year lease of Stanislaus River water
17	$30	10,000	PT	Surface	Lease	2000	Bureau of Rec	Semitropic Water Storage District	1-year lease for San Joaquin Valley Wildlife Refuges
18	$60	50,000	PT	Surface	Lease	Oct-99	Bureau of Rec	Oakdale & South San Joaquin Ids	1-year lease to augment San Joaquin River flows
19	$60	30,000	PT	Surface	Lease	Jun-99	Bureau of Rec	Vernalis Adaptive Management IDs	San Joaquin River augmentation
20	$65	10,000	PT	Both	Lease	2000	Bureau of Rec	San Luis Canal Company	1-year lease for San Joaquin Valley Wildlife Refuges
Average Price $/AF			All	203					
Average Price $/AF			M	267					
Average Price $/AF			PT	54					

[a] Price for purchases are converted into $/AF terms using an infinite time horizon and a 10 percent annual discount rate. Dollars are current for the year of the transaction (1998, 1999, or 2000).
[b] I = irrigation, M = municipal, PT = public trust.

B2-3 SUMMARY

Our review indicates that the value to agricultural and municipal users of water use foregone is at least $100 and $300/AF, respectively. These estimates are probably biased downward, and we therefore show an upper bound value of $200/AF and $1,000/AF for agricultural and municipal users, respectively.

For the purposes of this project, we need to identify a weighted average value of water lost because of enhancements in water flows in the delta for environmental purposes. We weighed the value per AF estimates based on the assumption of a proportional cutback in water supplies between agricultural and municipal users. We used CVP and SWP water uses as a basis for our weighting. Table B2-3 shows the results and a weighted value of water from $155/AF to $425/AF. Applying these values to 3 to 4 million AF per year, the opportunity cost of the water use foregone is in the range of $465 million to $1.7 billion annually.

Table B2-3: Summary of Uses and Values for Foregone Water to SWP and CVP Water Users

Water User Type	SWP and CVP Water Delivered (AF/yr)	% of Use	Estimated Value to Users ($/AF)
Municipal	2,569,328	28%	$300 to $1000
Agricultural	6,697,256	72%	$100 to $200
Total	9,266,584	100%	$155 to $425

Source: Davis et al., 1999.

Appendix B3: Special Status Species Population Estimates

The historical (target) and current abundances of delta smelt, longfin smelt, and Sacramento splittail were estimated to calculate the number of fish needed to restore current populations to pre-decline levels. This appendix describes the method used to estimate historical and current abundances of these special status species.

In their 1990 report to the California Fish and Game Commission, Stevens et al. (1990) calculated the delta smelt population by using the ratio of juvenile delta smelt to young striped bass caught in the fall midwater trawl survey. This ratio was multiplied by striped bass population numbers that were derived from a life table analysis. The resulting population estimate of delta smelt is the only known attempt to approximate total delta smelt populations in the Sacramento-San Joaquin Delta. Using the 8 years of available striped bass data, EPA extrapolated longfin, delta smelt, and Sacramento splittail populations through the 1990's and into 2000. This extrapolation involved:

- averaging (across the 8 years) the percentage of the total striped bass population caught in the trawling runs; and
- dividing the average percentage of the striped bass population caught in the trawling runs by delta smelt, Sacramento splittail, and longfin smelt abundance indices taken from the fall midwater trawl survey conducted annually for more than 30 years.

Tables B3-1 and B3-2 show annual population numbers derived for delta smelt, longfin smelt, and Sacramento splittail using this method. Table B3-1 shows population estimates for the baseline 8 years from 1968 to 1985 (nonsequential years are due to trawling surveys not conducted in that specific year). Table B3-2 presents population estimates for 1990-2000 based on the average striped bass index of 0.13 percent (striped bass caught versus estimate of total striped bass population) that was calculated across the baseline range (1968-1985).

Table B3-1: Sacramento-San Joaquin Delta Population Estimates of Striped Bass, Sacramento Splittail, Delta Smelt, and Longfin Smelt (1968-1985)[a]

Species	1968	1970	1971	1972	1975	1977	1984	1985
Striped bass	1,800,000	8,100,000	11,900,000	12,700,000	1,600,000	400,000	11,800,000	4,700,000
Delta smelt	302,390	1,634,065	1,630,634	2,620,372	245,207	217,894	326,333	293,750
Longfin smelt	1,433,744	6,382,913	20,006,867	1,574,295	991,733	95,130	13,374,290	2,649,091
Sacramento splittail	7,820	24,418	22,526	26,929	1,407	0	28,689	40,057

[a] Note: Population estimates for **delta smelt, longfin smelt,** and **Sacramento splittail** in this table are equal to each year's ratio of striped bass caught vs. estimated total striped bass population (Stevens et al., 1990), divided by annual trawling abundance indices for these special status species. See text for explanation.

Table B3-2: Sacramento-San Joaquin Delta Population Estimates of Striped Bass, Sacramento Splittail, Delta Smelt, and Longfin Smelt (1990-2000)[a]

Species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Striped bass	1,053,199	752,627	1,630,426	1,241,356	1,003,768	385,881	312,532	452,852	975,864	431,325	310,937
Delta smelt	290,208	549,322	124,375	859,462	81,322	716,750	101,254	241,574	334,855	688,845	602,739
Longfin smelt	193,738	106,835	60,593	636,225	434,514	6,893,233	1,106,617	550,119	5,305,063	4,179,312	2,741,029
Splittail	6,378	14,351	2,392	7,973	2,392	60,593	17,540	797	224,034	31,094	6,378

[a] Note: Population estimates for **striped bass, delta smelt, longfin smelt,** and **splittail** in this table are equal to the average of the 1968-1985 population estimates developed in Table B3-1. See text for explanation.

A Review of

Diablo Canyon Power Plant Independent Scientist's Recommendations to the Regional Board Regarding "Mitigation" for Cooling Water Impacts, July 27, 2005

by

Prof. Charles D. Kolstad[1]

21 July 2006

[1] For identification only: Bren School of Environmental Science & Management, University of California, Santa Barbara. Email: ckolstad@sbceo.org. Website: http://www.ckolstad.org.

INTRODUCTION

The subject report, *Diablo Canyon Power Plant Independent Scientist's Recommendations to the Regional Board Regarding "Mitigation" for Cooling Water Impacts, July 27, 2005* ("Independent Scientists" report) appears to be a report on benefits from reducing I&E and thermal impact loss at DCPP. But in fact, it is something else entirely. The authors state right at the beginning that they are responding to the Regional Board's request for a list of projects that might be undertaken to "mitigate" the I&E losses and thermal effects of cooling water intake and discharge at DCPP. In fact, the Regional Board appears to have given the authors a list of specific mitigation projects to analyze (p2).

Although the report is interesting and potentially useful, it is important to make one thing perfectly clear: this is not an estimate of the benefits of reducing I&E losses at DCPP. Nor is the report an estimate of damages from I&E at DCPP. My conclusion is based on accepted economic principles as well as my reading of the 316(b) regulations promulgated by EPA in the Federal Register (July 9, 2004).

The Independent Scientists seem a little confused about this point themselves. For the most part they quite appropriately describe the proposed projects as ways of mitigating the losses from I&E. The problem with the report arises when they interpret the costs of the projects as estimates of damages from I&E loss and thermal discharge (for instance, the first paragraph on p. 21 or the first paragraph of their conclusions on page 34). This is incorrect.[2] The cost of a project which fully mitigates damages only

[2] To non-economists, it may seem logical to equate damages to the cost of totally restoring the damaged ecosystem to its original state. But the fallacy in that argument can been seen through example. Suppose there is a enormous old tree in my front yard that provides shade but also sheds many annoying leaves and is close to the end of its life. A car accidentally hits the tree, knocking it over. The damage is not the cost

serves as an *upper bound* on those damages and that upper bound may (or may not) be orders of magnitude higher than the actual damages.

This approach of defining projects to mitigate the adverse impacts of I&E losses is what is known as "Habitat Replacement Cost" (HRC) in the context of 316(b) regulations. The EPA is quite clear that it does not consider HRC a valid method for measuring the benefits of reduced I&E. The EPA specifically discusses the appropriateness of using HRC in their national cost-benefit analysis of the 316(b) rule and excludes it from their analysis of benefits.[3]

In the context of appropriate ways of measuring benefits of I&E loss reductions in support of a site-specific determination of best technology available for I&E reductions, the EPA is clear about what methods should be used for measuring benefits:

> "When conducting quantitative benefits assessments, permittees should carefully review and follow accepted best practices for such studies. A discussion of best practices regarding valuation can be found in EPA's Guidelines for Preparing Economic Analyses (EPA 2000, EPA 240-R-00-003, Sept 2000) and OMB Circular A-4: Regulatory Analysis (September 17, 2003, www.whitehouse.gov/omb/inforeg/circular_a4.pdf)."[4]

The EPA Guidelines specifically address methods similar to those used by the Independent Scientists:

> "Alternative approaches that estimate the total value of ecosystems based on the replacement cost of the entire ecosystem ...have received considerable attention as of late. However the results of these studies should not be incorporated into benefit assessments. The methods adopted in these studies are not well grounded in economic theory nor are they typically applicable to policy analysis."[5]

---

of hauling in and planting another old enormous tree. That would be extremely costly and perhaps not even feasible. The damage is a more subtle concept of what money or other services (such a young and smaller native oak) would make up for my lost well-being or lost property value in losing the tree.

[3] Federal Register, July 9, 2004 (pp. 41624-5).

[4] Federal Register, July 9, 2004 (p. 41648).

[5] EPA, "Guidelines for Preparing Economic Analyses" (EPA Report 240-R-00-003, Sept 2000), p98.

It is clear that the EPA does not consider the approach used by the Independent Scientists to be a valid approach to estimating the benefits of reducing I&E losses.

Several caveats are in order regarding this review of the Independent Scientist's Report. One is that just because EPA does something in its own analysis[6] of the 316(b) rules does not necessarily mean that the EPA approach is economically correct or consistent with "best practice" in economics (though for the most part, the EPA analyses are very good). Another caveat is that I have assumed the biologic components of the Independent Scientist's Report are correct -- this reviewer is not a biologist.

GENERAL COMMENTS

These general comments address the specific questions in the Peer Review Charge. Each of the points raised here is further elaborated in the subsequent section on Specific Comments.

1. Is the organization of the report appropriate and does it present the material in a clear and concise manner? Are there any changes that are recommended?

As a report on mitigation projects, particularly considering that the list of projects is given by the client, the report is well-written. I would urge the authors to clarify what they mean by mitigation and what the significance is of the nexus of the mitigation project to the loss being mitigated. If their intent is to provide a study of 316(b) I&E losses, the authors may want to focus exclusively on I&E losses and not bring in losses from the thermal effects of discharged cooling water. In any event, thermal issues seem

[6] "Economic Benefits Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule," EPA Report EPA-821-R-02-001 (February 2002); and "Economic Benefits Analysis for the Final Section 316(b) Phase II Existing Facilities Rule," EPA Report EPA-821-R-04-005 (February 2004).

minor in the report. Most importantly, I would urge the authors to be quite clear that they are not valuing the I&E losses.

2. Is the report consistent with economic principles of measuring benefits? Are there any changes that would make it more consistent with accepted economic principles?

As a report on benefits of reducing I&E losses, the Independent Scientist's report is totally inconsistent with accepted economic principles of measuring benefits. The report would have to be totally redone for it to be an acceptable benefits assessment of reducing I&E losses at DCPP.

3. Is the report consistent with the EPA Phase II 316(b) regulations for measuring benefits? Are there any changes that would make it more consistent?.

The Independent Scientist's report is also inconsistent with guidelines provided by EPA for measuring benefits of reduced I&E losses in connection with 316(b) regulations (Federal Register, July 9, 2004). The EPA is quite explict regarding how it values these benefits and how permitees subject to 316(b) rules should value these benefits.[7] The report would have to be totally redone for it to be consistent with EPA guidelines.

4. Are the potential economic effects of I&E addressed in a manner consistent with standard principles and practices for conducting benefits studies?

As articulated above, the approach in the Independent Scientist report is totally inconsistent with standard principles and practices for conducting benefits studies. I say this with great respect for the undoubted credentials of the authors as biologists.

[7] To quote from p 41647 of the Federal Register (July 9, 2004): "Well-established revealed preference and market proxy methods exist for valuing use benefits, and these should be used in all cases where the I&E mortality study identifies substantial impacts to harvested or other relevant species." The section goes on to indicate when non-use benefits need to be monetized.

5. Are all of the relevant benefit categories included in the analysis? Are any significant categories omitted? If there are omitted categories, what methods could be used to reliably assess their value?

The report is remarkably silent on the commercial and recreational effects of reducing I&E losses. The focus is much more biologic with little reference to the economic context. For instance, the artificial reef is their recommended mitigation option but they acknowledge it does not help some species, such as the halibut. According to TER, the halibut accounts for over half the I&E losses to commercial and recreational fishing.[8] This is another illustration of the problems of focusing on mitigation projects.

6. Are potential nonuse benefits addressed in a way that is consistent with economic principles and benefits practices? Are they addressed consistent with the EPA Phase II 316(b) regulations? Are any changes necessary?

The authors do not explicitly consider non-use values and thus their treatment is inconsistent with EPA Phase II 316(b) regulations. This would need to change if the authors wish to treat this report as a benefits assessment of reduced I&E losses. However because of the approach the authors use, much of the benefit of the mitigation projects they consider are associated with biologic resources with little or no use value. Nevertheless, their analysis does not constitute a quantitative or qualitative treatment of non-use value as required by EPA.

7. Is the empirical analysis consistent with standard statistical and econometric procedures? Specifically, are the data appropriate for the task or could better data have been used? Are the benefit calculations performed in a manner that is consistent with

---

[8] Table A.3 (p 45) of TER Report.

standard economic practices? Are there improvements that should have been implemented?

The estimates of project costs for the several mitigation projects are remarkably informal. The cost estimate for the artificial reef seems to be based on a conversation with an engineer who was involved with a reef at another power plant. Even given that, costs of the rock needed for the reef are not completely estimated. Similar comments apply to the other projects considered.

8. Is the uncertainty analysis consistent with standard statistical principles and practices? Have the relevant sources of uncertainty been accounted for? Have the appropriate confidence intervals and other statistical principles been calculated and used in the appropriate manner? Are there any improvements that should be implemented?

Although the Independent Scientists recognize that there is uncertainty in many of their estimates, there is very little explicit consideration of uncertainty in the report. Certainly this component of the report should be upgraded if it is to meet the requirements of the 316(b) regulations.

9. Does the study provide a reliable estimate of the potential benefits of reducing I&E impacts at DCPP? If so, why so? If not, would it be reliable if the proposed changes you have recommended were implemented in appropriate fashion?

As has been articulated above, the study does not provide an estimate of the potential benefits of reducing I&E impacts at DCPP. This is a study of mitigation projects. In order to turn this study into a study of the benefits of reduced I&E losses, it would have to be completely redone, following the methodological lead of the EPA. An important step would be to include as a co-author of any revision someone qualified to address benefits of reductions in I&E losses. The Independent Scientists acknowledge (at the top of p21) that they are not economists and thus must only rely on beliefs to generate an estimate of the value of I&E losses. Similarly, in the last paragraph on p 20, they appear to be unaware of the enormous amount of literature generated by EPA and others regarding how to estimate the value of losses from I&E.

SPECIFIC COMMENTS.

The following are some specific comments on a number of points in the Independent Scientists'report.

1. Mitigation vs Compensation. One of the specific comments pertains to how the Independent Scientists use the word "mitigation". In many places mitigation is used in a direct, physical sense of projects that yield direct replacement of the losses from I&E (and thermal discharge). In fact, this definition is implied in a number of places, such as the top of p3 (and in section 3.7 on p30) where the use of PG&E facilities is dismissed as not mitigation. In other places, the authors take a broader view of the purpose of the proposed projects as compensating for impacts, broadly defined (eg, bottom of p2). There are numerous other examples in the text. My advice would be to clearly articulate how the authors are using the term "mitigation" as well as the relevance of "nexus" to the physical losses. Distinguish the notion of mitigation with a close nexus to the loss from other ecologically beneficial projects that simply compensate for the I&E losses (see bottom of p3).

2. Artificial Reef. Another set of comments applies to the discussion of the artificial reef in section 3.1. Two of the four key conclusions regarding the reef (p. 6) are simply unsupported by the analysis, in my opinion.

The first key conclusion (p. 6) is that the reef could "compensate for the majority of the impacts associated" with I&E. Unless this is purely a biologic concept with which I am unfamiliar, I find this conclusion unsupported by the analysis. Since the authors do not measure the impacts associated with I&E, how can they conclude that the majority are compensated by the reef. Perhaps it is simply the majority of lost larvae by weight, without regard to significance? What is of concern is that when the authors describe the reef project, they make it clear that sandy habitat species are not helped by the project. In Table 2, crab, sanddabs and halibut are three major species with considerable value to man that are apparently not helped by the artificial reef (at least if I am interpreting their Table and statements correctly – see the top of p9). In the TER Report, these three species make up over 90% of the commercial and recreational losses from I&E from DCPP. Clearly there is something amiss in the analysis or discussion.

The fourth key conclusion (p. 6) is similarly flawed. As has been articulated above, the cost of an artificial reef is NOT the single best estimate of the value of the lost resources, even if the reef did result in the replacement of all of the life lost to I&E. EPA makes this clear and it is accepted practice among valuation economists. The cost of replacing habitat can be an upper bound to the value of the lost resources but as an upper bound may be much higher than the true value, though that cannot be determined without an analysis of the value of the lost resources.

A minor note concerns the graphs reproduced on pp 16-18. To the uninitiated, it is unclear how they add to the discussion. At minimum, they should be redrafted and put into the context of the section.

The analysis of costs of the artificial reef (p 20) is a start but very loose for the key number in support of their estimate of mitigation-based losses. They should be more rigorous, for instance tracking down how much rock might cost to transport to the site, rather than indicating that this might raise the cost.

3. Marine Protected Areas. The discussion of marine protected areas is less lengthy than the discussion of artificial reefs. Apparently, one of the main advantages of a marine protected area is that it addresses those species which are not helped by the reef.

A minor point concerns item #5 at the top of p. 23. A marine reserve need not be permanent. It's lifetime can precisely match the period of I&E loss from DCPP.

At the bottom of p24, the Independent Scientists consider it unreasonable to ask PG&E to fund Marine Protected Areas for the entire State of California. Although I am sure PG&E would like to hear that, the statement is not supported by analysis and really doesn't belong in a report such as this. It is unsupported opinion; in fact, it is a policy statement and policy is one of the areas in which the Independent Scientists did not wish to venture (item #1 at the bottom of p3).

There is an additional cost to a marine protected area, at least to the extent commercial and recreational fishing and shellfishing is excluded. The authors should include that cost in their analysis.

In the first full paragraph at the top of p26, the authors say it is reasonable to err on the side of over-mitigating for entrainment losses. Why is this?

4. PG&E Lab Facilities. The Independent Scientists dismiss the use of the PG&E labs because of a lack of "nexus to the impacts." Yet other activities which are more favored are similarly disconnected (such as the docent program). Certainly the fact that the labs have been torn down is a good reason not to consider them. But consistency in the arguments would be helpful.

5. Conclusions. Many of the issues raised above also apply here. In the first paragraph of the conclusions, the Independent Scientists say that the cost of an artificial reef ($10.6 -- $26 million) is the best estimate for the "value" of the entrainment losses. In the very next sentence they acknowledge that this is not the "value" of entrainment losses as an economist would estimate them. I would reiterate that they should remove any conclusions that their analysis is anything more than an examination of a set of possible projects which could mitigate some of the I&E losses from DCPP. In fact, they should emphasize that their analysis is NOT a computation of the value of reducing I&E losses at DCPP.

INDEPENDENT PEER REVIEW

DIABLO CANYON POWER PLANT CLEAN WATER ACT SECTION 316(B)

ECONOMIC BENEFITS VALUATION STUDIES

Robert T. Deacon
Department of Economics
University of California, Santa Barbara

July 10, 2006

1 BACKGROUND

This "Background" section discusses the protocols and research results developed by EPA in connection with its rule-making for Section 316(b) of the Clean Water Act. EPA's research into the measurement of benefits from reduced I&E mortality and the format developed for valid a benefits valuation studies are both thorough and rigorous. In my view, EPA's recommended approach is designed to yield estimates that are as reliable as the current state of the art will permit.

1.1 Regulatory requirements and economic methodology

My understanding of the relevant regulation, Sec. 316(b) of the Clean Water Act, is based on:

> Environmental Protection Agency, *National Pollution Discharge Elimination System—Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities: Final Rule*, as published in Federal Register, Friday, July 9, 2004, pp. 41576-41692.

In my report I reference this document as follows; Fed. Reg., and appropriate page numbers.

A facility that demonstrates that the costs of compliance with performance standards and/or restoration requirements would be significantly greater than the benefits will be given a site-specific determination of best technology available for minimizing adverse environmental impacts (Fed. Reg., p. 41597). EPA carried out extensive analysis on the measurement of benefits of reduced impingement and entrainment (I&E) mortality and developed detailed protocols for such analysis. A description of EPA's general research approach, comments received and EPA responses and reactions are found in Fed. Reg. pp. 41623-41625. At various points, these same passages provide EPA conclusions regarding appropriate procedures for carrying out benefit studies, research methods considered reliable or unreliable and sources of additional information on EPA's more detailed research into these questions.

In Section IX, Implementation, H(2) Alternative Site Specific Requirements, (Fed. Reg., pp.41647-41648) EPA lays out requirements for a valid benefits valuation study. Such studies must use a comprehensive methodology to fully value impacts of I&E mortality and must include a description of the methods used to value commercial, recreational and ecological benefits including any non-use benefits, if applicable. Other requirements are that the effects of significant uncertainty be analyzed and that a narrative description of any non-monetized benefits be included. The same section delineates certain requirements: (i) that 'use benefits' to recreational and commercial fishermen be determined, using well-established revealed preference and market proxy methods; and (ii) that non-use benefits to ecological resources that the public considers to be important be considered and that these impacts be monetized if the I&E study identified substantial harm to threatened or endangered species or to the maintenance of (marine) community structure and functioning. In the course of examining the national costs and benefits of this rule, EPA carried out 'benefits analyses' for 46 facilities in various regions of the country. This research produced both an extensive set of procedures for implementing benefit estimation and a detailed body of empirical results that can be used to enable benefits analysis at specific facilities.

1.2 EPA procedures for determining 'use' benefits of reduced I&E mortality

The procedures developed by EPA for its regional analysis of the benefits from reducing I&E losses are described in Section 316(b) Phase II Final Rule—Regional Studies, Part A: Evaluation Methods. Figure A5-1 in this document illustrates the procedure and Chapter 5 (Methods used to Evaluate I&E) explains it in more detail.

Briefly, the procedure EPA developed proceeds as follows:

1. Data on I&E losses and species life history are compiled and analyzed. I&E losses are expressed in Age-1 equivalent losses for each species, both forage and fishery species.[1] Reductions in I&E losses resulting from compliance with section 316(b) are then computed.
2. Natural mortality rates are applied for subsequent ages to estimate the number of additional organisms surviving to each age considered, by species, as a result of reduced I&E mortality.
3. Age-specific fishing mortality rates are applied for each commercial or recreational fishery species. This gives potential 'direct' fishing yields gained from reduced I&E mortality, by species.
4. To determine benefits from reduced mortality of forage organisms (species or individual organisms not caught by commercial or recreational gear,) steps 1 and 2 above are followed and weight-by-age information is incorporated to determine the total gain (weight) of forage species due to reduced I&E mortality. Trophic transfer coefficients are used to translate this into additional biomass production commercial and recreational species. Step 3 is then applied to give increased fishing yields due to reduced I&E mortality of forage fish.
5. Total harvest gains due to reduced I&E mortality are split into commercial and recreational fractions based on the split of total harvests in the state, by species.
6. Prices are applied to commercial catches for each commercial species to determine the total revenue gain due to reduced I&E mortality. EPA guidelines estimate that 0%-40% of this total revenue would be captured by commercial fishing enterprises as producer surplus.
7. Unit values are applied to estimated increases in recreational harvests, to determine the associated recreational fishing benefit. These unit values were estimated in EPA's analysis of recreational fishing behavior.

In my opinion this protocol represents a thorough and sophisticated approach to valuing the use benefits associated with reduced I&E mortality.

---

[1] These estimates are based on a simple yield-per-recruit analysis of I&E losses. That is, one estimates the annual number of organisms lost due to I&E, by species. Then, natural mortality rates are applied to express these in terms of age-1 equivalent animals, by species.

1.3 Comments on the fishery model in EPA guidelines

The population growth model EPA uses assumes recruitment is fixed, survival rates to subsequent life stages are fixed, and fishing mortality rates are fixed as well. The most commonly used fishery economics models incorporate biological models that exhibit density dependent growth.[2] They postulate a finite carrying capacity for the population of a species based on the environmental conditions it inhabits, e.g., food sources, habitat, density of predators, etc. If the population is reduced below its carrying capacity, e.g., due to some new source of mortality, this model predicts that the natural growth rate will increase due to greater availability, per organism, of food, habitat, etc. If EPA had based its analysis on density dependent growth, the resulting benefit estimates might have been substantially different.

EPA's guidelines recommend that commercial fishing benefits should be calculated at 0%-40% of total revenue. A range of outcomes is possible because the fishery rent captured by harvesters will depend on the state of fishery regulation, how well regulations are obeyed, cost conditions and other factors. EPA provides no basis for the percentages it recommends and no guidance as to which percentage from this range should be applied to a particular species. I simply observe at this point that the literature on fishery economics may well allow more precise guidance than the 0-40% span on this question.

EPA's guidelines for commercial fishing benefits assume that reductions in I&E losses are too small to affect prices, hence no consumer surplus would be gained. This is almost certainly true for commercial fish destined for frozen or canned markets, as these markets extend over large areas. It is more questionable for fresh fish markets, which can be more localized.[3]

1.4 EPA's recommendation on non-use benefits

Non-use benefits from protecting a resource are benefits that are not connected with direct use of or interaction with the resource. Of the organisms protected by the section 316(b) Phase II rule, EPA estimates that only about 1.8% will be harvested by commercial or recreational fishing nationwide and only about 4.8% will be harvested in California. Any value society places on the remaining 98.2% nationwide, and 95.2% in California, will not be captured standard methods for measuring use values. The appropriate benefit concept for non-use values is society's willingness to pay for their protection.

One category of non-use benefit results from the fact that uncaught, and hence unused, fish serve as prey for stocks that do have direct use value. These prey resources are indirectly valuable in the provision of use benefits and the resulting benefits can be categorized as non-use (or perhaps indirect use) benefits. As explained in Section 1.2 of this report these 'prey effects' can, given sufficient biological information, be estimated and the associated benefits measured using methods appropriate for measuring use

---

[2] See Schaefer (1954), Clark (1976), Conrad and Clark (1987).

[3] As explained below TER assumes price reductions do occur.

benefits. This is an entirely appropriate extension of well-accepted economic theory and empirical methods.

Other non-use benefits from protecting a resource are associated with, for example, simply knowing that a resource exists and with the desire to preserve it for use by one's heirs. The only method that has been used to estimate such values in a broad range of applications is the elicitation of 'stated preferences' through surveys. It amounts to asking individual citizens what they would be willing to pay to have the resource in question protected to a specified degree. This approach is controversial and has not gained unanimous acceptance by the profession, but it does encompass the leading set of techniques applied in valuing non-use benefits.

EPA considered various methods for estimating non-use values for the organisms protected from I&E losses by the 316(b) rule and eventually concluded that, aside from valuing 'forage fish' as described above, the current state of the art for estimating such values is too imprecise for use in the present context. (See Federal Register, pp. 41624-41625, 41660-41662; see, also, EPA Regional Studies report, Part B: California, Chapter B5.) EPA noted that the reliability of stated preference approaches cannot generally be validated and that the estimates it produces are potentially subject to a variety of biases. EPA did not attempt to monetize non-use benefits in its California regional study, aside from valuing prey fish, and instead simply listed without discussion potential categories of non-use benefits.[4]

The 316(b) rule EPA requires a qualitative and descriptive discussion of non-use benefits form I&E mortality loss reductions and concludes that monetization is necessary only if an I&E loss assessment demonstrates that such losses impose a substantial harm to threatened or endangered species or to the maintenance of community structure and function. (See Fed. Reg., pp. 41647, 41648.)[5] While precise estimates of non-use impacts surely would be desirable, such precision is not possible given the current state of the art for valuing non-use benefits from protecting environmental resources.

1.5 EPA's recommended approach for treating uncertainty

In its regional studies report EPA acknowledges that both the structure of the biological and economic models used to assess I&E losses and the values of the parameters inserted into these models are subject to uncertainty. EPA makes a standard recommendation for addressing parameter value uncertainty, Monte Carlo analysis. The Monte Carlo approach requires one to specify a distribution of possible values for each parameter in the model that is considered uncertain. These distributions are typically based on experience or on intuition. Values of the parameters regarded as uncertain are then drawn from the specified distributions, inserted into the model, and the model's overall

[4] EPA does, in Chapter B6 of the regional studies report, explore a societal preferences approach and a benefits transfer approach for estimating non-use values for protecting threatened or endangered species, but does not put either into practice owing to uncertainties and imprecision that could not be resolved. As explained elsewhere in this report, EPA also considered approaches based on habitat replacement.

[5] In its own regional studies analysis of I&E mortality reductions in California (Regional Studies report Part B: California, Chapter B5: Non-use Benefits), EPA expressed a belief that non-uses values for I&E mortality reductions are likely to be "appreciable," but did not quantify what appreciable means in practice and referred to the entire state rather than to any specific Phase II facility.

prediction or result, e.g., the benefit from reducing I&E mortality, are recomputed.[6] Replicating this process numerous times yields a distribution of possible results that reflects the postulated uncertainty in the model's parameters. (EPA's discussion assumes 10,000 replications.) This general method for quantifying the effects of uncertainty on decision variables is common in economics and other disciplines.

1.6 Peer review criteria

In my opinion the research program EPA carried out in the process of determining the national *use* benefits of reduced I&E mortality is both thorough and sophisticated—it reasonably represents the state of the art for measuring such benefits. While I have questions on certain specifics of their approach to measurement, particularly the model of fishery growth used and the range of uncertainty provided for estimating commercial fishing benefits, these are relatively minor concerns.

While non-use benefits from reduced I&E mortality are potentially significant, EPA has no solution to the problem of providing reliable estimates of the magnitudes involved. This is a reflection of the fact that the state of the art in valuation of non-use benefits has not advanced to a stage where firm estimates of society's willingness to pay for such benefits can be made. In fact, I regard the EPA approach to valuing forage fish as a significant contribution to this problem, while recognizing that the value society attaches to 'uncaught fish' probably extends beyond what this method can represent.

On balance, and in light of the state of the art in this field, I regard EPA's overall approach to valuing the benefits from reduced I&E mortality as a 'best practice' template for assessing the benefits of reduced I&E mortality at DCPP, pursuant to Sec. 316(b) of CWA.

[6] It is common to specify a uniform distribution for the parameter values and to assume that the distributions of different parameters are independent, that is, that the value drawn for one parameter in a particular replication does not depend on the value drawn for other parameters.

2 TRIANGLE ECONOMIC RESEARCH STUDY

2.1 General Question:

Does the TER report provide reliable measures of the economic benefits of reducing I&E at DCPP? What changes, if any, would be needed to provide reliable estimates of these benefits?

See the response to question 9.

2.2 Specific Questions:

1. **Is the organization of the report appropriate and does it present the material in a clear and concise manner? Are there any changes that are recommended?**

Generally, the organization is appropriate and the presentation is clear and concise. Steps in the analysis follow the steps outlined for a benefits valuation study in the EPA regulation (Federal Register pp. 41647-41648). The TER sequence of analysis also generally follows the sequence of steps in EPA's regional study for California (Regional Studies Part B: California Chapters B2-B5.) Because it would be impractical to explain each step taken in the analysis for each species, TER describes its approach in terms of one example, valuation of brown rock crabs, which constitute about 92% of commercially and recreationally valued organisms lost to I&E mortality according the data TER used. Overall, I found TER's explanation of the steps taken to be clear and in accord with the procedures developed by EPA in its regional studies (as reported in EPA Regional Studies Part B: California.) I have no recommendations for changes.[7]

2. **Is the report consistent with economic principles of measuring benefits? Are there any changes that would make it more consistent with accepted economic principles?**

The concepts and methods used by TER are consistent with economic principles for measuring benefits. The TER concept of *use benefits* for recreational and commercial harvests is illustrated in Figures 2 and 3 of the TER report in Section 2 and the links

[7] The TER presentation was unclear at two points, but these instances did not materially impair my ability to understand and evaluate TER's analysis. The passages in question are: (i) p. 18: "However, the number of fish not valued is small. For example, …" I believe TER means to state that its method of valuing forage fish conservation does assign a value to fish that are not directly used by commercial and recreational harvesters. This phrase could be interpreted to mean that their method captures all non-use values. My interpretation here is consistent with a subsequent statement by TER in fn. 35, p. 37. (ii) The explanation on p. 20 regarding the ratio of eggs to larvae entrained was unclear.

between factors determining fishery value are laid out in Figure 4. The concepts of producer and consumer surplus are standard tools in benefit estimation.[8]

The method TER uses to estimate the economic benefits of enhanced commercial catches departs from the EPA approach spelled out in Chapter A10 of its regional studies report. TER assumes that increased commercial catches resulting from lower I&E mortality will result in lower prices for consumers, yielding a gain to consumers, but total revenue is unchanged, so there is no gain to commercial harvesters. EPA assumes that all gains accrue to producers and, as it turns out, the EPA estimate of producer gains equals 0% to 40% of the gain TER attributes to consumers. The question of which approach (EPA or TER) is more appropriate depends on the price elasticity of demand for fish and neither EPA nor TER provides hard evidence on this.

In any case, the practical effect of this difference in procedures is small, and the direction of the effect is that TER's value of enhanced commercial catches exceeds what an application of the EPA procedure would yield.

3. Is the report consistent with the EPA Phase II 316(b) regulation for measuring benefits? Are there any changes that would make it more consistent?

TER's approach to estimating the benefits of enhanced commercial and recreational fishing due to reduced I&E mortality is consistent with the EPA Phase II 316(b) regulation for measuring benefits. The EPA guidelines for estimating commercial and recreational fishing benefits are outlined in Federal Register Section IX, H (Implementation), part 2, pp. 41647-41648. More specific guidance regarding methods for measuring benefits and an extended discussion of EPA's recommended procedures is found in EPA Regional Studies report, Part A, Chapters A9-A12. With one minor exception noted in the response to question #2 (regarding the valuation of enhanced commercial catches), TER followed the EPA guidelines.

4. Are the potential economic effects of I&E addressed in a manner consistent with standard principles and practices for conducting benefits studies?

In general the *use benefits* associated with reduced I&E mortality are addressed in a manner consistent with applicable economic principles. (Non-use benefits are discussed in a separate question.) The basic economic concepts in play here are simple. The fishery model laid out as a guide by EPA assumes that a set of constant parameters can be applied to egg and larvae losses to obtain implied losses in harvestable populations and, ultimately, to actual harvest levels. The total harvests implied by this mechanistic application of parameters is then divided between recreational and commercial harvesters by applying the recreational and commercial harvest shares for each species examined in statewide landings data. These harvests are then valued by applying appropriate unit values to the enhanced catches.

---

[8] The TER discussion of economic benefit concepts is similar to the more detailed EPA discussion of relevant economic concepts that appears in the EPA Regional Studies report, Part A, Chapters 9-11.

As noted elsewhere in my report, application of a different fishery model may have resulted in substantially different estimates of the effect of I&E mortality on commercial and recreational catches and on recruitment to adult size for non-fished species. It is beyond the scope of my evaluation to assess whether or not the fishery model used in these analyses (and recommended by EPA) is entirely appropriate. It is also beyond the scope of my evaluation to assess the accuracy of the natural mortality and fishing mortality rates used in any of the studies I examined (TER, IS and EPA.)

As explained in my response to question #2, TER's approach to estimating gains from enhanced commercial harvests differs from the EPA approach in a way that results in larger benefit estimates from reducing I&E mortality. Neither EPA nor TER rigorously defends the particular assumptions they employ regarding the price elasticity of demand. It is plausible that the two estimates serve as sensible end points on the true impact.

Regarding gains due to enhanced recreational harvests, TER follows EPA guidelines by applying species-specific unit values (pseudo prices, or willingness to pay estimates) to projected changes in recreational catches. EPA gives very explicit, sensible guidance on this and TER followed it.

5. **Are all of the relevant benefit categories included in the analysis? Are any significant categories omitted? If there are omitted categories, what methods could be used to reliably address their value?**

All relevant benefit categories are discussed in the TER report. Direct use values by commercial and sport harvesters are estimated. Values resulting from the enhancement of stocks of prey species and organisms, operating through enhanced commercial and recreational catches, are examined. Non-use benefits are discussed qualitatively and descriptively, per EPA guidelines, but are not estimated quantitatively.

It would have been desirable to provide quantitative estimates of non-use benefits. Unfortunately the state of the art does not permit these values to be reliably measured at present. The method most frequently used to estimate non-use benefits uses surveys to elicit stated preferences, or respondent reports of willingness to pay. Although widely applied, this method it remains controversial.

6. **Are potential nonuse benefits addressed in a way that is consistent with economic principles and benefits practices? Are they addressed consistent with the EPA Phase II 316(b) regulations? Are any changes necessary?**

Regarding applicable economic principles and practices, TER points out that non-use benefits are typically associated with protecting 'unique' resources whose loss is likely to be irreversible. If, as TER states, the Tenera Environmental I&E study did not find impacts on threatened or endangered species or identify impacts on community maintenance or function, then TER's claim that non-use benefits are likely unimportant (TER report, p. 38) is plausible. It is not decisive, however, as the fundamental question is whether or not society is willing to pay significant sums to reduce mortality among fish that will never be caught by recreational or commercial fishermen. The most well developed method for answering such questions involves surveying citizens in the relevant population. While this method has been widely applied, it is not based on actual payments (direct or indirect) by individuals in circumstances where preferences are revealed by actual choices. For this reason, the environmental economics profession has not unanimously endorsed this method as a vehicle for measuring non-use benefits; consequently, there is no reliable method for measuring non-use benefits. TER clearly recognizes shortcomings with existing stated preference approaches to estimating non-use benefits. TER also appropriately rejects the use of habitat replacement cost (HRC) or a 'societal revealed preference' approach to estimate non-use benefits, echoing the logic laid out by EPA in Federal Register pp. 41647-41648 and elsewhere.

Regarding the regulatory question, the documents I examined did not present evidence that application 316(b) Phase II technologies would significantly reduce losses of threatened or endangered species or enhance the maintenance of community structure or function. Also, TER states that the I&E mortality study completed for DCPP (by Tenera Environmental) did not uncover evidence that threatened or endangered species would benefit significantly from I&E mortality reductions. I have not attempted to investigate this question further by searching for additional data on I&E losses that would require monetization of non-use benefits. Absent such evidence, monetization is not required under section 316(b) and TER's treatment of non-use benefits is consistent with the regulation.

7. **Is the empirical analysis consistent with standard statistical and econometric procedures? Specifically, are the data appropriate for the task or could better data have been used? Are the benefit calculations performed in a manner that is consistent with standard economic practices? Are there improvements that should have been implemented?**

The protocol for valuing I&E mortality reductions described in Section I of this report (developed by EPA) does not necessarily require statistical or econometric analysis. EPA carried out statistical and econometric analysis in developing benefit valuation procedures and results for use by others, particularly for valuing recreational fishing benefits.[9] Based on a quick inspection, EPA's use of econometric and statistical analysis in developing these results appears to be entirely consistent with accepted practice and the data employed in this research appears to be at least at the standard normally deemed acceptable for such work.

TER describes the method it used to estimate commercial and recreational fishing benefits on pages 15-25. Aside from the uncertainty analysis discussed in the next question, the calculations required to determine benefits simply involve multiplying price (or marginal value) times quantity and summing across species. The prices in these calculations come either from data on dock prices (commercial catches) or from application of EPA's recreational fishing choice models (recreational catches.) The commercial fishery price data TER used in these calculations were taken from reputable sources and, as explained elsewhere in my report, the recreational value data are of high

[9] Presumably such analysis could be carried out if, for example, one had reason not the use the EPA models for valuing recreational catch, but it is not required.

quality. Numerous calculations are required and actually checking these calculations is beyond the scope of my review (and beyond the data and other materials provided). Nevertheless, from the descriptions of how these calculations were carried out I have no reason to doubt their accuracy.

The quantity numbers in these calculations result from combining counts of I&E losses (produced by Tenera Environmental) with information on natural mortality and fishing mortality at each age, by species. Apparently, these data were largely taken from various portions of EPA's analysis, either directly for the species in question or by transferring life history parameters from one species to another similar species. While I did not examine these calculations (and, as an economist, do not claim expertise in applying fishery population models,) it appears from the descriptions that these calculations were performed competently and appropriately.

8. Is the uncertainty analysis consistent with standard statistical principles and practices? Have the relevant sources of uncertainty been accounted for? Have the appropriate confidence intervals and other statistical principles been calculated and used in the appropriate manner? Are there any improvements that should be implemented?

In keeping with common practice in the profession and EPA recommendations, TER used Monte Carlo analysis to assess the implications of parameter uncertainty on its benefits estimates. Six sources of uncertainty were considered

(i) Uncertainty regarding I&E mortality: TER used data from the DCPP I&E study to develop ranges of loss rates and used these in Monte Carlo simulations. The ranges are species-specific, and vary from 4% to 65% of the mean loss rate recorded for individual species;

(ii) Life stage parameters for commercial and recreational species: TER specifies ranges for natural and fishing mortality rates for each species, based on the perceived quality or accuracy of the underlying data. In cases where the data used pertain to the exact species studied, no uncertainty is assumed to be present. Where data from one species was 'transferred' for use to another species, an uncertainty range was specified, with the degree of uncertainty increasing for more 'distant' data transfers. The ranges varied from 0% to 10% of the mean value used in generating results.

(iii) Egg-to-larvae ratio: The ratio for entrained organisms was allowed to vary by plus or minus 5% from the central value of 0.5.

(iv) Recreational values: values for each species were allowed to vary by plus or minus 2.5% from the central value used in generating results.

(v) I&E loss rates for forage species: These rates were allowed to vary by plus or minus 29% from the central values used in generating results.

The ranges specified for parameter values in items (i) and (v) above are based on actual experience to some degree; the others appear to be based on intuition. While it is best to base such analysis on experience this is often impossible owing to the fact that the true parameters are, after all, unknown.

In summary, TER's treatment of uncertainty is consistent with standard practice. It is also consistent with EPA guidelines. Additional sources of uncertainty in the model were not addressed by TER. Examples are the assumed price elasticity of demand, the assumed trophic transfer coefficients used in valuing forage species, and the ages at which various species become susceptible to commercial and recreational fishing gear. Nevertheless, TER's analysis as explained in Appendix B and reported in Table 3 of Section 3 is adequate for establishing the fact that uncertainty is present and for illustrating the effect of uncertainty on results from the model used.

9. Does the study provide a reliable estimate of the potential benefit of reducing I&E impacts at DCPP? If so, why so? If not, would it be reliable if the proposed changes you have recommended were implemented in an appropriate fashion?

I found TER's analysis to be both rigorous and consistent with the protocols developed by EPA for measuring benefits. The one departure in method (see discussion of question 2) is relatively minor and does not have a substantial impact on the benefit estimates TER produced. Based on my analysis of the protocols TER followed, I believe TER's estimates of use benefits are as reliable as can be produced with the data presently available. The absence of non-use value measures in TER's analysis is a reflection of the current state of the art for measuring non-use benefits.

Confidence in the reliability of TER's estimates could be enhanced by a systematic comparison and reconciliation of the TER benefit estimates with the regional estimates provided by EPA. I believe this would be useful because EPA's benefit estimate for California facilities, on a per facility basis, is higher than TER's estimate. According to TER (p. 31), EPA's Regional Analysis for eight northern California estimates the benefit from reduced I&E losses at $0 to $22,755 for commercial fishing and $790,560 for recreational fishing. This implies a total benefit of over $100,000 (recreational plus commercial) for the average northern California facility. This is roughly four times as great as the TER estimate for DCPP, without accounting for the effect of TER's more generous method for estimating commercial fishing benefits. Of course, Phase 2 facilities no doubt differ substantially in their physical attributes and in their local environmental and economic conditions, so these differences may be entirely reasonable. Reconciling the two sets of estimates would enhance confidence in the reliability of TER's analysis.[10]

[10] I did not have access to the separate benefit study performed for northern California and hence did not investigate this further.

3 INDEPENDENT SCIENTISTS'S STUDY

3.1 General Question:

Do the reports provide reliable measures of the economic benefits of reducing I&E at DCPP? What changes, if any, would be needed to provide reliable estimates of these benefits?

See the response to question 9.

3.2 Specific Questions

1. **Is the organization of the report appropriate and does it present the material in a clear and concise manner? Are there any changes that are recommended?**

The organization is generally clear and follows a logical sequence. Steps in the IS analysis do not follow the steps outlined for a benefits valuation study in the EPA regulation (Federal Register pp. 41647-41648), but rather take an entirely different approach (as explained elsewhere in this report.)[11]

2. **Is the report consistent with economic principles of measuring benefits? Are there any changes that would make it more consistent with accepted economic principles**?

The Independent Scientists' approach, which is based on a habitat replacement cost (HRC) concept, is not consistent with economic principles for measuring either use or non-use benefits. The Independent Scientists first estimate the cost of mitigation measures that might offset I&E losses and then assert that these costs are an appropriate measure of the value of the lost resources.[12] This approach has no basis in economic theory. The only possible relevance HRC can have for benefit estimation derives from the fact that it necessarily places an upper bound on the size of any benefits that may exist. That is, the use and non-use benefits that can be attributed to an action that protects

[11] The IS presentation was unclear at a few points, but none of these instances materially impaired my ability to understand and evaluate the IS analysis. The points in question are: (i) on p. 5 the IS report refers to geographic information on impacts in Table 1, but I found no such information in that table; (ii) I found unclear the explanation, on p. 9, of how ETM calculations are interpreted; (iii) Figures III.19-III.24 are presented in the IS report without discussion or interpretation.

[12] The two mitigation measures that receive greatest attention are construction of artificial reefs and the establishment of a marine reserve. The Independent Scientists provide estimates of the costs of these actions. Artificial reefs of the size they recommend are estimated to cost $10.6-$26 million to construct. Marine reserves are estimated to cost $6-$8 million, although this does not appear to be a firm estimate and ongoing costs for monitoring are not separately estimated.

organisms from I&E mortality cannot exceed the cost of providing the same protection via habitat restoration or some other action. Consequently, HRC can only serve to restrain other benefit estimates and cannot serve as a defensible estimate in itself. There is no principle of economics that allows one to substitute the cost of one action for the benefit or value of another action and there is no way the Independent Scientists' replacement cost estimates could be modified to provide a defensible estimate of the value of I&E mortality reductions.

The well-understood, extensively studied concepts of consumer and producer surplus are standard theoretical tools for measuring use values associated with enhanced fish populations. There are well-established methods for estimating use values associated with both commercial and recreational fishing.[13] The IS analysis makes no mention of these concepts and methods.

3. **Is the report consistent with the EPA Phase II 316(b) regulation for measuring benefits? Are there any changes that would make it more consistent?**

The method IS used to estimate benefits from reduced I&E mortality is not consistent with the 316(b) regulation. EPA considered, and appropriately rejected, 'habitat replacement cost' (HRC) as a proxy measure for nonuse benefits (Federal Register 41624-41625.) EPA also considered a variant of the habitat replacement approach which bases benefits on the values of services provided by the new habitat rather than replacement costs, but ultimately rejected this as well.[14] This point is discussed further in the answer to question 6, which concerns non-use benefits.

There is no change that would render the basic IS approach consistent with benefits assessment requirement of rule 316(b). This is not surprising as the clear intention of the IS study was not to address policy or legal issues (IS report, p. 3.)

4. **Are the potential economic effects of I&E addressed in a manner consistent with standard principles and practices for conducting benefits studies?**

The economic effects of I&E losses are not addressed quantitatively. They are discussed at various points, but economic effects are not quantified or valued.

Costs and benefits are referred to at various points in the IS study, but not in a fashion that is consistent with standard practice in benefits studies. For example, the

---

[13] EPA recognizes the existence of these methods, describes them briefly in Fed. Reg. 41658 and 41659 and in more detail in the regional studies report, and recommends their use in the context of applying rule 316(b).

[14] EPA also considered, and rejected as insufficiently defensible, a 'societal revealed preference' approach to estimating non-use benefits. This method interprets actions taken by governments to protect marine organisms or other resources as evidence that society values these resources by amounts at least as great as the cost of the actions. There is an element of circularity in applying this notion in the present context. In any event, the state of knowledge on how well government decision-making is linked to the preferences of constituent is too imprecise to recommend this approach as a defensible benefit estimation procedure.

benefits associated with establishing marine reserves are describes as "fishery management" and "conservation" benefits. The costs that marine reserves would impose on recreational and commercial fishermen are not mentioned. Any effects such reserves might have on stocks and harvests outside of no take zones are not quantified. Comparisons of costs and benefits are sometimes difficult to interpret and difficult, at best, to reconcile with the conclusions reached.[15]

5. **Are all of the relevant benefit categories included in the analysis? Are any significant categories omitted? If there are omitted categories, what methods could be used to reliably address their value?**

The relevant benefit categories are the use values that would accrue to commercial and recreational fishermen as a consequence of enhanced fish populations and the non-use values that society more broadly attaches to the same stock enhancements. The IS study makes no systematic attempt to address these benefit categories quantitatively or conceptually.

6. **Are potential nonuse benefits addressed in a way that is consistent with economic principles and benefits practices? Are they addressed consistent with the EPA Phase II 316(b) regulations? Are any changes necessary?**

The Independent Scientists' approach to estimating both use and non-use benefits from I&E reductions is based on the cost of actions (artificial reefs and marine reserves) that would replace the eggs and larvae lost to I&E mortality. This method is not consistent with economic principles or practices for estimating non-use benefits. As pointed out elsewhere in the present report, there is no universally accepted method that will give a reliable, comprehensive measure of non-use benefits. There is, however, a well-developed method for valuing one category of non-use benefits, the value of uncaught 'prey' fish that ultimately nourish stocks caught by commercial and recreational fishermen. This method is described elsewhere in the present report and was developed extensively in EPA's background studies for rule 316(b). The Independent Scientists made no attempt to implement this method and, indeed, present no discussion of standard economic principles and practices for estimating non-use (or use) benefits at all.

Regarding the regulatory question, EPA's discussion of the 316(b) rule-making process notes that the problem of estimating non-use values for organisms lost to I&E mortality is particularly troublesome. At various stages in its analysis, EPA considered habitat replacement cost as a vehicle for estimating non-use benefits.[16] EPA also considered a variant of this general idea that involves measuring willingness to pay values for the habitat attributes that would result from restoration or replacement. In its

---

[15] The discussion on p. 22 is an example. "Conservation benefits result from a return to a more pristine ecosystem, and permanent protection of the ecosystem. In contrast, entrainment losses are temporary. It is therefore reasonable to conclude that the long0term benefits of marine reserves are greater than the temporary impact of entrainment." This argument is repeated on p. 23.

[16] See Fed. Reg. p. 41624, 41625 for a discussion of this process.

Regional Studies, Part A: Chapter A9, EPA expressed a belief that this method could serve as a useful supplement or alternative to other assessment methods, or that it could provide otherwise useful information. In the end, however, EPA elected not to include benefit estimates based on this approach in its own national benefits analysis due to inherent limitations and uncertainties.

More importantly, the actual 316(b) rule states that non-use benefits can generally only be monetized through the use of stated preference methods[17] and states that non-use benefits only need to be monetized only when an I&E mortality study demonstrates substantial harm to a threatened or endangered species, to the sustainability of populations of important species, or to the maintenance of community structure and function. This requirement for monetization has not been demonstrated in the Independent Scientists' report or in the other documents I reviewed. Even if it had been demonstrated, the HRC approach cannot yield a reliable estimate of non-use values.

7. **Is the empirical analysis consistent with standard statistical and econometric procedures? Specifically, are the data appropriate for the task or could better data have been used? Are the benefit calculations performed in a manner that is consistent with standard economic practices? Are there improvements that should have been implemented?**

There is no statistical or econometric analysis in the Independent Scientists' analysis and the IS benefit estimates do not rely on statistical or econometric analysis done by others.

The IS benefit estimation method does use the Tenera data on I&E losses and, to my knowledge, the Tenera study yielded reliable data. The Independent Scientists also used an empirical transport model (EMT), which incorporates information on ocean currents to estimate the source water body for the larvae entrained. This, in turn, was used to estimate the amount of habitat, reef in this case, that would be needed to replace I&E losses. The resulting estimate of reef required for the replacement is 85-400 hectares. The details of the EMT model were not presented in the IS report and could not be evaluated.

The other key item of data in the IS analysis is the cost of constructing artificial reef and of establishing and maintaining a marine reserve. For artificial reef construction the IS study relies on cost data from the San Clemente Artificial Reef. I have no way to verify the accuracy of these data. They are based on actual experience and for that reason may well be reasonably accurate. In any case, I know of no source of superior information. The IS cost estimates for establishing a marine reserve are more speculative. The source given is a discussion with the Resources Legacy Foundation Fund.

Regardless of data accuracy, the illegitimacy of habitat replacement cost as an approach to measuring benefits renders this question moot.

8. **Is the uncertainty analysis consistent with standard statistical principles and practices? Have the relevant sources of uncertainty been accounted for? Have the appropriate confidence intervals and other statistical**

[17] The relevant text is in Fed. Reg. p. 41647, 41648 in Section IX, Implementation, part H.

principles been calculated and used in the appropriate manner? Are there any improvements that should be implemented?

There is no statistical analysis in the IS study.

Uncertainty regarding various aspects of their analysis is mentioned at various points, but the likely effects are not quantified in any way.[18]

9. **Does the study provide a reliable estimate of the potential benefit of reducing I&E impacts at DCPP? If so, why so? If not, would it be reliable if the proposed changes you have recommended were implemented in an appropriate fashion?**

The IS approach, which is based on habitat replacement cost and makes no references to standard economic concepts and methods for measuring benefits, cannot provide a reliable estimate of the benefits of reduced I&E mortality. There is no way that the IS analysis, given this approach, can be revised to yield a reliable estimate.

From text in the IS report it seems clear that the authors did not set out to perform a benefits valuation study for reduced I&E mortality. Rather, the goal was to identify a set of mitigation actions that would replace the organisms lost to I&E mortality and to provide estimates of the costs of these actions. Toward this end, they estimated the size of artificial reef and the area of marine reserve that would suffice to offset I&E losses, and the associated direct costs. (Opportunity costs such as foregone recreational or commercial catches in no take zones are not addressed.) The IS report refers in various places to this replacement cost as the best value measure for I&E losses. As noted repeatedly in this peer review report, replacement cost is unconnected from the value individuals in society place on a resource and cannot serve as a defensible benefit measure.

[18] It is mentioned on pp. 2 and 5 that uncertainty will be considered in the IS analysis. Pages 21 and 25 refer to uncertainty in the entrainment study and the mitigation that would result from marine reserves, but no quantification is presented.

References

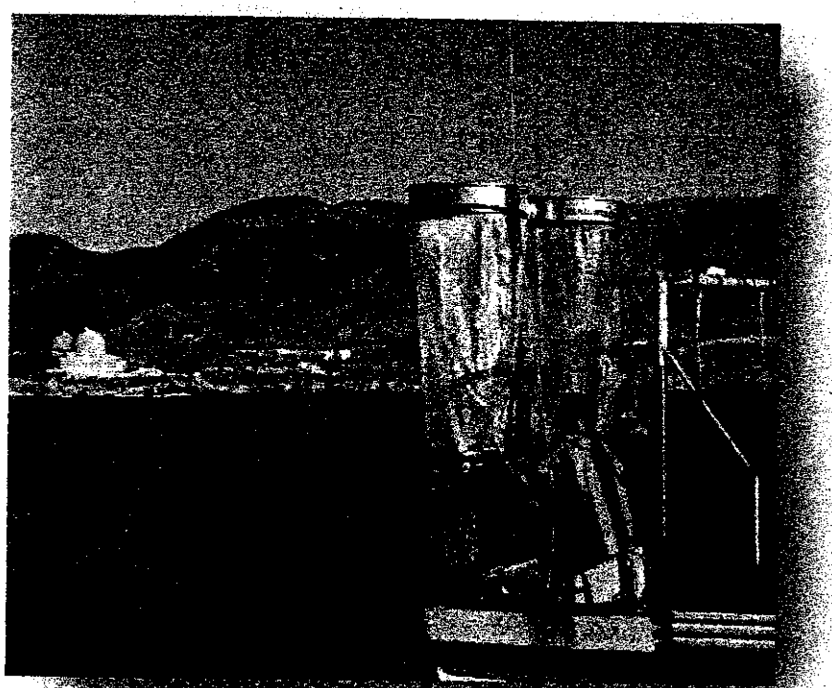
Conrad, Jon M., and Colin W. Clark, 1987. *Natural Resource Economics: Notes and Problems*. Cambridge: Cambridge University Press.

Clark, Colin W., 1976. *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*. New York: Wiley-Interscience.

Schaefer, Milner B., 1954. "Some aspects of the dynamics of populations important to the management of commercial marine fisheries," *Bulletin of the Interamerican Tropical Tuna Association*, Vol, 1, pp. 5-56.

Diablo Canyon Power Plant

316(b) Demonstration Report



Plankton sampling offshore of DCPP

March 1, 2000

Document No. E9-055.0

Prepared for:

Pacific Gas and Electric Company
77 Beale Street
San Francisco, CA 94105

Prepared by:

TENERA Environmental Services

6.0 EVALUATION OF ALTERNATIVE INTAKE TECHNOLOGIES

A number of cooling water technologies are explored which are currently in use elsewhere or proposed for use in power plant cooling water systems to minimize the loss of aquatic organisms due to entrainment and impingement. Section 316(b) of the Clean Water Act (CWA) states that "cooling water intake structures" are to "reflect the best technology available for minimizing adverse environmental impacts." As discussed in the Introduction (**Section 2**) of this report, USEPA has indicated that assessment of adverse environmental impacts (AEI) should be based on an evaluation of population-level effects. This report shows that Diablo Canyon Power Plant (DCPP) has not caused population-level effects and therefore, we concluded that DCPP has not caused AEI. However, we provide this section on alternative technologies in response to a requirement by the RWQCB. This section of the report includes a description of potential modifications to the present intake structure at DCPP. Additionally, for informational purposes, this section presents discussion of possible operational and technological alternatives to the current cooling water system that are not part of the intake structure although consideration of these alternatives is beyond the scope of the CWA.

This section evaluates the applicability of installing operational and technological alternatives for the existing DCPP cooling water system. For those applicable alternative technologies, we provide additional information relative to the potential cost of implementing the technology and the possible reduction of biological effects. These technologies include (1) cooling water system alternatives, (2) intake configuration alternatives, (3) behavioral and physical barriers, (4) fish collection and removal conveyance systems, and (5) intake maintenance and operational modifications.

6.1 Evaluation Criteria

A hierarchical evaluation system was used to assess which alternative intake technologies were initially evaluated on the basis of the following three criteria (**Figure 6-1**):

1. The alternative technology is available and proven (i.e., demonstrated operability and reliability at a cooling water intake similar in size and environment to the DCPP site).
2. Implementation of the altẽrnative technology might result in a reduction in the loss of aquatic organisms compared to the present operating conditions.
3. Implementation of the alternative technology is applicable at the DCPP site, based on site-specific considerations of engineering, operations, and reliability.

For those alternatives that meet the three criteria, a detailed evaluation of applicability and general cost estimate is described in **Section 6-2**. All technologies considered and the application of the evaluation criteria are shown in **Table 6-1**.

A brief description and justification for the alternatives that do not meet Criteria 1, 2, and 3 are presented in the attached Appendices.

Appendix L– alternatives not meeting Criterion 1.

Appendix M–alternatives not meeting Criterion 2.

Appendix N–alternatives not meeting Criterion 3.

6.2 Applicability Analysis and Cost Estimates

This section discusses the applicability of each alternative intake technology that has met all three evaluation criteria. It is divided into two subsections: alternatives that reduce impingement and alternatives that reduce entrainment.

For those alternatives presented in previous reports, the cost figures presented here represent those original estimates (TERA 1982 and PG&E 1988a) in present day dollars as of December 1999. The annual cost and the life-of-plant cost figures presented in these earlier reports each consisted of two components: 1) capital, operation, and maintenance costs and 2) lost revenues. Other than considering the changing value of labor and material, the capital, operation, and maintenance costs of any of the alternatives was assumed not to have changed from previous estimates. To translate original cost estimates to present day values, we used representative indices from the Bureau of Labor Statistics for labor and material.

Due to significant changes in the price of electricity since the original estimates, the lost revenue component was re-forecast using the same assumed lost generation (MWe) resulting from load reduction (deratings) and lost production, but valued using a realistic plant capacity factor and the California Energy Commission's forecast of Power Exchange (PX) pricing for the price of electricity for the next 25 yr.

For comparative purposes, the cost of alternatives is expressed in net present value (NPV), which includes the total capital cost, the cost of the cumulative lost revenue, and increased maintenance costs over the life of the plant. Additionally, for the alternatives that reduce impingement, the cost per kg of fish is derived by dividing the total NPV by the cumulative weight (kg) of fish impinged for each option over the remaining licensed plant life, assumed to be 25 yr.

The cost estimations are considered to be accurate within an order of magnitude only. More accurate estimates would require detailed and plant-specific design of the various technologies. For example, neither TERA (1982) nor PG&E (1988a) considered the following costs, which would substantially add to the current estimates:

- Demolition and relocation of existing utilities, system components, plant facilities, buildings, etc.
- Security during construction and effect on permanent security boundary.
- Nuclear licensing (License Amendment Request to the NRC).
- Permitting (i.e. California Coastal Commission, RWQCB, etc.).
- Seismic design considerations.

Additionally, for cooling tower cost estimations, the following additional costs were not considered by TERA (1982):

- Tie-in with existing circulating water conduits.
- Change in pumping plant location, design, and configuration.
- New circulating water pumps (CWP) and system components.
- Changes in the turbine and condensate systems to accommodate higher cooling water temperatures.
- Salt water drift damage to existing plant facilities or structures and to electrical or mechanical equipment.

- Salt water drift damage to surrounding lands, terrestrial habitat and ecology, and agricultural productivity.

Therefore, the cost estimates provided in this report are considered approximate, likely to be conservative (low) and adequate as order of magnitude estimates.

6.2.1 Alternatives That Reduce Impingement Losses Only

The impingement rate at DCPP is low, based on 1985–86 impingement data and ongoing field observations (**Section 5.1.2**). In the 1985–86 study (Tenera 1998a) impingement rates were estimated at about 0.32 to 0.73 kg/day/unit. Divers observe fishes and invertebrates freely moving within the intake structure forebays and directly in front of the traveling screens (Tenera 1997a). Therefore, modifications to the intake structure can provide little improvement in reducing the number of impinged fish. The following discussion, however, provides information on possible alternative technologies to reduce impingement at DCPP, their estimated costs, and the comparison of costs to potential impingement reductions.

6.2.1.1 Increased Area Intake Structure

A detailed review of the intake velocities at DCPP (Wyman 1988), the literature on laboratory swimming performance of juvenile fish (reviewed in Tenera 1998a), and diver observations of impingement avoidance at the DCPP intake (Behrens and Larsson 1979) showed that fish impingement should be virtually independent of intake approach velocities of less than about 0.8 to 1.0 fps (present velocity at DCPP). Based on studies at Contra Costa Steam Plant (Kerr 1953) impingement is predicted to increase at intake approach velocities greater than 1.5 fps, particularly among juvenile fish that are less than approximately 80 mm in length. A reduction in approach velocities is not expected to substantially reduce fish impingement rates at DCPP. However, one approach to possibly reduce impingement would be to reduce the intake approach velocity. The approach velocity is inversely proportional to the cross-sectional area through which the water passes. Therefore, velocities entering the intake structure can be reduced by increasing the cross-sectional area exposed to the flow. Reduction in the intake approach velocity would require expansion of the intake structure including additional traveling screens to increase the intake's cross sectional area. A design that halves the existing approach velocity was considered.

This design change assumes that reduced flow velocity translates to reduced impingement. A level of uncertainty exists around the use of a single parameter such as flow rate or velocity to accurately predict the potential for reducing impingement. Taft (1999) compares several sites with similar intake designs and flow characteristics that experience large differences in impingement. Higher rates of flow and intake velocity (through the traveling screens) are usually associated with higher impingement losses. Taft (1999) illustrates from the available data that neither velocity nor flow appear to be closely correlated to impingement rates. He concludes that impingement should be viewed as a site-specific event that is influenced by many parameters. It is the combinations of environmental conditions and species life stages that interact to influence impingement.

Plan and section views of the proposed modification to the intake structure are presented in **Figures 6-2** and **6-3**. As indicated in these figures, the modification would involve expanding the intake structure towards the ocean side with approximately 45° flare and deepening the existing intake invert slab elevation to (-) 46.0 feet.

Construction of the expanded intake structure would result in a major construction effort and require installing a cofferdam and dewatering the existing intake structure. Disruption associated with construction and dredging activities would contribute to localized impacts on kelp and benthic organisms inhabiting the Intake Cove.

During intake construction, the circulating water flow required for the operation of Units 1 and 2 would be disrupted, resulting in a complete loss of generating capability from both units for a period of approximately one year. Operating one unit while modifying the other unit would not change the cumulative revenue loss appreciably, because the construction duration for each unit would not change substantially. A major challenge to any construction project in front of the existing intake structure would be the potential for storm conditions interfering with work in the intake bays.

While the units are shut down, the auxiliary saltwater (ASW) system would have to remain operable to preserve the function of those systems necessary to maintain the plant in a safe shutdown mode and protect the nuclear fuel. Therefore, an extension of the ASW system would be required to provide continuous flow to the ASW pumps. Since the ASW system is a nuclear safety-related system, necessary safety-related design considerations such as seismic safety, control of heavy loads, and interaction between safety and non-safety related items would have to be evaluated as part of intake structure design and modification.

Prior to finalizing the design of the expanded intake structure, a detailed engineering evaluation would be necessary to ensure compatibility between hydraulic flow patterns, cooling water volumes, and pressure regimes associated with the expanded intake structure and the existing Units 1 and 2 condenser system. License amendments required to accommodate a modification such as this have not been reviewed. Additionally, other environmental and safety design considerations such as the effects of earthquakes, tsunamis, and probable maximum loads would require evaluation. These would result in additional costs that have not been factored into the following cost estimates.

The estimated capital cost for this project would be on the order of $51,000,000. In addition, the cumulative lost revenue and increased maintenance would be approximately $590,000,000 over the life of the plant. The implementation of this technology has a net present value (NPV) of (-) $275,000,000. This results in a cost of $61,700 to save each kilogram of impinged fish, assuming a 100% reduction in impingement over the remaining life of the plant.

6.2.1.2 Angled Screen Intake Structure

Angled traveling screen intakes are designed with conventional screens set at an angle to the incoming flow. A fish diversion system is installed at the downstream end of the intake such that incoming fish are directed along the face of the screens to the fish diversion path. Fish diversion systems include various designs of pivoting, fixed, or traveling screens, louvers, associated with traditional bar racks.

These intake designs have been utilized in both hydroelectric and thermal power station intakes to minimize impingement. At Brayton Point Station Unit 4 in Massachusetts, an 18 mo (October 1984 to March 1986) biological evaluation was conducted to determine the species, number, and initial and extended survival of fish diverted from the angled screen intake (Davis et al. 1988). The angled screen intake system had a high diversion capability and demonstrated effectiveness for mitigating fish impingement. Initial and extended survival varied by species; however, a certain group of numerically dominant taxa was classified by the authors as "fragile" (primarily, bay anchovy and Atlantic silverside). The fragile group had a calculated survival below 25 percent and a "hardy" group, dominated by winter flounder and northern pipefish, had survival values greater than 65 percent. The diversion efficiency for all species combined was 76 percent. Nine of the top 12 taxa collected had diversion efficiencies greater than 83 percent. The diversion flow collections resulted in an initial survival rate of 58 percent for all taxa (n= 28,186) combined. The initial survival rate ranged from 6 percent for bay anchovy to nearly 100 percent for American eel. Initial survival with the exclusion of bay anchovy was 83 percent. Extended survival for all fish (n=9,209) collected at the diversion flow was 63 percent. Extended survival trends were similar for the major species involved. Survival ranged from a low (bay anchovy) of 0 percent to a high over 99 percent (tautog wrasse).

Oswego Steam Station Unit 6 utilizes an angled screen diversion system similar to the system at Brayton Point Station (LMS 1992). Biological studies were conducted to investigate the effectiveness of the screens as systems. Alewife (herring) and rainbow smelt made up 90 percent of the collected species (from April 1981–March 1983). Diversion efficiency was 79 percent and 74 percent for alewife and rainbow smelt, respectively. The combined diversion efficiency for all the species collected was 78 percent, ranging from 53 percent for mottled sculpin to 95 percent for gizzard shad. Initial survival ranged from a low of 45 percent for rainbow smelt to a high of 87 percent for emerald shiner. A total of 34,294 individuals from the seven most frequently collected species were examined for initial survival, and 7,534 fish were observed for latent survival. The lowest latent survival rate was exhibited by alewife (22 percent) while the highest was mottled sculpin (94 percent). Overall, the angled screen system was effective in diverting fish from the primary screenwell through the secondary screenwell back into the lake. The degree of effectiveness varied widely by species; size class or age, and condition of the population.

A full-scale angled screen test facility was constructed at the Danskammer Point Generating Station on the Hudson River in 1981 (LMS 1985). The angled screen facility was located in the cooling water intake canal and consisted of two 3 m (10 ft) wide vertical traveling screens set at a 25 degree angle to the approach flow. The effectiveness of the system was evaluated over a three year test period (LMS 1985). Diversion efficiency ranged from 95 to 100 percent, with a mean of 99 percent. Species included bay anchovy, blueback herring, white perch, spottail shiner, alewife, Atlantic tomcod, pumpkinseed (sunfish) and American shad. Overall, system efficiency (diversion efficiency times initial survival times latent [96 h] survival) ranged from 68 percent (alewife) to 99 percent (spottail shiner) with a mean of 84 percent (LMS 1985).

Angled traveling screen intake structures have been used in a marine environment and are well suited for reducing impingement. Wave energy and debris loading events that occur at DCPP were probably not experienced at facilities that have installed these screens. Angled screen intakes do not prevent entrainment of larval organisms.

One feature of angled screen intakes is that the velocities normal to the screens is quite low, on the order of 0.03 m/s (0.1 ft/sec) to 0.15 m/s (0.5 ft/sec) (EPRI 1999). Implementation of an angled screen intake at DCPP would require a major reconstruction of the intake to accommodate additional (at least twice the number currently installed) screens in the angled configuration. Although a specific design and cost estimate has not been prepared for this configuration, it is judged that the costs would be similar to the costs associated with the expanded area intake described in **Section 6.2.1.1**. Since this alternative addresses only impingement, the costs compared to the reported impingement rate would not make this option cost effective for implementation at DCPP.

6.2.1.3 Traveling Screen Operating Cycle Modifications and Fish Conveyance Systems

Operational modifications to the vertical traveling screens, such as the use of continuous screen rotation, screen baskets with "fish buckets", low-pressure spraywash, and fish return sluiceways, are alternatives that have been proposed by the industry to increase the biological effectiveness of conventional vertical traveling screens. Typically, all of these elements must be used together to effectively reduce impingement mortality. Costs for the combination of modifications are presented in the section on *Combinations of Vertical Traveling Screen Modifications* (below).

Continuous Traveling Screen Rotation

Several studies have been performed to determine the effectiveness of continuous screen rotation on impingement survival. Studies conducted at the Pittsburg Power Plant (PG&E 1992) show that increasing the screen rotation frequency from 3 h intervals to continuous rotation did not result in consistently improved impingement survival for invertebrates such as California bay shrimp, brackish-water crabs, and oriental shrimp.

In contrast, more (26–56% after 96 h) young-of-the-year (YOY) white perch (*Morone americana*) survived impingement on continuously operating traveling screens compared to those operated 2–4 h intermittently (19–32% survival after 96 h). Likewise, striped bass (*Morone saxatalis*) latent survival improved (32–62%) after impingement on continuously operating screens compared to bass impinged on intermittently operated screens (26% after 96 h; King et al. 1978). King et al. (1978) concluded continuous traveling screen operation allowed maximum initial and latent survival for white perch and striped bass YOY.

Continuous screen rotation did not consistently result in improved impingement survival of the marine organisms examined at the Moss Landing Power Plant (PG&E 1988a, Section 4.2). Among impinged fish, hardy species such as plainfin midshipman and crabs had a high rate of survival regardless of screen rotation frequency. Increasing screen rotation frequency at the Moss Landing Units 6 and 7 intake did, however, contribute to a substantial increase in impingement survival for both surfperch and rockfish, which together constitute about 11 percent (by weight) of the fish impinged at DCPP (PG&E 1988a, Section 4.2).

The studies referenced above show that impingement survival varies from site to site and is species specific. Testing of continuous screen rotation at DCPP would be required to determine if a reduction in impingement is achievable.

The current debris removal system at DCPP is designed to handle large quantities of kelp and other debris. The material washed from the screens is washed to a sluiceway and directed to a large sump. This material and wash water is pumped to a location approximately 244 m north of the intake structure at the shore end of the west breakwater. Grinders are installed at the entrance to the refuse sump to reduce the size of the kelp and algal debris to prevent clogging of the debris removal system. No impingement survival is expected with this system. This system is needed to support plant operation with the high debris loads. Increasing intake screen rotation offers the possibility of increasing survival of some impinged organisms only if this method is used in conjunction with other modifications (such as a gravity sluiceway and fish baskets to increase survival). These configurations are described in the next two sections.

Gravity Sluiceway Fish Return and Low Pressure Spraywash

There are two basic types of sluiceways for the return of impinged organisms and debris to the waterbody: one uses a pump to transport collected material away from the intake and one uses gravity flow. Based on the existing DCPP intake design, a gravity return sluiceway directing flow to the south end of the intake would be the least complex and least expensive option.

As described in the previous section, the current DCPP screenwash system is not designed to return impinged organisms to the receiving waterbody intact. The high debris loading experienced at DCPP requires that this system function in a way that makes impingement survival unlikely, and hence no survival of impinged organisms is expected.

To increase impingement survival at DCPP, a separate fish return trough, low pressure spray wash, and fish collection baskets as described in the next section would be required. Based on construction estimates, the implementation of a low pressure spray wash and fish return system would cost about of $12,000,000. NPV analysis for this modification in conjunction with replacing screen baskets is included in the next section.

Combinations of Vertical Traveling Screen Modifications

Several modifications to conventional vertical traveling screens have been studied in recent years in an attempt to reduce the mortality of impinged organisms by incorporating new design features that improve the survival of impinged organisms. Such state-of-the-art modifications act to enhance fish and invertebrate survival related to screen impingement and spraywash removal. Screens modified in this manner are commonly called "Ristroph Screens". These modifications include the following features:

1. Hydrodynamically improved, watertight fish collection buckets along the base of each screen panel to provide a holding area for organisms during screen rotation;
2. Smooth woven mesh (e.g. 1.6 mm by 12.7 mm rectangular mesh) installed on the screen baskets to minimize abrasion;
3. Lighter composite screen baskets which allow for increased rotational speed;
4. A second sluiceway/fish return system with combined low pressure spray wash to transport organisms removed from the screen by the low-pressure spraywash back to the receiving waterbody;
5. Improved screen-to-collection trough flap seal design; and
6. Modifications to traveling screen bearings and motors to permit continuous rotation and cleaning, minimizing the time an organism is impinged on the screen.

Studies of the biological effectiveness using these modified Ristoph screens was conducted at the Salem Generating Station on Delaware Bay in New Jersey (Ronafalvy et al. 1999; Heimbuch 1999). An initial evaluation was performed after six of the 12 existing traveling water screens at the cooling water intake structure had been replaced with the new, improved screens, allowing a side-by-side comparison of the effectiveness of the old and new screens. Tests were conducted on 19 separate dates between June 20 and August 24, 1996. Fish collected from the old and new screens were held separately for observation of 48 h survival. The only species occurring in sufficient numbers to provide a statistically valid data analysis was juvenile weakfish (*Cynoscion regalis*; n = 1082 for the old screens, n = 1559 for the new screens). Overall, statistical analyses demonstrated a 48 h survival rate (uncorrected for control mortality) of 57.8 percent with the old screens and 79.3 percent with the new screens.

A second series of impingement survival studies was conducted in 1997 and 1998 to provide estimates of impingement survival rates with all 12 of the modified screens installed on Salem Units 1 and 2 (EPRI 1999). White perch (*Morone americana*) impingement survival rate estimates ranged from 98 percent in December to 93 percent in April. Estimates for weakfish ranged from 88 percent in September to 18 percent in July. For bay anchovy (*Anchoa mitchilli*), survival estimates ranged from 72 percent in November to 20 percent in July. Atlantic croaker (*Micropogonias undulatus*) survival estimates ranged from 98 percent in November to 58 percent in April. The estimated survival for spot (*Leiostomus xanthurus*) was 93 percent in November (November was the only month in which a significant number of spot were collected). *Alosa* species (herrings) combined produced survival estimates that ranged from 82 percent in April to 78 percent in November.

Impingement mortality rates for the modified screens (1997 and 1998 studies) were compared to mortality rates for the original screens from the 1978 to 1982 studies. Based on the comparisons, intake modifications were effective in improving the rates of fish survival. Estimates of impingement mortality rates were lower for the modified screens than for corresponding estimates from the original screens for white perch, bay anchovy, Atlantic croaker, spot, and the *Alosa* species.

Based on impingement survival data collected at the Diablo Canyon and Moss Landing power plants and at other facilities, it was concluded that operation of modified intake screens in combination with fish return sluiceways could enhance impingement survival of many of the fish and macroinvertebrates impinged at DCPP, including skates and rays, rockfish, sculpin, plainfin midshipman, tubesnouts, rock crabs, and sea urchin (PG&E 1988a). On the basis of data collected in the impingement survival studies (PG&E 1988a), it was estimated that losses of impinged fish and selected macroinvertebrates may potentially be reduced by approximately 75 percent under conditions of intermittent rotation, assuming no incremental mortality associated with passage through the fish return system. Rotating intake screens continuously could reduce impingement losses of fish and selected macroinvertebrates, assuming no incremental mortality resulting from passage through the fish return system. In light of DCPP's low impingement rate, however, this percentage reduction will not result in an appreciable biological benefit. The screen improvements are not expected to provide any reduction in entrainment.

Traveling screen modifications to reduce impingement mortality must be accompanied by a sluiceway designed to return organisms to the receiving waterbody. Most installations of modified traveling screens use a dual sluiceway return system: 1) a gravity sluiceway return system for impinged organisms removed from the screens by the low pressure spraywash and 2) another sluiceway for debris removed by the high-pressure spraywash. This type of system was selected for this evaluation.

The estimated capital cost for this project would be on the order of $13,000,000. In addition, the cumulative lost revenue and increased maintenance would be approximately $11,000,000 over the life of the plant. The implementation of this technology has a net present value (NPV) of (-) $11,000,000. This results in a cost of at least $2,200 to save each kilogram of impinged fish assuming a 100% reduction in impingement over the life of the power plant. The scope of implementing this alternative is expected to extend the duration of routine refueling outages, adding additional costs that have not been factored in to the estimates.

6.2.2 Alternatives That Reduce Entrainment Losses

The major focus of this study concerns losses to fish and invertebrate populations caused by withdrawal of larval stages. A majority of the young larvae are weak swimmers and cannot escape even very low entrainment velocities. In order to reduce entrainment, alternatives that use less cooling water are considered. The following discussion provides information on possible alternative technologies to reduce entrainment at DCPP and the estimated costs to install them.

6.2.2.1 Closed-Cycle Cooling Towers With Saltwater Makeup

Both mechanical and natural draft (hyperbolic) cooling towers using saltwater makeup were evaluated for applicability at DCPP (TERA 1982). Operational problems and environmental considerations (including air quality impacts from cooling tower drift and effects on vegetation from salt deposition) have limited the application of closed-cycle cooling where brackish water or saltwater is used as a make-up source. The report concluded that no operating or proposed electric generating facilities in the United States use seawater in closed-cycle cooling systems. Since that report was written, natural draft cooling towers with saltwater makeup have been installed and operated at Crystal River units 4 and 5. Two cooling towers provide cooling for the two 750 MW coal-fired units. The towers are operated with a high blowdown rate (10%), such that the total saltwater demand from the ocean is reduced approximately 80 percent compared to a once-through system. Therefore, saltwater cooling towers, either with mechanical or natural draft, have been demonstrated on the scale required for a closed-loop system at DCPP. Based on the Crystal River experience, the use of closed-loop cooling towers with saltwater makeup at DCPP would reduce the cooling water flow rate by 80 percent (from 1.6 Mgpm to 0.32 Mgpm per unit), reducing entrainment by a similar percentage.

Conceptual designs and design parameters for both mechanical draft (**Figure 6-4**) and natural draft cooling towers (**Figure 6-5**) have adverse environmental impacts on air and water quality, land use, and aesthetics (TERA 1982).

- Air Quality — Would produce 37 h/yr of ground level fog, visible vapor plume and emit ca. 6,080–9,070 kg/d of salt drift.
- Water Quality — Would increase salinity of cooling water discharge by 1.5 times, worst case; effluent limitations could be exceeded if a treatment system is not installed.
- Land Use — Would require an additional 12 to 22 ha for cooling towers. Additionally, the terrestrial impact of salt drift would be significant downwind of the plant site, as well as to the plant facilities.
- Aesthetics — For a hyperbolic (natural draft) system with two 142 m diameter x 170 m high cooling towers, the vapor plumes could reach 1,000–2,000 m high. For a mechanical draft system with six 94 m diameter x 22 m high cooling towers, the vapor plumes could reach 100–200 m high.

The estimated capital cost for the hyperbolic system alternative is on the order of $658,000,000. In addition, the cumulative lost revenue and increased maintenance would be approximately (-) $454,000,000 over the life of the plant. The NPV of this alternative's costs is (-) $503,000,000.

Actual project costs would be higher than the estimate as the use of a closed-loop cooling system would require major design changes to the DCPP turbine plant. The present circulating water pumps (CWP) are too large to supply a cooling tower system, so new cooling tower makeup pumps would be required. A new set of cooling tower supply pumps of similar capacity to the existing circulating water pumps would have to be installed in a new pumping facility. Supply and return water conduits would also have to be constructed. Since the DCPP main condenser and turbine cycle are designed to operate with cooling water temperatures between 11 and 14°C, extensive redesign and retrofitting of the condenser and other turbine systems would be required to allow reliable plant operation with closed-loop cooling with a supply temperature of 26 to 31°C. The costs of these modifications are not included in this estimate and would add substantially to the overall cost.

6.2.2.2 Closed-Cycle Cooling Towers with Freshwater Makeup

A closed-cycle cooling system using freshwater makeup is a well proven technology used at many different nuclear and fossil power plants on a scale similar to that required at DCPP. A conceptual design is outlined in this report.

A freshwater cooling tower system would require approximately a 132,500 m^3/d (92 m^3/min) makeup water supply. This corresponds to 43–49 million m^3 of freshwater per year. There is no supply of fresh water (including sanitary treatment plant effluent) within 40 km of DCPP available to supply cooling tower makeup (TERA 1982). A multistage flash distillation plant could supply the needed fresh water, as could a reverse osmosis system of similar capacity. Both flash distillation and reverse osmosis systems have been constructed on a scale needed to support fresh water cooling towers at DCPP.

Environmental impacts are similar to those described for the closed-loop cooling tower with saltwater makeup except that the use of fresh water would reduce the emission of particulates to approximately 1,540 kg/d.

The use of freshwater cooling towers would reduce the required saltwater flow for condenser cooling from ca. 9.5 million m^3/d (101 m^3/sec) to ca. 0.4 million m^3/d (5 m^3/sec). This would reduce intake flow by 95 percent, reducing entrainment by a similar amount.

The construction effort involved would be similar in cost to the saltwater systems described previously, except for the additional costs for a desalination plant of sufficient capacity to supply cooling tower makeup.

The estimated capital cost for this alternative is on the order of $1,174,000,000. In addition, the cumulative lost revenue and increased maintenance would be approximately $1,367,000,000 over the life of the plant. The net present value of this alternative's costs is (-) $1,072,000,000.

The use of saltwater or freshwater closed-loop cooling tower systems would reduce saltwater flow by 80 to 95%, reducing entrainment and impingement by a similar amount. Cooling tower technology is proven at many power plants, saltwater cooling tower operation has been demonstrated, and desalination plants of a size needed for freshwater cooling towers have been constructed. The implementation of a closed-loop system at DCPP would require a substantial design and construction effort. The costs of retrofitting a closed-loop system at DCPP (which range in net present value from (-) $503,000,000 to (-) $1,072,000,000 not including permitting challenges and extensive plant modifications to ensure reliable plant operation with cooling towers installed) would be difficult to justify, especially considering the uncertain value of the plant's electrical output as California deregulates electric generation. Although it would be possible to install a closed-loop cooling tower system, it is doubtful that an investment of the type described above would be viable in the current or future electrical generation market.

6.2.2.3 Fine Mesh Screens

Fine-mesh screening, frequently used in centerflow screens, has been investigated in laboratory studies to determine its potential to minimize entrainment at power plant intakes (Magliente et al. 1978). Application-specific studies are necessary to evaluate the survival of fish eggs and larvae impinged on fine-mesh screens.

Information from laboratory tests (Tomljanovich et al. 1978) shows that traveling screens equipped with 1.0 mm (0.04 in) screen mesh would substantially reduce entrainment of fish eggs and larvae at DCPP, and that entrainment of larval fish and macroinvertebrates could be virtually eliminated by use of 0.5 mm (0.02 in) intake screen mesh. Impingement survival for fish larvae, however, is species-specific: under laboratory conditions, the survival rates for larvae at 48 h after a 16 minute impingement on fine-mesh screens ranged from less than one percent for striped bass to 96 percent for bluegill and smallmouth bass (PG&E 1988a, Appendix D; Tomljanovich et al. 1978). The smaller intake screen mesh would increase impingement of larval and juvenile fish and invertebrates presently entrained at DCPP. The finer mesh screen would convert normally entrained organisms into impinged organisms.

In 1980, Tampa Electric Company (TECO) performed a pilot scale evaluation of a fine-mesh Ristroph screen in the intake canal to its Big Bend Station on Tampa Bay, Florida (Taft et al. 1981; Brueggemeyer et al. 1988). TECO agreed to evaluate the potential effectiveness of fine-mesh screens to reduce losses of the selected Representative Important Species: bay anchovy, black drum, silver perch, spotted seatrout, scaled sardine, tidewater silverside, stone crab, pink shrimp, American oyster, and blue crab. The screen was of the No-well design, a duo-flow screen design with the screen attached directly to the pump. Based on the positive results of the prototype testing, the regulatory agencies determined that Unit 4 could be constructed with a once-through condenser cooling system provided that fine-mesh screens were incorporated into the intake structures of both Units 3 and 4. Accordingly, six, 0.5 mm mesh No-well screens were installed at the station and studies of their biological effectiveness were conducted in 1985 (Brueggemeyer et al. 1988).

Initial and latent mortality varied by species and life stage. Collected invertebrates had mortality rates ranging from 10 to 35 percent. Engraulidae (primarily bay anchovy) had initial mortality rates ranging from 42 to 84 percent and latent mortality rates ranging from 32 to 35 percent. Bay anchovy, Atlantic tomcod, and Atlantic silverside eggs showed a total mortality of 72.4 percent (unadjusted for control). Yolk-sac larvae of mummichog, Atlantic silverside, Atlantic tomcod, white perch and winter flounder mortality ranged from 62 to 100 percent with the exception of winter flounder, which had a projected mortality 11 to 62 percent. Assumed mortality for post-yolk-sac larvae ranged from 36 to 100 percent for all species in this life stage. The conclusion of the study was that survival rates were comparable to, and in some cases exceeded, those obtained during the prototype study. There was no significant difference in survival rates between the two sample locations.

At Brayton Point Station Unit 4, biological evaluations were conducted to determine the number, species, and initial and extended survival of fish impinged on the modified intake screens (Davis et al. 1988; LMS 1987). These fine-mesh, angled screens were installed at a new Unit 4 intake to divert larger, motile life stages and gently collect and recover early life stages. The lowest survival was calculated for bay anchovy and the highest was for tautog. Initial and extended survival varied by species; however, a certain group of numerically dominant taxa was classified by the authors as "fragile" (primarily, bay anchovy and Atlantic silverside). The fragile group had a calculated survival below 25 percent while a "hardy" group, dominated by winter flounder and northern pipefish, had survival values greater than 65 percent.

Retrofitting the existing DCPP through-flow screens with a fine mesh would be difficult due to the increased flow resistance increasing the potential for screen failure under high debris loading. The size of the existing DCPP circulating water pumps and the intake configuration would preclude the retrofitting of No-well screens. No-well screens would require a new, open intake structure, with new circulating water pumps.

As part of an evaluation of screening technologies for DCPP (PG&E 1996), retrofitting the DCPP intake with center flow screens with curved baskets and a fine mesh (2mm) was considered as a way to improve debris filtration. The curved baskets of the centerflow design would increase flow area and offset the flow restriction caused by the finer mesh. These screens could be equipped with finer mesh screens (1 mm) that would potentially allow screening of larval organisms. These screens could reduce entrainment but would require a site-specific evaluation to determine the following parameters:

1. The survivability of larval organisms washed from the screens.

2. The potential increase in impingement due to the screen basket shape and the flows associated with a centerflow design.
3. The ability of a fine mesh screen to function under high debris loading conditions experienced at DCPP.
4. The ability of the refuse handling system to process debris with minimal impact to screened organisms.

The estimated cost for these screens is estimated $7,000,000 (PG&E 1996). This does not include any modifications to the debris handling system or potential modifications to the intake structure to accommodate the new screens. The total cost would be approximately $10,000,000. The net present value of this modification is (-) $7,906,000.

Center flow screens have a much more complex distribution of flow velocities, especially when installed in a screen well type intake like that used at DCPP. The entrance area to the center flow screen is roughly 60% as wide as the existing traveling screens, so the velocity at the screen entrance would be about 67% greater (1.3 to 1.7 ft/sec). The velocities at the screens are about 70% compared to the current screen approach velocity. In between, the flow turns 90 degrees, resulting in a complicated flow pattern. These flow patterns could increase impingement of juveniles and adults. In addition, the baskets for the proposed center flow screen are convex in cross section, which could increase retention of any fish impinged. With the mixed survivability data for larval organisms impinged on fine mesh screens, any biological benefit (or cost if there is an increase in impingement) would have to be evaluated prior to determining the effectiveness of this alternative.

6.2.2.4 Single Circulating Water Pump Operation

A reduction in the number of operating CWP would reduce cooling water flows, proportionately reducing the number of organisms entrained at DCPP.

The Diablo Canyon Power Plant is designed and operated as a base-loaded plant with relatively constant electrical generation for extended periods of time. The operational characteristics of Units 1 and 2 limit the potential effectiveness of single pump operation as an alternative for reducing entrainment and impingement losses. This would require extended operation at 50%

power, which lowers plant efficiency, reduces revenue, and degrade critical plant equipment. An option to running both units at 50% power levels would be to run only one unit at 100% power.

The use of a single pump per unit at DCPP with the units operating at reduced load would also present certain technical operating difficulties. The motors that operate the CWP are large (13,000 hp) and undergo substantial stress and wear during the startup. In order to achieve appropriate performance of the unit at reduced load (e.g. at 50% power or less) or to increase load above 50% in response to increased demand, the second circulating water pump would be needed from time to time. Intermittent re-starts of the second pump would greatly increase the wear, reduce pump motor reliability, and increase the frequency of maintenance.

A second difficulty arises directly from single pump operations. With one circulating water pump operating, there is no backup on-line. Thus, if the operating pump were to fail, the unit would undergo a forced shutdown. Ordinarily, with two circulating pumps running, failure of one requires a curtailment to only 50% power. Although there is no increased risk of an accident affecting the health and safety of the public by operating with one circulating water pump, plant operational transients that force a unit shutdown are regarded as a negative indicator by the Nuclear Regulatory Commission.

Because of the loss of reliability, potential equipment degradation, and operational inefficiency of generating units that would accompany operating each unit with one circulating water pump in service, a more likely strategy would be to take the option of shutting down one unit and both of its pumps, if operation in this mode was expected to be for a long period.

The NPV of this option is extremely negative, based on loss of generation. The lost revenue and NPV for this option are, however, considered proprietary information.

This option has a negative contribution to the environment as a result of the need for the ISO to purchase replacement power for the 1,100 MW reduction in power production. It is assumed that the replacement power will be generated by gas-fired power plants constrained to the state of

California emission standards. The increased amount of emissions from a natural gas-fired power plant generating 1,100 MW would be as follows (tons/yr):

NO_X	CO	CO_2
5,500	3,700	5,900,000

NO_X and CO are EPA criteria pollutants regulated under Title V of the Clean Air Act. CO_2 is a "green house" gas and is of concern for global warming. Additional air toxics such as 1,3 butadiene, acroliene, and formaldehyde are generated in smaller quantities, but can represent a greater risk to the population and environment. These calculations are based upon emissions from a 750 MWe gas-fired power plant with moderate amounts of emissions controls. Emissions used were 95 ppm NO_X; 100 ppm CO, and 9.6% CO_2. Mass emissions were based upon operation of 24 h/d, 365 d/yr.

Because of the loss of generation that would accompany reduced circulating water pump operation, single circulating water pump operation or single unit operation is not considered an alternative that could reduce entrainment at DCPP in a cost effective manner.

6.2.2.5 Variable Speed Circulating Water Pumps

Installation of variable-speed motors on the circulating water pumps represents one approach to reducing cooling water flows to the minimum level necessary to maintain efficient operation of the unit at a specific generating load. For this analysis, the assumption is that circulating water flow would be reduced to that required for 100% power operation. The basis for this is that DCPP is designed to operate as a base loaded plant at 100% power and does not change power output on a daily or other scheduled basis.

The pumps currently in use are limited to no-flow or full-flow operation. Variable-frequency drives could be installed to allow these pumps to operate at lower speeds (and hence lower flows), thereby reducing the numbers of organisms entrained. Thus, the circulating water flow rate could be adjusted to provide only the flow needed for condenser cooling within operating limits imposed by ΔT and back pressure operating criteria. The magnitude of the resultant reductions in entrainment losses would depend on the reduction in cooling water flow and the abundance of organisms at the times when the circulating water pumps were operated at reduced flow rates.

The intent of variable speed pumps is to reduce intake flow without impacting plant power operation (by adjusting circulating water flow to that needed to just allow operation within thermal limits) then the biological benefits of such a modification would be limited and based on the amount of flow reduction. DCPP was not designed for large extremes in cooling water ambient temperature, so there is little margin for reducing circulating flow. Based on calculations (VR Foster, PG&E, pers. comm. 1999), the maximum expected flow reduction would be 2–10% when ocean water temperatures are below the average (14.4° C). These calculations allowed for a temperature differential rise of 11.1° C (to allow for margin to the temperature limit) and did not consider the impact of condenser fouling. Further decreases in cooling flow would cause additional heating of the discharged circulating water.

Operation of the existing circulating water pumps is also limited by the pumps' ability to operate at reduced flows without cavitating. Hydraulic model test results for the existing circulating water pumps revealed that the available suction head in the present installation restricts operation at reduced speeds without subjecting the pumps to serious cavitation. There is data for cavitation performance of the circulating water pumps at 80%, 90%, and 100% of rated speed. The data demonstrates that the pumps will be more susceptible to cavitation as speed is reduced. Based on existing data, it is estimated that the greatest flow reduction would be on the order of 20 to 30% (corresponding to a speed reduction of 10%; PG&E Drawing DC663021-Sht. 29). The present circulating water pumps are not capable of reliable service at a significantly reduced speed. Since the circulating water pumps are embedded in the concrete intake structure, replacement of the circulating water pumps with pumps designed for variable speed operation would require the construction of a new intake structure similar in size to the existing structure. Variable speed circulating water pumps can allow substantial reductions in cases where power plants load follow (change power over the course of a day or week) and where plants are designed for large variations in heat sink temperatures. Since DCPP is a base loaded plant designed for a relatively constant heat sink temperature, there is little flow reduction that can be expected (up to 10%). This limits the biological benefit of installing variable speed drives on the existing pumps. Since variable speed drives of a size needed are not normally produced, the costs for this modification are difficult to estimate. Based on input from one experienced vendor, the net present value of installing variable frequency power units would be approximately (-) $7,652,000.

Due to the low reduction in flow and relatively high (and uncertain) costs to install these drives. the minimal reduction in entrainment is not considered to provide a substantial biological benefit.

6.2.2.6 Refueling Outage Scheduling

Diablo Canyon Power Plant Units 1 and 2 are periodically removed from service for refueling and maintenance. The unit outages occur at an interval of approximately 18 mo. Future outages are expected to last approximately 30 d. The seasonal planned reduction alternative would involve the selective scheduling of unit outages to coincide with the peak periods of abundance for key larval taxa in the area. Ideally, refueling outages would be scheduled for specific times of the year when densities of entrained organisms are greatest.

Over the past 15 years the majority of the 18 refueling outages have occurred during the months of March–April (7 outages) and September–October (5 to 8 outages). Fall outages have occurred regularly during these months, but in recent years winter outages started earlier, running from February–March. Of the 14 target taxa including subgroups, the majority reproduce during the spring months of March–June (**Table 6-2**). Few of these taxa are vulnerable as larvae during fall. A shift in outage scheduling to the spring would lessen the susceptibility of these larvae to entrainment. Having both units refuel each spring is highly uneconomical. Extending each unit to a 24 mo cycle would allow for spring outages, but is not possible with current fuel design. During the normal operational cycle about one-third of the fuel is consumed over an 18–21 mo period before refueling is required. This limits the possibility of modifying outage schedules to a shorter duration. Without the ability to lengthen fuel cycles, outages could not be scheduled only during the spring. Without this flexibility, shortening outage schedules to occur on 12 month intervals would become inefficient.

A second scenario of reduced operation could involve curtailments during periods of greater larval density. Monthly densities of fish larvae peak during the spring months from March through June, as depicted for 1997 and 1998 in (**Figure 6-6**). During the months March –May approximately 55% of the fish larvae for the nine months ending in September are at risk to entrainment. This nine month period was used because plankton data after September 1998 were analyzed only once-per-month with paired study grid surveys. During both years, larval densities peak in May each year when 23 and 31 percent of larvae were collected. These strategies would be protective of many species including KGB rockfish (*Sebastes* spp. V_De), northern anchovy, monkeyface eel, Pacific sardine, northern lampfish, smoothhead sculpin, white croaker, and California halibut. Spring time curtailments, however, would not be protective of other fishes including clinid kelpfish, blackeye goby, blue rockfish (*Sebastes* spp. V), snubnose sculpin, and some KGB rockfish (*Sebastes* spp. V_D) .

A dual unit curtailment for a three month period each spring would have a significantly negative financial impact on PG&E. The NPV of this option is extremely negative, based on loss of generation. The lost revenue and NPV for this option are, however, considered proprietary information. Replacement power obtained from gas-fired facilities would generate about one-half the EPA criteria pollutants and "green house" gas emissions calculated in **Section 6.2.2.4** each year under this scenario.

6.2.3 Conclusion

A hierarchical evaluation was used to assess which alternative intake technologies were technically feasible and could reduce impingement and entrainment at DCPP.

A reassessment of the 1985–86 316(b) Demonstration Study (Tenera 1998a) confirmed that estimated impingement at DCPP is very low (0.32 to 0.73 kg/d/unit). The current report found that, for any type of modification, very little improvement can be made to the present DCPP intake configuration to reduce the number of impinged fish, without incurring substantial costs relative to the benefit achieved. Regardless, **Section 6-2** of this report studied the feasibility of three alternative technologies: an increased area intake, angled screen intake, and modified traveling screens with enhanced fish handling equipment.

Increasing the cross-sectional area of the intake structure would decrease the water flow rate. But, apparently healthy juvenile and adult fish have been observed living and swimming inside the intake structure at DCPP without being impinged. Also, implementing this alternative would require very substantial disruption of the intake cove as a cofferdam would be required to de-water the cove while dredging and associated modifications took place. The angled screen intake design is judged to have similar costs and benefits as the increased area intake, with the potential for increase fish recovery.

The cost of implementing either the increased area intake or the angled screen intake alternatives is estimated to have a net present value of approximately (-)$275,000,000. This equates to approximately $61,700 per kilogram of fish saved, assuming the modification could completely eliminate impingement.

Due to the high cost as well as the high impact to the Intake Cove during construction and negligible reduction in impingement, these alternative intake technologies are not considered cost effective for DCPP.

Applicability of the most current intake screen and fish conveyance technologies were evaluated. Proposed modifications to the existing configuration include the addition of angled intake screens, watertight fish collection buckets, low pressure spray wash, a gravity sluiceway to convey fish back to the ocean, and modifications to the screens to allow continuous rotation.

None of the organisms impinged on the screens at DCPP are assumed to survive because of the current debris removal configuration. Installation of a gravity sluiceway and low pressure spray wash could reduce the mortality rate of impinged organisms.

Although there is insufficient data to perform a thorough site-specific analysis, modified angled traveling screens with continuous rotation, low pressure spray wash, and watertight fish collection buckets have the potential to reduce the mortality of impinged organisms at DCPP. Implementation of this modification has associated capital and maintenance costs resulting in a net present value (NPV) of (-)$11,000,000. The cost of saving impinged fish with this modification, assuming 100% survival, is on the order of $2,200 per kg of impinged fish assuming a 100% reduction in impingement. Site-specific testing of this proposed modification would be required to determine the actual biological benefit.

Because impingement at DCPP is already low, modification of the current traveling screens to further reduce impingement is not considered cost effective for DCPP.

For entrainment, five alternative technologies have been identified as technically feasible at DCPP. The alternatives are closed-cycle cooling towers, fine mesh screens, single circulating water pump operation, variable speed circulating water pumps, and changes to refueling outage scheduling.

Two types of closed-cycle cooling towers were evaluated. Both would reduce the cooling water requirement, possibly as much as 80–95%, and result in entrainment reductions. However, installation and operation of closed-cycle cooling towers have negative environmental impacts on air quality (salt drift), increased salinity of the cooling water discharge, terrestrial impacts of salt drift, and poor aesthetics as a consequence of high cooling towers and vapor plumes.

Additionally, closed-cycle cooling towers have high capital and maintenance costs. Both units would be de-rated to accommodate the new cooling medium. Order of magnitude estimated net present values (NPV) range from (-) $503,000,000 to (-) $1,072,000,000, plus costs for design, licensing, demolition of existing facilities, and environmental damage to the land. Because of the adverse terrestrial environmental impacts and high implementation costs associated with close-cycle cooling towers, they are not considered feasible at DCPP

Center flow screens with fine mesh (1 mm) baskets could be retrofitted to the existing DCPP intake structure to allow screening of larvae. Studies have shown wide ranging mortality rates for impinged larvae, ranging from 5% to near 100%, depending on species. A site-specific investigation would be needed to determine the mortality for larval organisms at DCPP. In addition, there is a potential that the center flow screens, with their higher inlet velocities, complex flow patterns and curved baskets could increase impingement of juvenile and adult fishes. Both survivability of larvae and any changes to impingement would have to be evaluated prior to assessing a biological benefit for fine mesh baskets on center flow screens. The net present value of this modification is (-) $7,906,000, with an uncertain benefit.

Single circulating water pump operation was also evaluated as a method to reduce entrainment. Operating only one of the two CWP running per unit would reduce the cooling water requirement by about half, reducing entrainment by the same amount. Single circulating water pump operation would require that both units at DCPP be operated at 50% power or less or that one unit be shutdown. The loss of revenue associated with single circulating water pump operation does not make this a feasible alternative.

Variable speed drives for the circulating water pumps offer the possibility of reducing flow to the minimum required flowrate (optimizing generation and condensate depression) needed to support operation at a specific level of plant output. Since DCPP is a base loaded plant operating at 100% power most of the time, the potential flow reduction is limited to 2 to 10% of rated flow, depending on ocean temperatures. Additional flow reductions are limited by the capabilities of the pumps themselves, such that significant flow reductions (even with a reduction in power are limited to flow reduction of approximately 20 to 30%). The costs and limited potential flow reduction with this alternative does not make this a cost effective alternative.

The feasibility of scheduling refueling outages to coincide with periods of high larval densities of certain organisms was also evaluated. During refueling outages, the amount of cooling water required is reduced and strategic scheduling could reduce the amount of entrainment. It is possible that at least some of the refueling outages could be scheduled to coincide with periods of high density of certain larval fish or invertebrate taxa. Many fishes produce larvae to benefit from the increase productivity associated with spring and summer months. Conducting outages during the spring could reduce the impact on nearshore taxa 7–10% assuming two cooling water pumps are out of service for 30 d.

Longer curtailments of cooling water pump operation, exclusive of refueling outages were also evaluated. Water flow conditions would be severely reduced for one to three months under this scenario. Some or all cooling water pumps would be shut down when a majority of the fish larvae are present in the plankton. The current data indicate a large percentage of the larval fishes are vulnerable to entrainment through the spring months March–June. Suspending pumping operations, except for vital ASW flows, for three months would protect about half of the fish larval density from risk of entrainment. The costs of these measures are extreme and many fishes that reproduce at other times or have long-lived larval stages would remain vulnerable to entrainment during the 9–11 months of operation.

Table 6-1. Listing of the alternative technologies evaluated and location of the evaluation in this report.

Category	Intake Technology	Meets Criteria 1	Meets Criteria 2	Meets Criteria 3	Evaluated in noted Section or Appendix
Cooling Water System	Once Through	N/A	N/A	N/A	in use at DCPP
	Closed-cycle cooling tower (saltwater)	•	•	•	Section 6.2.2.1
	Closed-cycle cooling tower (fresh water)	•	•	•	Section 6.2.2.2
	Closed-cycle Cooling Pond or Canal	•	•		App. N
	Cooling system component modification				App. L
Intake Configuration	Offshore Intake Location / Velocity Cap	•			App. M
	Alternate Onshore Intake Location	•			App. M
	Shoreline	N/A	N/A	N/A	in use at DCPP
	Recessed	•			App. M
	Increased Area Intake Structure	•	•	•	Section 6.2.1.1
	Angled Screen Intake Structure	•	•	•	Section 6.2.1.2
Behavioral Barriers	Light	•			App. M
	Sound	•			App. M
	Bubble screen	•			App. M
	Velocity gradient (water jet or other turbulence)				App. L
	Electrical barrier				App. L
	Louvers				App. L
	Chemicals barriers				App. L
	Magnetic field (barrier)				App. L
	Chain and cable barriers				App. L
Physical Barriers	Vertical traveling screen	N/A	N/A	N/A	in use at DCPP
	Drum screen	•			App. M
	Centerflow traveling screen	•			App. M
	Fine Mesh Screen	•	•	•	Section 6.2.2.3
	Media filter				App. L
	Stationary screen				App. L
	Horizontal traveling screen				App. L
	Inclined Plane screens				App. L
Fish Collection, Removal and Conveyance Systems	Combinations of vertical traveling screen modifications	•	•	•	Section 6.2.1.3
	Gravity sluiceway	•	•	•	Sections 6.2.1.2 and 6.2.1.3
Maintenance and Operational Modifications	Maintenance Dredging	•			App. M
	Single circulating water pump operation	•	•	•	Section 6.2.2.4
	Variable Speed Circulating Water Pumps	•	•	•	Section 6.2.2.5
	Continuous screen rotation	•	•	•	Section 6.2.1.3
	Refueling outage scheduling	•	•	•	Section 6.2.2.6

N/A: Not applicable

Table 6-2. Estimated equivalent adults, months of peak density, and evaluation of susceptibility to entrainment for target crab and fish taxa collected in DCPP entrainment and study grid plankton samples.

Common Name	Months of peak density		Estimated Equivalent Adults	Reduced Entrainment
	Entrainment	Study Grid	(*FH* and *AEL*)	Feb-Mar & Sep-Oct
Cancer crabs				
Brown rock crab	Spring	May–Jun	9,100–23,400	maybe
Slender crab	Winter–Spring	May–Jun	895–5,460	maybe
Pacific sardine	Mar–May	Mar–May	3,170–8,460	Yes
Northern anchovy	Dec–May	Mar–May	16,100–120,000	Yes
Rockfishes				
KGB complex	Mar–Jul	May	497–1,120	Yes
Blue complex	Jan–Mar	Jan–Feb	18–353	Yes
Painted greenling	all year, esp. Mar–May	May–Jun	nd	Yes
Sculpins	Apr–Jul	Apr–Jul	nd	No
White croaker	Dec–Mar	Dec–May	5,110–15,000	Yes
Monkeyface prickleback	Mar–Jun	Apr–May	nd	Yes
Kelpfishes	Jan; Jun–Aug	Dec–Feb	nd	No
Blackeye goby	Mar–Nov	July–Sept	10,300–75,400	Yes
Flatfishes				
Sanddabs	Jul–Sept	July–Sept	92–2,370	Yes
California halibut	April–May	Apr–May; Jul	nd	No

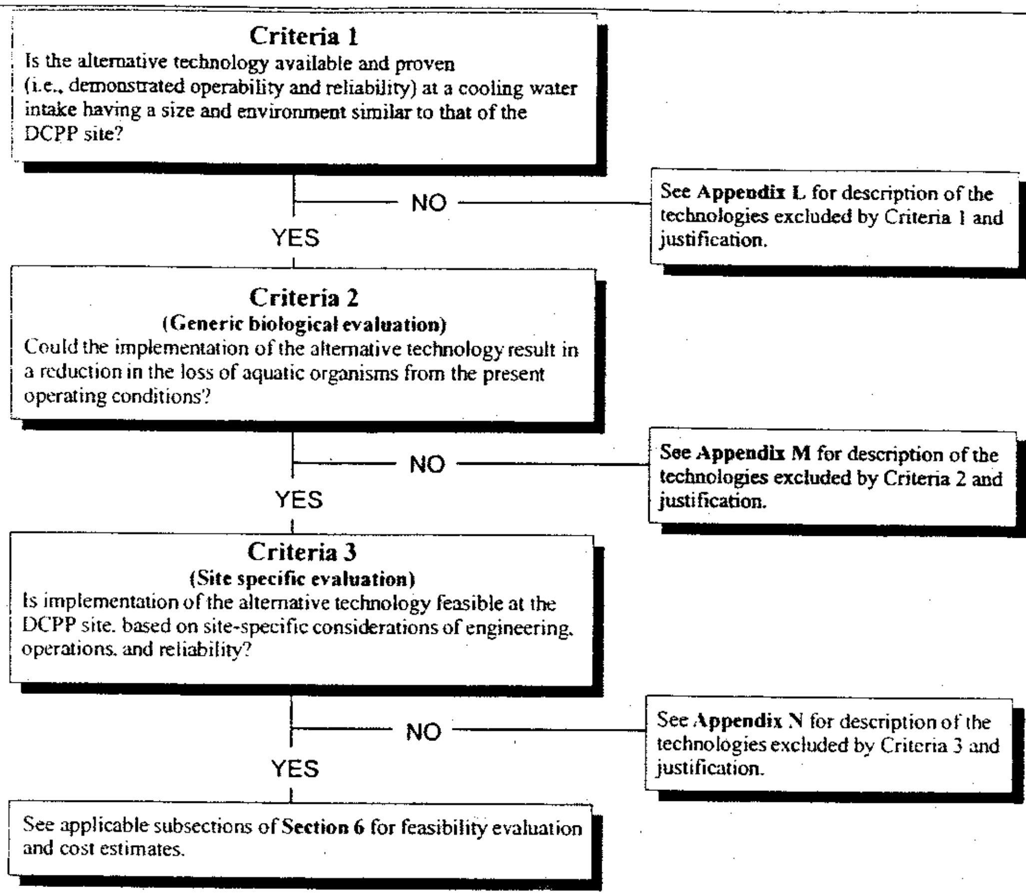


Figure 6-1. Alternative intake technologies evaluation flow chart.

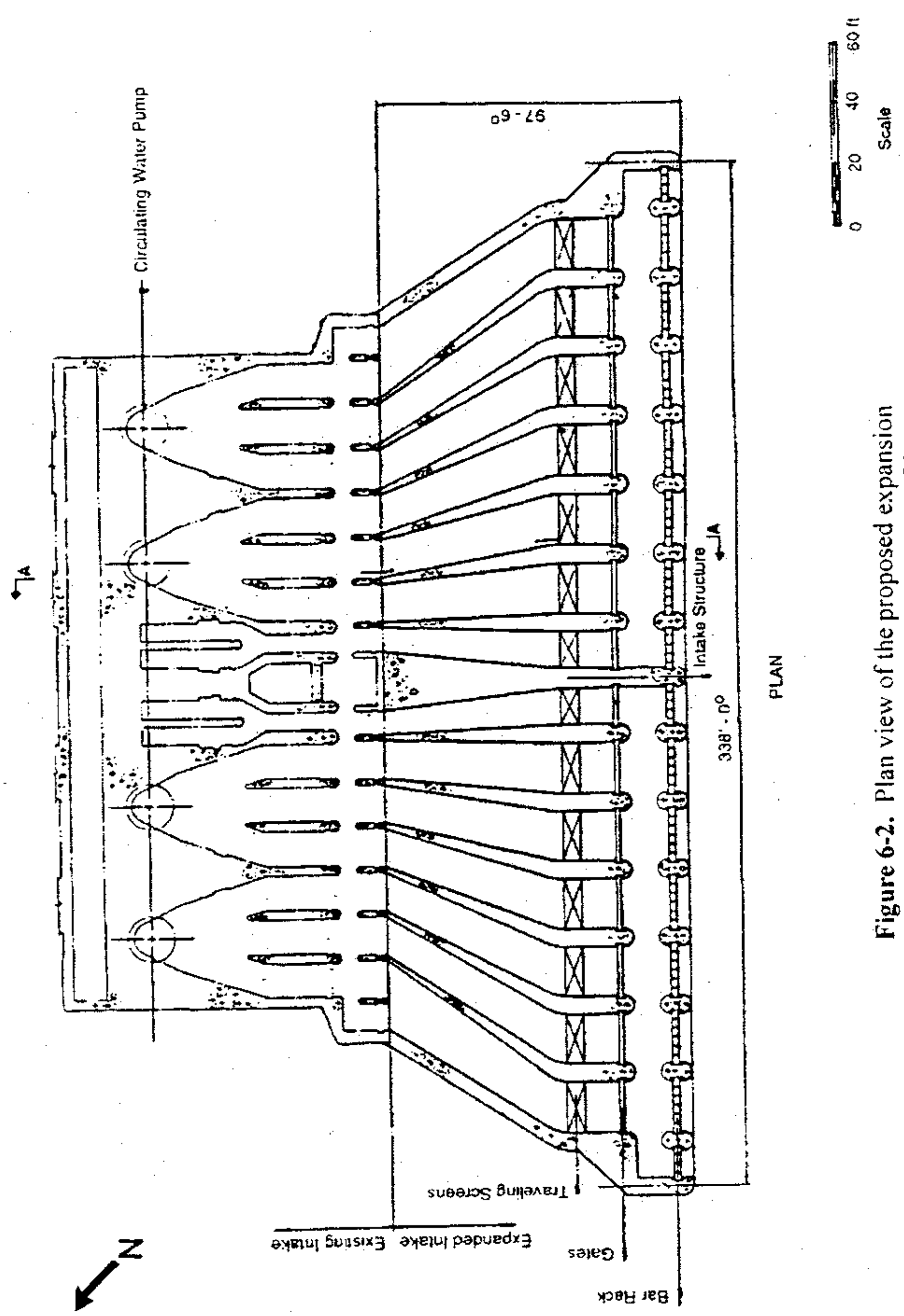


Figure 6-2. Plan view of the proposed expansion of the intakes at the Diablo Canyon Power Plant.

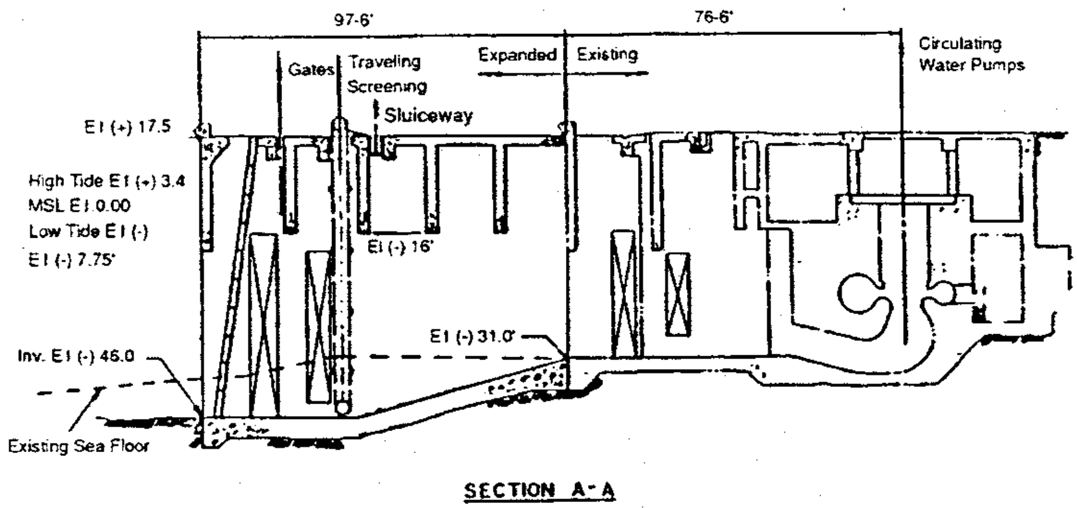


Figure 6-3. Sectional view of the proposed expansion of the intake at the Diablo Canyon Power Plant.

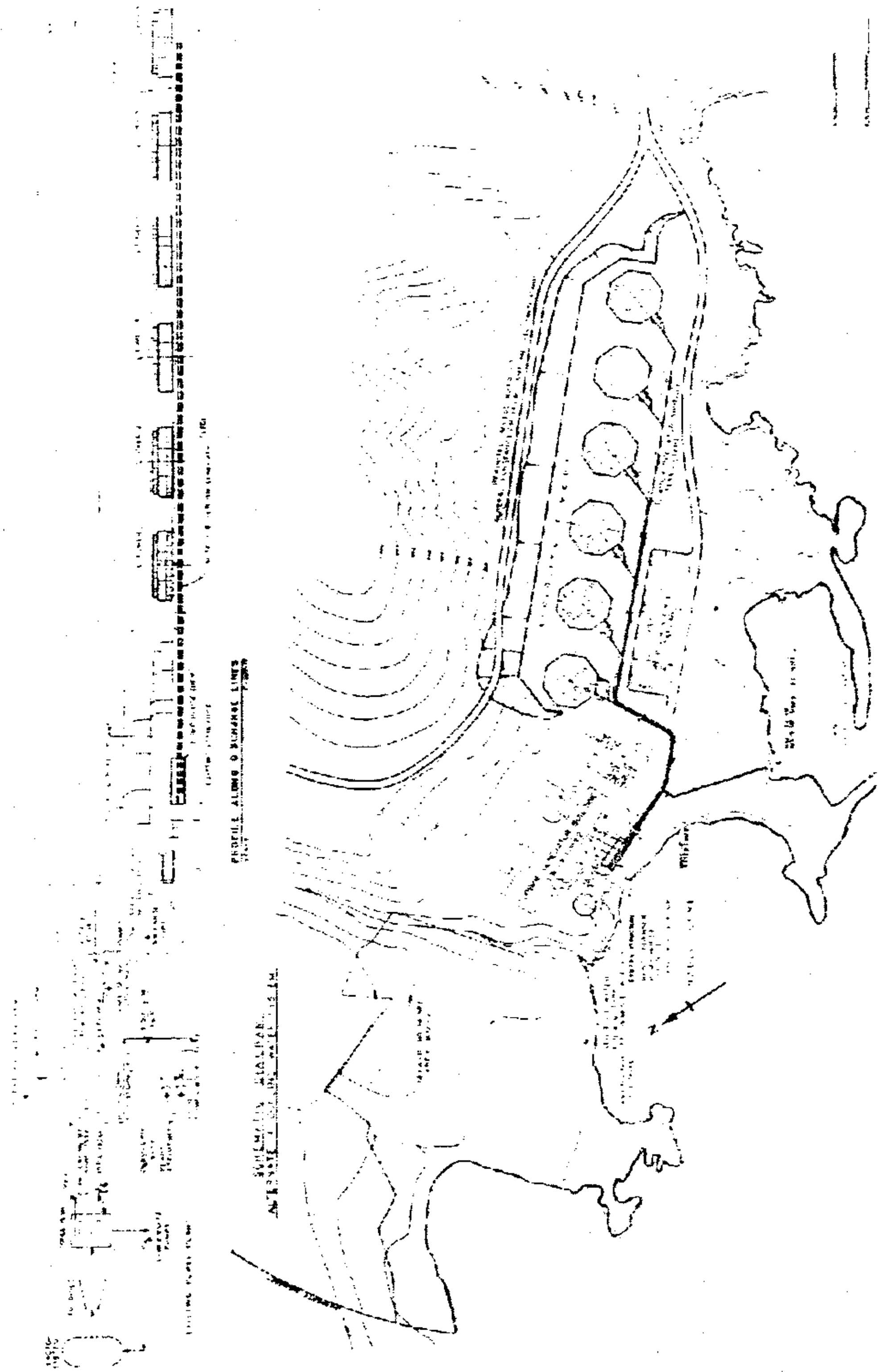


Figure 6-4. Schematic drawing of potential siting of mechanical draft cooling towers at the Diablo Canyon Power Plant site.

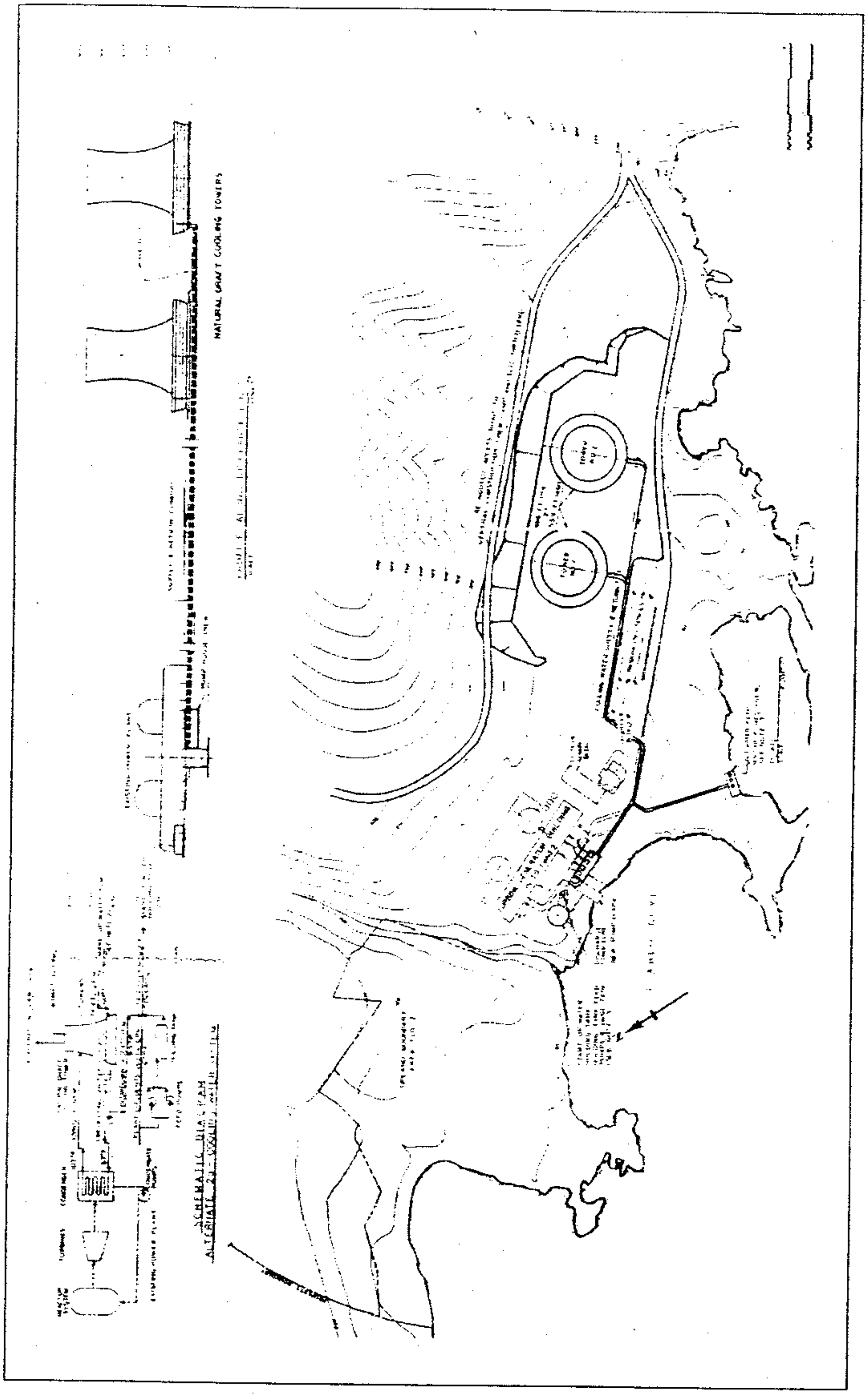


Figure 6-5. Schematic drawing of potential siting of natural draft cooling towers at the Diablo Canyon Power Plant site.

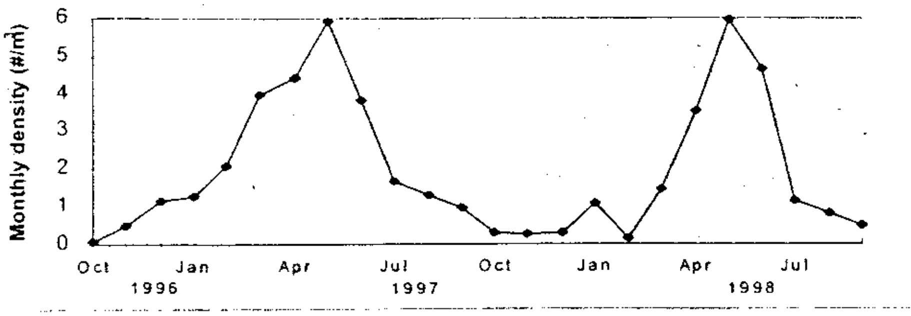


Figure 6-6. Monthly density of all fish larvae collected in weekly entrainment surveys conducted from Oct 1996 to Sep 1998.

Diablo Canyon Power Plant
Independent Scientist's Recommendations to the Regional Board
Regarding "Mitigation" for Cooling Water Impacts

July 27, 2005

Goal: The goal of the independent scientists is to provide the Regional Board with our best professional judgment regarding environmentally beneficial projects (type of projects, scale, and balance) that might be funded as part of PG&E's Diablo Canyon Power Plant permit.

The independent scientists work with the technical workgroup. The technical workgroup consists of Regional Board staff, the Board's independent scientists, PG&E staff, and PG&E's consultants. The recommendations in this paper reflect the best professional judgment of the Regional Board's independent scientists, and are not necessarily the opinion of PG&E.

The Regional Board's Independent scientists on this project are:

1. Pete Raimondi, U.C. Santa Cruz
2. Gregor M. Cailliet, Moss Landing Marine Laboratories
3. Michael S. Foster, Moss Landing Marine Laboratories

All costs in this white paper are as of July 2004

EXECUTIVE SUMMARY

As directed by the RWQCB, the independent scientists considered mitigation alternatives for addressing cooling water impacts at DCPP, with specific direction to consider Marine Protected Areas, artificial reefs, the uncertainty regarding impacts and mitigation measures, performance monitoring for any mitigation projects, thermal effects mitigation projects, and a reduced thermal effects monitoring program.

This report considers several types of mitigation projects with respect to entrainment and thermal effects, including:

Creating offshore reef habitat
Establishment of marine reserves (Marine Protected Areas)
Terrestrial conservation easement (RWQCB/PG&E settlement)
Fish hatchery work
Restoration of marine habitat
Use of PG&E lab facilities (RWQCB/PG&E settlement)
Abalone Research (RWQCB/PG&E settlement)
Central Coast Ambient Monitoring Program (RWQCB/PG&E settlement)
CALCOFI work (ocean monitoring/research)
State Parks Docent Program (Thermal effects)

We also recommend a modified thermal effects monitoring plan.

Our recommendations/conclusions are:

- Regarding **entrainment**, three mitigation options are applicable in this case: artificial reefs, establishment of Marine Protected Areas, and the terrestrial easement described in the RWQCB/PG&E settlement.
- Artificial reefs would provide the most direct compensation for entrainment losses. The best current estimate of the area of artificial reef required would be between 85 and 200 hectares (210 to 500 acres). The cost of constructing the artificial reefs is estimated to be between $10.6 million (for 85 hectares) and $26 million (for 200 hectares). These estimates are based on extensive artificial reef mitigation research done at the San Onofre Nuclear Generating Station (SONGS). Note that the cost estimate does not include performance monitoring (a requirement in the SONGS mitigation).
- Permanent preservation of marine habitat via establishment of marine reserves would also provide mitigation for entrainment losses, but marine reserves are likely to benefit only harvested species, which constitute only a portion of those entrained. There might also be some benefit with regard to species harvest via by-catch.
- We recommend that the terrestrial easement be part of the settlement agreement, and conclude that both options we were directed to evaluate, establishment of Marine Protected Areas or creation of an artificial reef on the central coast, could provide a level of compensation for entrainment at DCPP. We discuss the issues around the establishment of Marine Protected Areas in detail in this paper, including the

process for implementation, likelihood of success, and costs. This paper also details the scale, cost, and benefits of artificial reefs as mitigation for entrainment impacts.

- Fish hatchery work, physical restoration of marine habitat, and CALCOFI research funding are not currently recommended as projects.
- Use of the PG&E lab facilities (RWQCB/PG&E settlement) is not mitigation for impacts, and is not recommended.
- The abalone research project (RWQCB/PG&E settlement), as currently proposed, is unlikely to provide any mitigation benefit for either entrainment or thermal impacts, and is not recommended.
- The Central Coast Ambient Monitoring Program (CAMP) funding (RWQCB/PG&E settlement) is an important program, but general ambient monitoring is not mitigation for impacts. We recommend that funds be directed toward performance monitoring as part of any implemented mitigation projects, and that the performance monitoring be overseen by independent scientific experts from the relevant fields of study.
- The States Park Docent Program is unlikely to provide mitigation for either Entrainment or thermal effects if it was in conjunction with opening access to restricted areas. There could be some value associated with this program if it was applied to access control in existing marine parks.
- Regarding **thermal effects**, there are three applicable mitigation options: Marine Protected Areas, the terrestrial easement, and passive restoration of intertidal areas (chiefly through a docents program). Marine Protected Areas would include intertidal and shallow subtidal areas (the same type of habitat affected by the thermal discharge). The terrestrial easement provides permanent protection for a relatively large amount of intertidal habitat (relative to the amount of intertidal habitat impacted by thermal effects). Again, we recommend that the terrestrial easement be included in the settlement. Also, intertidal areas are degraded in some State Park areas on the Central Coast due to public access (trampling). Funds could be directed to a docent program designed to minimize this impact.

The benefits, costs, and likelihood of success for the recommended projects are discussed in this report.

DISCUSSION

1.0 Boundaries, Understandings

The independent scientists' recommendations are made within these boundaries/understandings:

1. The independent scientists will not address policy or legal issues. The independent scientists will make realistic, defensible recommendations based on science.
2. It may not be possible to mitigate or compensate for all environmental losses due to entrainment and/or the thermal discharge. For example, hundreds of species are entrained, and it is infeasible to replace these entrained organisms on a one for

one basis. Therefore, projects are considered that provide a benefit to habitat known to be critical to impacted species (which should help replace some of the losses).

3. The geographic scale from which entrainment losses occur is relatively large. Proposed projects in response to entrainment losses are therefore considered on a similar scale.
4. The geographic scale of the thermal effects is more local. Projects related to thermal effects are therefore considered on a local scale. The thermal effects of concern are those that are above and beyond the predicted effects considered in State Water Resources Control Board Order No. 83-1.
5. Research or surveys are also considered. For some projects, research or surveys are needed before the actual project can begin or to track impacts over time.
6. The independent scientists will scale, balance, and cost projects to the extent possible, with consideration for the major limitations involved. In many cases, costs are likely to be an unknown and only gross estimates will be made.
7. The independent scientists will consider the uncertainties associated with the power plant impacts and potential projects to allow comparison between likely impacts and likely benefits.
8. The independent scientists' recommendations are based on current knowledge of local conditions, the marine environment and scientific literature. The basis of these recommendations is a consideration of potential projects that would benefit the marine environment (but not necessarily directly replace losses).
9. The independent scientists will also recommend a thermal effects monitoring program sufficient to follow biological communities over time (likely to be much less comprehensive than the current program).

2.0 Uncertainties Regarding Entrainment Losses and Projects

Evaluation of the impacts resulting from entrainment requires a basic understanding of the typical life history of most marine species, together with an understanding of the complexity in conducting an entrainment study.

Most nearshore marine species have a "complex" or "bipartite" life history. This means that the life of a species is divided into at least two distinct phases: a dispersing larval stage followed by a typically reef resident adult stage. Note that even those species without a reef resident stage typically have lower dispersal in the adult stage than in the larval stage. Relatively much is known about the duration of the dispersing stage (especially for fish, because otoliths can be used to determine the larval period). By contrast, almost nothing is known about the distance over which larvae may disperse. Most estimates of the geographic scale of larval dispersal come from coupled oceanographic-life history models, which (essentially) estimate larval dispersal as the distance a passive particle would be transported (over a set number of days) due to net movement of the prevailing water mass. Here, a set number of days represents the larval period prior to entrainment. Consultants contracted by PG&E (Tenera) were able to calculate a distribution of dispersal distances prior to entrainment for all target species.

Larval size as a proxy for days in the plankton, this distribution could then be used to estimate the geographic range of impact and the intensity of impact as a function of distance from the intake. For the species evaluated in the 316b study the geographic range of impact was often very large, (see Table 1, below) usually with the intensity at any given location being fairly low. By itself, this does not mean that the impact was small, instead it simply means that the impact was spread over a wide geographic area.

Entrainment studies are difficult to conduct for many reasons, including:

1. The large spatial and temporal scales over which impacts may occur
2. The massive sampling effort required
3. The difficulty in identifying species
4. Evaluating assumptions that must be made to fully parameterize the "effects" model (i.e. the model used to determine loss rate)
5. Evaluating the effects of variability

RWQCB staff and the Regional Board's independent scientists have concluded that entrainment losses cause an impact (essentially decreased numbers of larvae), but estimates of total impact (direct effects) have fairly large uncertainty (but not larger than is typical in impact studies of this complexity). If fact, we consider the recent entrainment study done at DCPP to be the finest ever done for power generating facilities in the State of California. Reducing the uncertainty would take many years and cost tens of millions of dollars, but the resulting estimates are likely to still have very large errors. This problem has no financially practical solution.

The benefits of projects to enhance the environment may also be difficult to measure. Hence, the independent scientists have endeavored to propose those projects that are likely to either provide substantial value per dollar spent or that can be most accurately evaluated.

3.0 Potential Projects Regarding Entrainment Losses

The independent scientists may consider any potential projects to benefit the marine environment, however, the Regional Board specifically directed us to further consider marine reserves and the overall uncertainty associated with "mitigating" impacts.

Projects considered:

Creating offshore reef habitat (artificial reefs)
Establishment of marine reserves (Marine Protected Areas)
Terrestrial conservation easement (RWQCB/PG&E settlement)
Fish hatchery work
Restoration of marine habitat
Abalone Research (RWQCB/PG&E settlement)
Use of PG&E lab facilities (RWQCB/PG&E settlement)

Central Coast Ambient Monitoring Program (RWQCB/PG&E settlement)
CALCOFI work (ocean monitoring/research)

3.1 Artificial Reef Habitat as Compensation for Entrainment Losses

Key conclusions

1) *An artificial reef of sufficient size and with appropriate design and placement could compensate for the majority of impacts associated with entrainment at DCPP.*
2) *Based on Empirical Transport Models (ETM) and estimates of rocky reef habitat in the source water body the estimated range of reef sizes sufficient to compensate for entrainment losses is between 85 (low end) and 412 hectares (high end). Based on information we currently have we have concluded that the most reasonable range is between 85 and 200 hectares.*
3) *As of July 2004, The estimated cost for the construction of an artificial reef ranged from 10.6 million (85 hectares) to 26 million (200 hectares) dollars (cost of transportation of material could cause these estimates to increase).*
4) *The cost associated with the construction of the artificial reef is the single best estimate of the value of the lost resources. If the reef is of sufficient size and of proper design, it has the potential to compensate for almost all entrainment impacts measured and unmeasured.*

Background

Diablo Canyon Power Plant entrains well over 30 billion planktonic forms per year. The reported value (30 billion larvae, based on estimated entrainment for sampled species including all larval stages of crabs and fish, PGE 316B Demonstration) is a vast underestimate of the true number entrained as only a very small subset of entrainable organisms were assessed. For example, no estimates were made for most invertebrates, any algae and marine plants, or any holoplankton. By contrast, entrainment of fish larvae was well characterized. For coastal intakes it has been difficult to develop mitigation strategies that have the potential to compensate for losses due to entrainment. In part this is due to the difficulty in establishing a loss basis (e.g. adult stock) that could be used as a currency for comparing mitigation alternatives. It is also difficult because restoration activities that are used in estuarine and freshwater system are infeasible when losses are mainly to open coast species. Here we evaluate artificial reef habitat that: (1) has the potential to scale directly with a reasonable estimate of impact (larval loss), (2) provides a robust method to value the loss resources (important in the new 316B context), and (3) may compensate for most losses (both measured and unmeasured).

Approach

The basic approach is to estimate the amount of new reef habitat that would be required to produce the juveniles lost to entrainment. Table 1 below shows the estimates for entrainment at DCPP for a series of target fish taxa. Target taxa are defined as the subset of all taxa for which entrainment was estimated and for which a calculation of ecological loss was attempted. Three such measures were used. Fecundity Hindcast (FH) and Adult

Equivalent Loss (AEL) estimate are based on the idea of hindcasting or projecting larval losses to adult stock. The third method, based on a modified Empirical Transport Model (ETM) produces an estimate of proportional mortality (Pm), which is an estimate of the larvae at risk of entrainment, that were entrained. Those larvae at risk of being entrained are considered to be in the source water body, defined as the geographic area from which entrained larvae could have come. The estimate of source water body is based on the period of vulnerability of the larval form (species specific) coupled with an estimate of oceanographic currents that transport the larvae along the coast. By example, an estimate of Pm could be: 10% of larvae of species A in an area stretching 100 km along the coast were lost due to entrainment. Of the three methods the independent scientists agreed that the ETM approach was the most reliable and reasonable approach for the analysis done at DCPP. Hence, our approach here is to determine the amount of habitat that would be required to produce the juveniles lost to entrainment, based on ETM calculations. The table below (Table 1) shows the estimates of adjusted annual entrainment ($\hat{E}_{Adj-T}$) for Analysis Periods 1 (October 1996–September 1997), 2 (October 1997–September 1998), and 3 (July 1997–June 1998) for the 14 target fish taxa collected and analyzed at DCPP (for reference, the Brown Rock Crab and Slender Crab were also evaluated. The combined estimated annual entrainment for these two species was > 27 billion larvae between December 1996 and November 1997).

Table 1: Estimated entrainment for target fish species (PG&E, 316b Demonstration) for Analysis Periods 1 (October 1996–September 1997), 2 (October 1997–September 1998), and 3 (July 1997–June 1998).

Taxon	Analysis Period	Adjusted Annual Entrainment $\hat{E}_{Adj-T}$
Pacific sardine	1.	8,470,000
	2.	22,600,000
	3.	22,600,000
Northern anchovy	1.	136,000,000
	2.	376,000,000
	3.	377,000,000
KGB rockfish complex	1.	275,000,000
	2.	222,000,000
	3.	222,000,000
Blue rockfish complex	1.	84,040,000
	2.	33,800,000
	3.	33,900,000
Painted greenling	1.	24,200,000
	2.	9,610,000
	3.	12,100,000
Smoothhead sculpin	1.	57,700,000
	2.	115,000,000
	3.	129,000,000
Snubnose sculpin	1.	110,000,000
	2.	83,500,000
	3.	105,000,000
Cabezon	1.	51,900,000
	2.	36,300,000
	3.	36,300,000
White croaker	1.	305,000,000
	2.	440,000,000
	3.	447,000,000
Monkeyface prickleback	1.	83,100,000
	2.	61,500,000
	3.	60,200,000
Clinid kelpfishes	1.	181,000,000
	2.	308,000,000
	3.	458,000,000
Blackeye goby	1.	128,000,000
	2.	109,000,000
	3.	128,000,000
Sanddabs	1.	7,160,000
	2.	1,540,000
	3.	6,610,000
California halibut	1.	8,260,000
	2.	15,700,000
	3.	15,500,000

All but five of the species shown above are associated with rocky reefs, primarily shallow ones. The exceptions are sanddabs, California halibut and white croaker, which typically are associated with sandy substrates, and Pacific sardines and northern anchovies, which are more pelagic species. Indeed the majority of all species for which entrainment was calculated are associated (as adults) with rocky reefs. Moreover it is extremely likely that this is also true for unmeasured species except holoplankton.

This is important because it strongly supports the idea that creation of new rocky habitat could compensate for most entrainment losses. The logic of this argument follows. Recall that the estimate of losses based on the ETM model are depicted as the proportion of larvae lost to entrainment that came from the source water body. Essentially this means that larvae were produced in the source water body, or at least had been produced nearby and reached the source water body while still larvae. Note, that this does not necessarily have to be true if very early larval stages were not vulnerable. However it is true that the source water body for a given species will be of the same dimensions regardless of the window of vulnerability so long as the duration of vulnerability is the same. Therefore it follows that since the species are reef residents as adults, larval production is a function of the amount of reef available. A simplifying assumption (that will be assessed later in this document) is that artificial reefs support similar densities of adults as do natural reefs. By knowing the amount of reef available in the source water body we can calculate the amount of new reef that would be required to produce larvae equal to those lost to entrainment. For example, assume that 10% of species A larvae in an area 100 miles along shore by 2 miles cross shore (the source water body for this example) are lost to entrainment. Further assume that within the source water body there are 3,000 acres of reef. It follows that if, somehow, 300 acres of new reef appeared of quality equal to that of average natural reef, there would be additional larvae produced equal to those lost to entrainment (3,000 acres x 10%).

An underlying assumption of our interpretation of ETM calculations is that Pm estimates for individual species represent replicate observations that can be used to come up with an overall estimate of larval loss. This means that an individual Pm value really is meaningful only as it contributes to the overall estimate. We have decided that the average Pm value calculated across sampling periods and species is the most reliable estimate of the true impact. This approach has another valuable attribute. The average Pm calculated across all appropriate target species should be a reliable estimate of the impact to non-targeted species because it is an estimate of the expected Pm across independent, replicate and representative observations.

Pm estimates, as noted, above are only informative when placed in the context of source water body. Therefore we calculated two parameters for use in determining the size of an artificial reef. First, average Pm as discussed above. Second, average source water body calculated for the same species and sampling periods as done for Pm.

In these calculations we used all target fish species except those associated with sandy habitats as adults. The results of these calculations are shown in the table below.

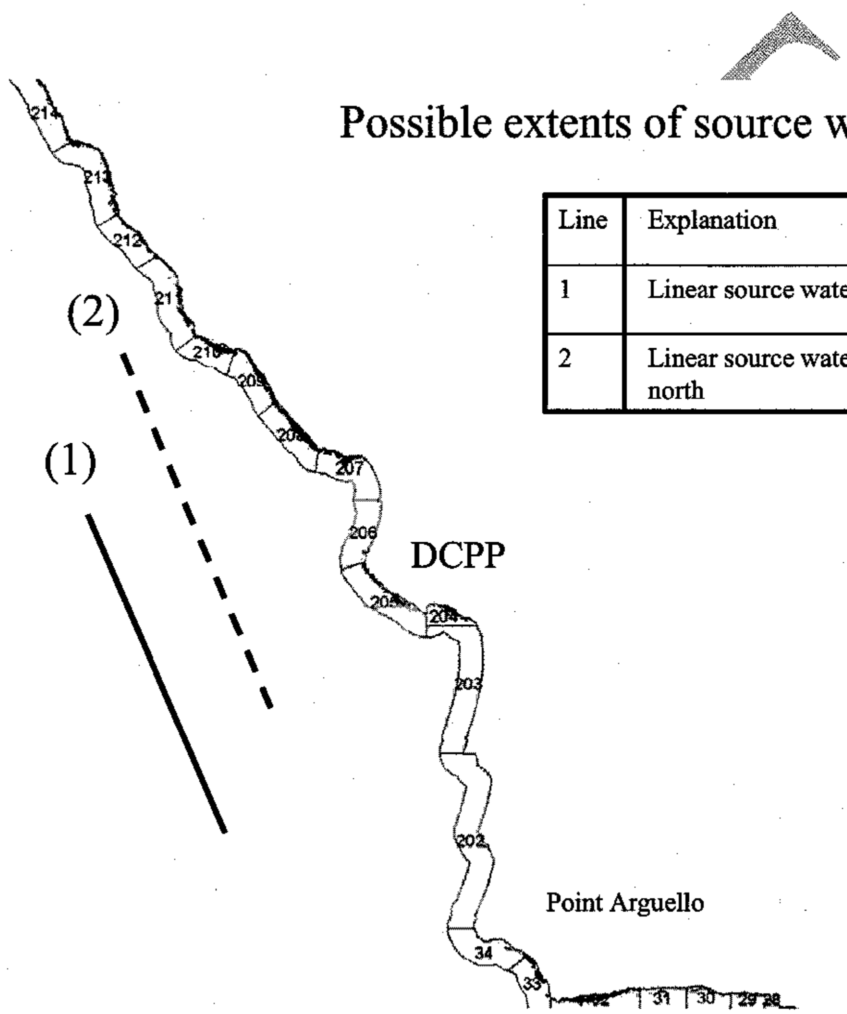
Table 2: Estimates of duration at risk, mortality rate and source water body for target species (PG&E, Revised 316b Demonstration Results: as of June 30, 2005). Larval mortality rates (Pm) based on maximum period of larval risk (defined in 316B document)

Taxa	Adult Habitat	Sample Period	Duration at Risk (Days) - Maximum Length	Mortality rate (Pm)	Source water body, alongshore distance over which Pm can be calculated (km)	Ratio of extrapolated source water to sampled source water (1/Ps)
Smoothhead sculpin	Rocky	97-98	35	11.39%	120.41	6.92
		98-99	35	22.57%	88.57	5.09
Monkeyface prickleback	Rocky	97-98	25	13.76%	106.31	6.11
		98-99	25	11.76%	105.79	6.08
Clinid kelpfishes	Rocky	97-98	32	18.94%	99.88	5.74
		98-99	32	24.97%	76.21	4.38
Blackeye goby	Rocky	97-98	5	11.51%	28.54	1.64
		98-99	5	6.54%	21.92	1.26
Cabezon	Rocky	97-98	8	1.11%	41.06	2.36
		98-99	8	1.52%	33.23	1.91
Snubnose sculpin	Rocky	97-98	42	14.94%	105.79	6.08
		98-99	42	31.02%	91.35	5.25
Painted greenling	Rocky	97-98	24	6.26%	88.22	5.07
		98-99	24	5.58%	77.26	4.44
KGB rockfishes	Rocky	97-98	16	3.88%	67.16	3.86
		98-99	16	4.80%	76.21	4.38
Blue rockfish	Rocky	97-98	13	0.41%	47.15	2.71
		98-99	13	2.77%	52.72	3.03
White croaker	Sandy	97-98	22	[illegible]	[illegible]	[illegible]
		98-99	22	[illegible]	[illegible]	[illegible]
Sanddabs*	Sandy	97-98	11	[illegible]	[illegible]	[illegible]
		98-99	11	[illegible]	[illegible]	[illegible]
California halibut*	Sandy	97-98	[illegible]	[illegible]	[illegible]	[illegible]
		98-99	[illegible]	[illegible]	55.16	3.17
	Averages for Rocky reef			10.76%	73.77	
	Averages for all targeted fish species			8.59%	70.34	

The best estimate of Pm for reef associated species is 10.76%. Note that this value represents the best single estimate of Pm. In more recent analyses for other plants we have also estimated a confidence interval for Pm estimates. This allows a calculation of how uncertainty in calculations of Pm could affect estimation of impact. Such a calculation was not done for the revised estimates of Pm for DCPP. Because all of the species considered above are nearshore taxa we assume an offshore distance equal to that of the 316B study grid =3 kilometers. Hence, the average source water body is an area 74 kilometers alongshore by 3 kilometers offshore.

The next step is to determine the area of rocky reef within the source water body (henceforth ASWB, *average source water body*). This is difficult for two reasons. First there has been no comprehensive examination of rocky reef habitat along the California Coast. Second, the position of the ASWB is somewhat unclear. We have concluded that the most reasonable ASWB's are linear alongshore areas that are either centered at or that has their southern limit near to DCPP (Figure 1):

Figure 1: Possible extents of source water bodies, overlaid on map showing kelp coverage. Distance of lines offshore is simply to avoid overlap. All ASWB's are assumed to extend from the shoreline to 3 km offshore.

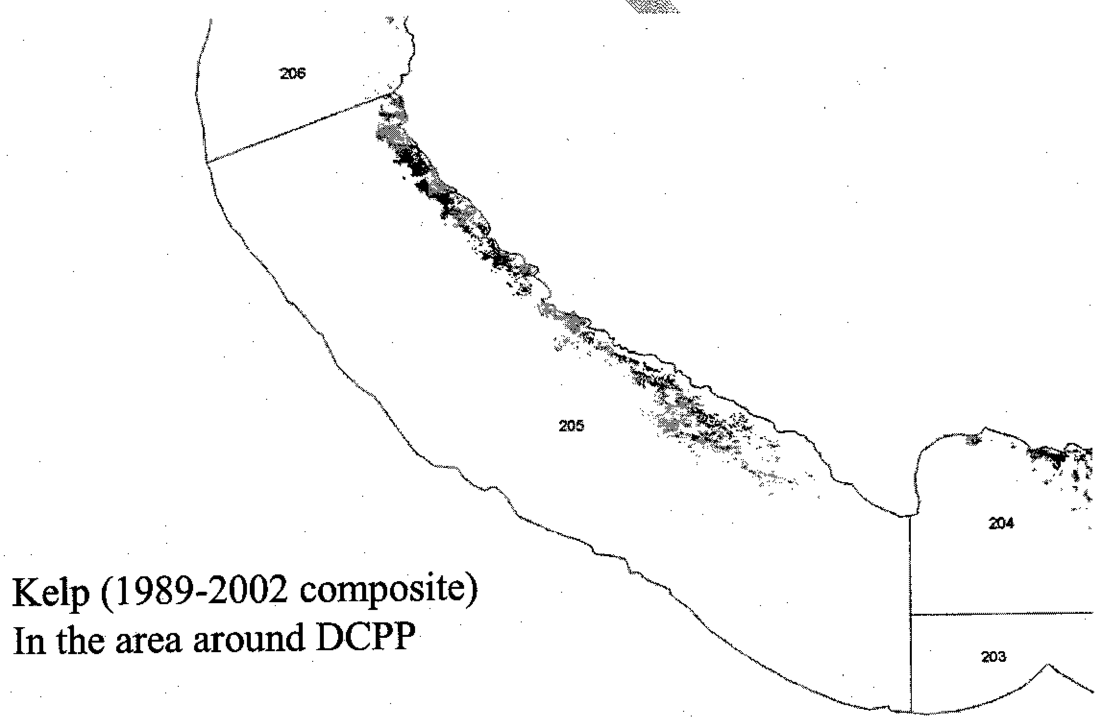


Line	Explanation
1	Linear source water body balanced N/S
2	Linear source water body, biased to the north

Based on current measurements and the configuration of the coastline, the lines above represent the range in reasonable ASWB's. It is clear from the discussion is the 316B document that source water body was estimated as linear multiples of the sampling grid. Therefore, lines 1 and 2 are the most appropriate estimates of the ASWB. The difference between them is in their orientation with respect to DCPP. ASWB 1 has the assumption that transport is equally likely from the north or south. ASWB 2 has the assumption that transport is more likely from the north.

Estimation of the amount of rocky reef is difficult, as noted above. However, we think that there is an approximation that makes sense. Along the central coast most rocky reef habitat that occurs between the 5 and 30 meters depth is likely to support *Macrocystis*. (Indeed many of the affected species are primarily found in kelp forests). Therefore, we can estimate at least the rocky habitat in that depth range by calculating the area covered in kelp. Kelp area varies from year to year with environmental conditions; hence the best estimate of rocky reef in the 5-30 meter depth range would come from an integration of areas covered by kelp over a series of years. Such data exist and are available in GIS format through California Fish and Game. Using the integrated kelp maps (1989-2002) we were able to determine the area of kelp (hence rocky reef in the 5-30 meter depth range) for all ASWB's shown in Figure 1 (the brown areas in figure 1 represent areas that had kelp at least at some point in the period 1989-2002). A blow up of State kelp bed 205 (offshore of DCPP) is shown in Figure 2 to indicate the detail present in the maps.

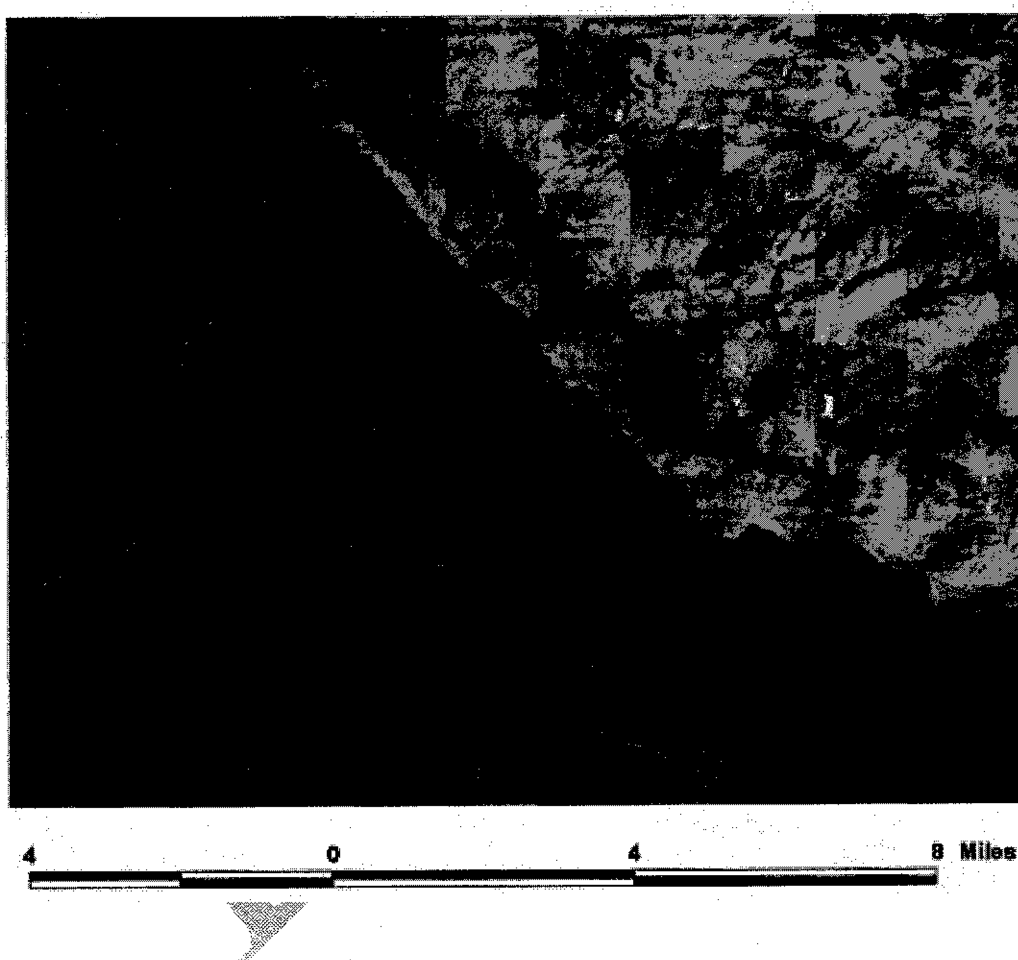
Figure 2: Kelp area in kelpbed 205



Clearly there are rocky areas that do not support kelp. These can be categorized as either being inshore from the kelp bed or offshore. Inshore approximation is easier using the logic that if there is a kelp bed offshore and rocky intertidal areas in shore, the area in between is likely to also be rock. Offshore rocky reefs are more difficult to quantify. As an example of the former condition we show figure 3. In this figure the area of kelp forest is clearly delineated and there is a margin that has no kelp between the bed and the coast. This is area that is likely to have rocky habitat.

Figure 3:

Landsat image with kelp (Administrative Bed 208)
South of Cambria, in San Luis Obispo County, California



We took the approach of using a multiplier to bracket the likely rocky reef areas per ASWB's. The lower limit of the multiplier is 1, which would mean that there is no rocky area other than that associated with kelp. We used a multiplier of 2 to yield an upper limit of the amount of rocky habitat. This is based on inshore rocky areas that can be approximated and ones outside of kelp beds (here the approximation is based on knowledge of the few areas where most rocky reefs are known). In the end the upper limit is based on best professional judgment.

Our best estimate of the range in area of artificial reef necessary to compensate for entrainment impacts to rocky reef species is 85 – 400 hectares (approximately 200-1000 acres).

Table 3: Area of kelp per average source water body (2 projections) and the amount of artificial reef required to compensate for entrainment impacts to rocky reef organisms.

Line	Kelpbeds	Explanation	Area (hectares)	Multiplier	PM estimate	Art Reef habitat (hectares)
1	202-208	Straight balanced N/S	792	1	0.1076	85.21
2	205-210	Linear source water body, biased to North	1916	1	0.1076	206.16
1	202-208	Straight balanced N/S	792	2	0.1076	170.42
2	205-210	Linear source water body, biased to North	1916	2	0.1076	412.32

Quality of artificial reef

One obvious assumption of the calculations shown above is that an artificial reef will be as productive as the average natural reef. This is an important assumption, particularly since some artificial reefs that have been evaluated have been shown to be biologically different from natural reefs. Probably the best examination of this question is an ongoing study of artificial reef design being carried out by the California Coastal Commission as part of the mitigation for San Onofre Nuclear Power Generating Station (SONGS). This work has been done near San Clemente and is called San Clemente Artificial Reef (SCAR). In that study two substrate types and three levels of cover were manipulated (see table 4). For each combination of treatments seven 40 x 40 meter replicate reefs were established in 1999. In addition two natural reefs have been sampled since 1999.

Table 4: Reef type, and cover at SCAR (average values over the period 2000-2003). Cover refers to the cover of rocky substrate.

Reef Type	Substrate Type	Cover of Hard Substrate (category)	Average cover
Artificial	Rock	Low	59%
Artificial	Rock	Medium	69%
Artificial	Rock	High	85%
Artificial	Concrete	Low	51%
Artificial	Concrete	Medium	56%
Artificial	Concrete	High	80%
Barn Kelp (Natural)	Rock		52%
San Mateo (Natural)	Rock		46%

The SCAR study was developed to test various reef designs and was done in anticipation of the build out of the full mitigation reef and in recognition that artificial reef performance has been variable. The following figures come from the 2004 annual report, which compares the performance of SCAR to that in natural reference reefs (Barn Kelp and San Mateo Kelp). The basis for the comparisons is the operating permit for SONGS, which requires that the ecological performance at the build out reef be similar to natural reefs in the region. Only data for fish species are shown, however data have been collected for invertebrates and algae as well.

Figure III.19. Change in the mean density of resident kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

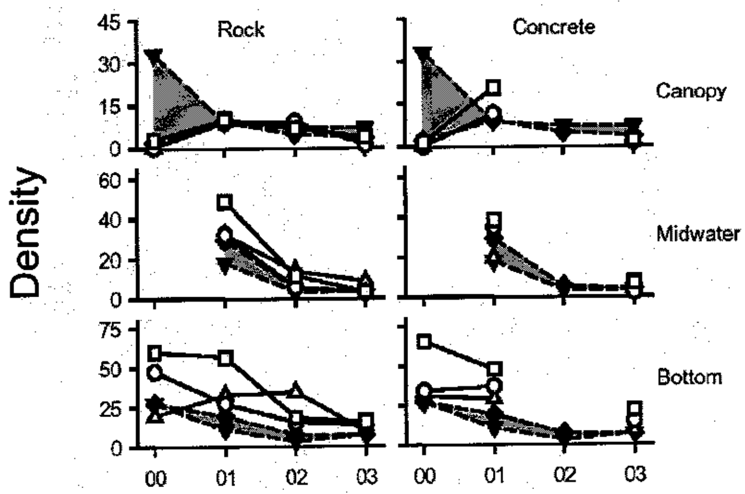


Figure III.20 Change in the number of species of resident kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

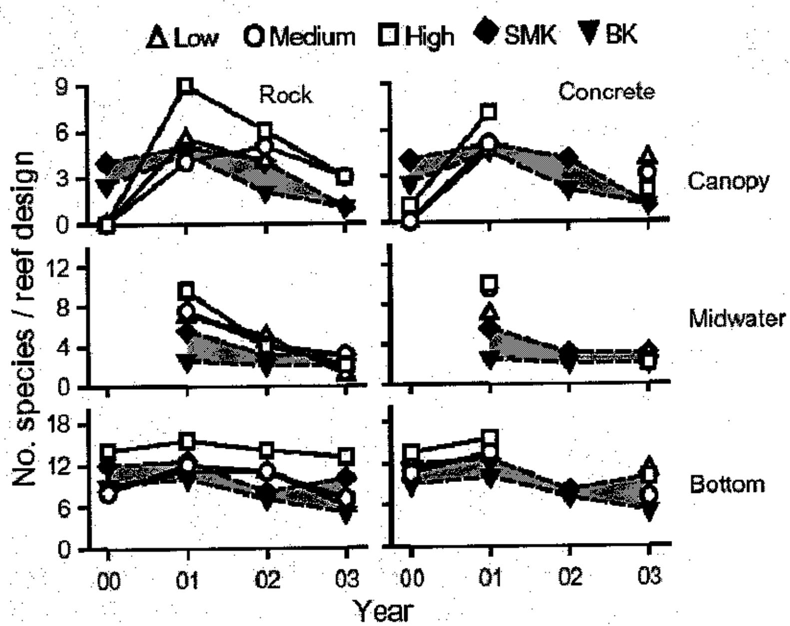


Figure III.21. Percent similarity in the assemblages of resident kelp bed fish between the six artificial reef designs and the mean of the reference reefs Barn (BK) and San Mateo (SMK) (open symbols and solid lines) and between BK and SMK (closed symbols and dashed lines).

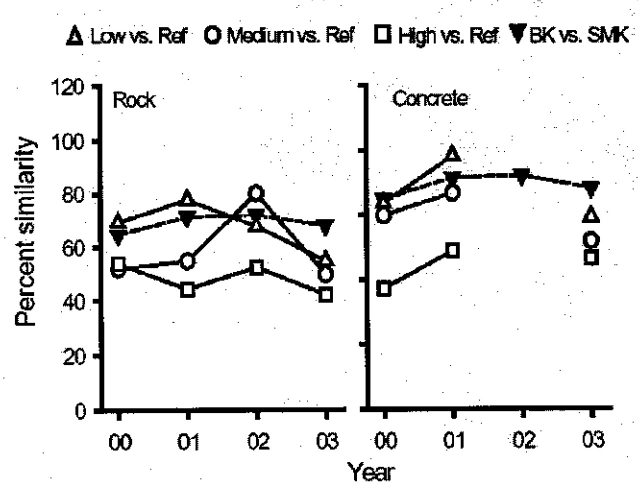


Figure III.22 Change in the mean density of young-of –year kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

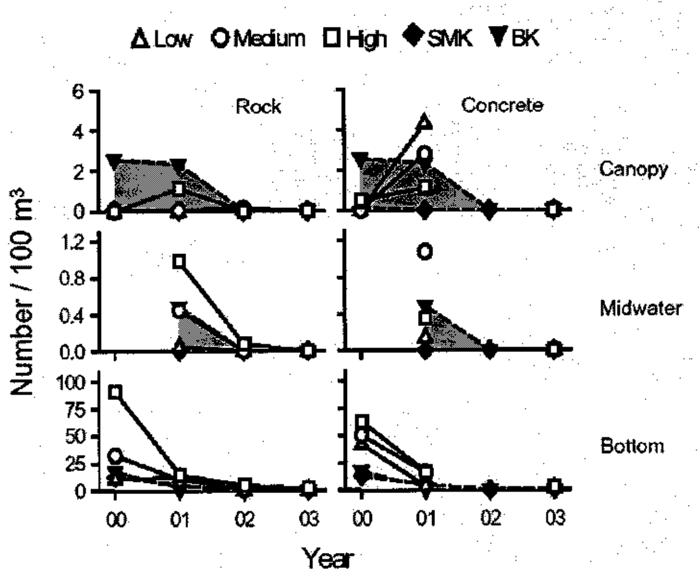


Figure III.23. Change in the number of species of young-of-year kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

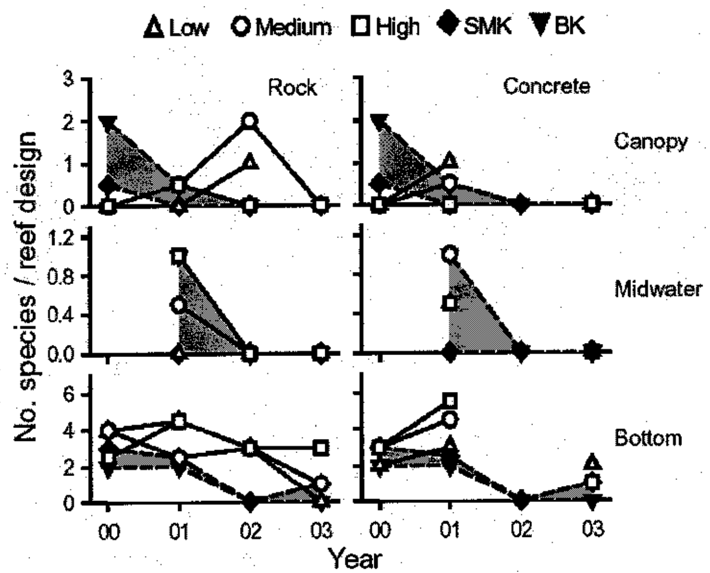
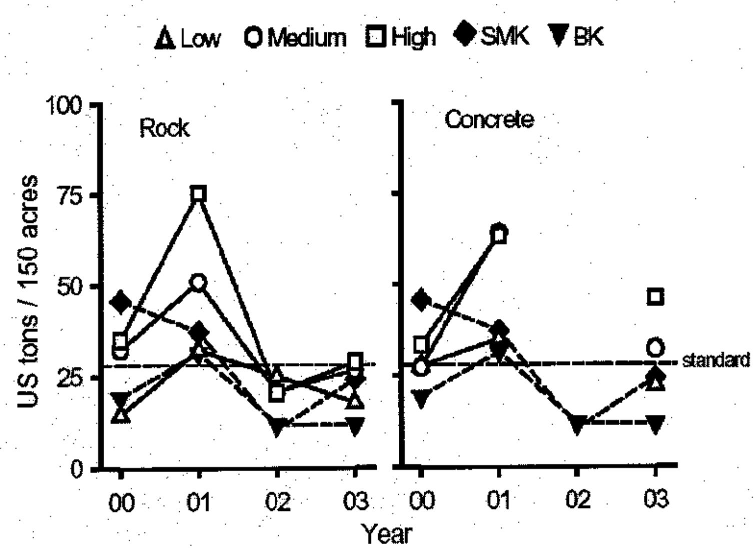
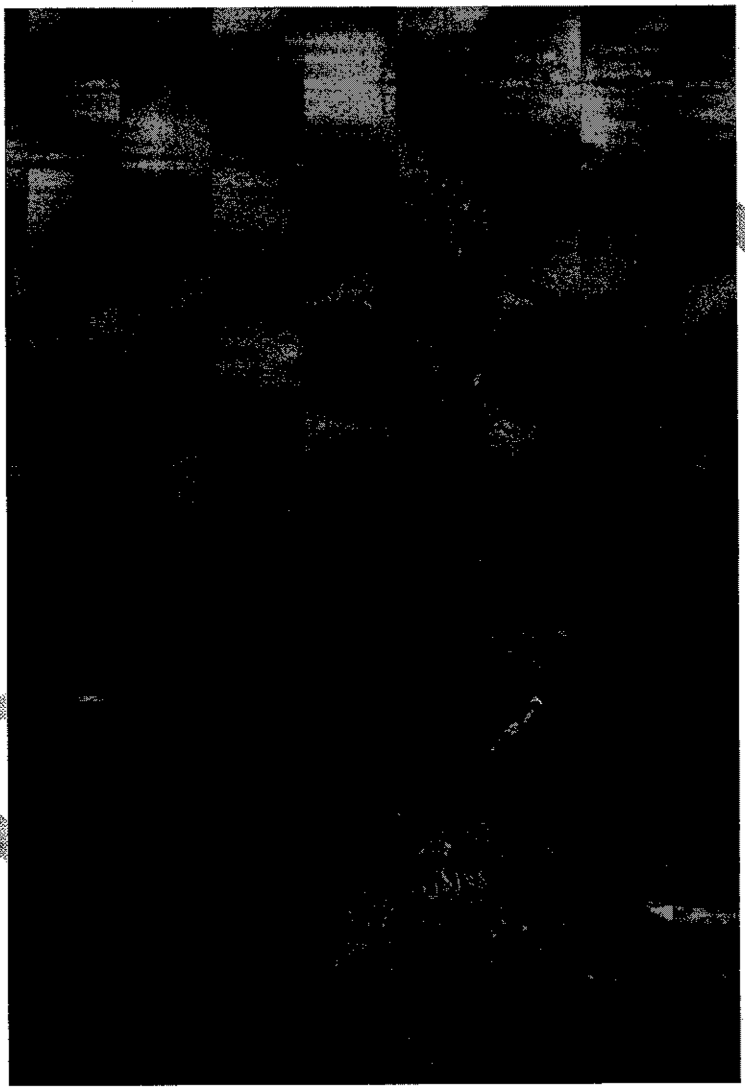


Figure III.24. Change in the projected standing stock of kelp bed fish over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). The dashed horizontal line indicates the permit standard of 28 tons for the 150 acre mitigation reef. See text for how projections were made.



For all the comparisons made artificial reefs performed at least as well as natural ones. Importantly, there was often an effect of cover of hard substrate but even "low" cover reefs performed comparably to natural ones. Therefore we conclude that it is reasonable to assume that a properly constructed artificial reef will be at least as productive as a natural one.

Figure 4: Photo from artificial reef at SCAR



Cost of an artificial reef

The cost of an artificial reef (here we consider only rock – not concrete) is driven in large part by three criteria: (1) quantity of rock (which is manifested as cover and depth), (2) precision in placement of rock, and (3) the distance that the rock has to be transported. We used CCC data from SCAR to come up with estimates of costs for a build out reef for

DCPP mitigation. The total cost of the reef construction at SCAR was $2,600,000. The total acreage is ~22 acres. In total there are 56 modules that are 40 x 40 meters. Hence, the estimated cost per acre based on this is $118,182. The average cover (of rock) per reef is 70%. Conversations with Hany Elwany (who helped engineer SCAR) indicate that: (1) cost is directly related to the cover. (2) There would be an estimated 40% decrease in cost associated with the build out of a large reef because of the lessened need for precise deposition and coverage. Hence a 50% reduction in cover would lead to an estimated 50% reduction in cost. Unfortunately we have little information on the average cover of hard substrate in a rocky reef. For the two reference reefs used in the SONGS study the cover averaged about 50%. Using this as the basis for a build out reef coupled with a cost reduction associated with a reduced need for precise placement of rock, the cost drops to approximately $50,000 per acre or $125,000 per hectare. The estimated costs of the possible reefs are shown in Table 5. Note that the cost may be greater than this value depending on the cost associated with transport of rock. We are awaiting a more detailed cost estimate from Connolly-Pacific (who is the contractor for the SCAR reef).

Table 5: Estimated costs (July 2004) of artificial reefs based on ASWB's (see table 3). All costs are based on reefs with 40-50% cover of hard rock and a cost savings associated with low precision-placement of rock (see text)

Line	Kelpbeds	Explanation	Area (hectares)	Multiplier	PM estimate	Art Reef habitat (hectares)	Cost @ $125 per hectare
1	202-208	Straight balanced N/S	792	1	0.1076	85.21	$10,651,250
2	205-210	Linear source water body, biased to North	1916	1	0.1076	206.16	$25,770,000
1	202-208	Straight balanced N/S	792	2	0.1076	170.42	$21,302,500
2	205-210	Linear source water body, biased to North	1916	2	0.1076	412.32	$51,540,000

The range in estimated costs for the build out of an artificial reef is $10.6 to $50 million, with the latter being the upper limit. We think the appropriate reef size for mitigation is between 85 and 200 hectares and would cost between $10.6 and $26 million. Note that: (1) this does not include any costs associated with performance monitoring of the reef (a requirement in the SONGS mitigation); and (2) costs may be higher depending on transportation (of rock) costs.

The costs associated with the construction of an artificial reef, while substantial, are much less than they would be if SCAR had not been implemented. An artificial reef used to mitigate the entrainment effects at DCPP would greatly benefit from lessons learned at SCAR study in the planning, permitting, design, construction and evaluation phases of the reef.

Valuation

One of the most difficult things about establishing a value associated with entrainment is that for most of the affected species there is no obvious way to estimate a true value. Most of these species have no commercial value and direct estimates of ecological value are essentially impossible. Moreover, most entrained species are not even sampled leading to immensely increased valuation uncertainty, at least using traditional methods.

By contrast, we believe (as admitted non-economists) that the costing of an artificial reef represents the most relevant value of the resources lost to entrainment. While some sandy bottom or deep-water species have larvae that are lost to entrainment, the vast majority are associated with fairly shallow rocky reefs; exactly of the kind of habitat provided by an artificial reef. An artificial reef, of sufficient size and of proper design therefore has the potential to compensate for almost all entrainment impacts. This makes intuitive sense as the artificial reef is in essence replacing a natural reef of similar size from which nearly all resources save substrate have been lost. Therefore the cost of a compensatory artificial reef may be the most relevant and straightforward estimate of the value of the lost resources. Based on this logic, the value of resources lost to entrainment at DCPP is estimated at between $10.6 and $26 million (as of July 2004).

Some Final Remarks

1) The artificial reef proposed in this document is based on the idea that it would NOT be a Marine Protected Area. If the artificial reef were designated as a "no take" marine reserves then the projected size and cost of the reef would decrease. It is difficult to determine at this point by how much (although we could do this with some additional study). Recall though that very few of the affected species are regularly harvested and protection from extraction would likely benefit only those species. We think the overall size and cost would decrease approximately 20% or less if the artificial reef were designated as a "no take" marine reserve.
2) The most problematic parameter used to calculate reef size is the multiplier used to estimate the amount of rocky reef that is not associated with kelp. It is likely that we could come up with a better estimate than "2" with some additional research, but given the information we currently have we have concluded that a reasonable upper limit for the multiplier is 2.
3) The cost projected for the reef does not include any costs associated with monitoring for performance.
4) Artificial reefs cannot be located in all sandy locations. The work done in preparation for the SONGS reef could be used to help locate suitable sites.
5) There are few data available for establishing the percent cover of rock in natural reefs. Estimates used in calculating the cost of the DCPP artificial reef are based on 50% cover of rock, which is the average for two reference reefs used in the SCAR study. It is possible that the value for typical reefs along the San Luis Obispo coastline have greater or less cover. This would affect the cost of the reef.

3.2 Marine Reserve Areas as Compensation for Entrainment Losses: Given the characteristics of entrainment impacts, such as relatively large uncertainty (or confidence intervals), large geographic area of influence, potential ecosystem level impacts, and the infeasibility of replacing all entrainment losses, the benefits and flexibility of marine reserves are attractive and could provide a level of mitigation for entrainment. There are several potential benefits of marine reserves, including permanent overall conservation of resources, increased density of fish, increased size, and increased larval productivity, relative to non-reserve areas. It is important to note that the degree of benefit (other than conservation) is determined by the amount of "take" (fishing pressure) occurring in the area prior to the reserve being established. Additionally, marine reserves may benefit both entrained and thermally impacted species. Accordingly, the independent scientists considered the pros and cons of marine reserves (in and of themselves) and their applicability to entrainment losses and thermal effects. This option is applicable in this case, and is discussed in detail below.

Potential Benefits of Marine Protected Areas

There are two general classes of benefits that may be obtained by the establishment of marine reserves: fisheries management and conservation. With respect to fisheries management there are again two classes of benefit: spillover effects and enhanced production of larvae that will be exported to other reefs. Spillover effects result when abundance within a reserve builds to the point that individuals "spill over" to adjacent exploited areas. Larval export is thought to occur through enhanced fecundity in Marine Protected Areas. This can result from either increasing the abundance of formerly exploited species or through increased individual size (leading to non-linear increases in fecundity), or both. The degree of benefit from spillover effects and enhanced production of larvae are relative to the amount of exploitation that occurred prior to establishment of the Marine Protected Area.

The benefits afforded via conservation are considered to be less speculative. Conservation benefits result from a return to a more pristine ecosystem, and permanent protection of the ecosystem. In contrast, entrainment losses are temporary. Therefore, it is reasonable to conclude that the long-term benefits of marine reserves are greater than the temporary impact of entrainment.

The potential benefits of Marine Protected Areas are supported by many scientists who believe that reserves provide a reliable management tool for the long-term protection of marine resources. There is scientific evidence that marine reserves provide major benefits for both fisheries management (although this is controversial) and particularly conservation (see references listed at the end of this paper).

Other important considerations are:

1. Certain benefits derived from marine reserves are likely to be dispersed over a large geographic scale, similar to the area from which entrainment losses occur.
2. There is legislation requiring the establishment of Marine Protected Areas, which includes marine reserves. The State budget situation temporarily stalled the agency process, but the California Department of Fish and Game (DFG) currently has limited funding to implement the marine reserve process. Other groups are interested in pursuing the Marine Protected Area process and can provide matching funds, as discussed below.
3. The broad scientific support and existing legislation suggests that Marine Protected Areas, including marine reserves will eventually be established throughout California if adequate funding is provided and the essential tasks are completed (discussed below).

4. The costs associated with establishing and maintaining Marine Protected Areas are likely to be relatively low compared to the permanent benefits derived (discussed below).
5. The benefits of marine reserves are permanent, and will likely be manifested throughout the ecosystem. By contrast, entrainment losses are temporary.
6. There are few data (habitat surveys) on which to base the appropriate size and location of marine reserves in the Central Coast area. Identifying those areas likely to provide the maximum benefit (habitat surveys) coupled with a post-establishment performance monitoring are necessary components of a marine reserves project.
7. There are limited scientific data on the benefits of marine reserves in California. The data that do exist suggest that the "restoration" type benefits provided are related to the level of regional exploitation (exploitation of resources prior to the reserve being established). Most of the research is associated with the Channel Islands (which shows evidence of ecosystem level benefits). Some research exists for the Big Creek Ecological Reserve, where there was no detectable benefit, most likely because the area was not heavily fished prior to the reserve being established (that is, the area was relatively pristine prior to the reserve being established, so no biological changes were detected). However, the conservation benefit of permanently protected resources at Big Creek remains.
8. The Regional Board has no authority to establish marine reserves, but can work with other groups on a process for establishing a reserve, or multiple reserves, on the Central Coast.
9. Marine reserves do not directly address entrainment losses for all species. Some taxa are likely to benefit, while others may not.
10. For marine reserves to be effective there is a need for stricter and more extensive management and enforcement. Thus, support for these activities should be considered.
11. Surveys to measure the efficacy of the marine reserves should use the recently-derived PISCO/CRANE SCUBA survey methodology (http://www.piscoweb.org/research/community/subtidal/index.html) for areas accessible to divers and the protocols recently used the Delta submersible in the Big Creek Ecological Reserve at deeper depths than SCUBA (Yoklavich et al. 2002) is presently capable of surveying. The underlying hypotheses to be tested are:

    a. Density is greater in reserve than non-reserve areas
    b. Individual size is greater in reserve than non-reserve areas
    c. Production of larvae per unit area is greater in reserve than non-reserve areas

    With respect to entrainment losses the key hypothesis is item c., however, it is also the most difficult and expensive to measure. Hypotheses a. and b. are often used in functions as proxies for fecundity (larval production) and may be of greater practical value because of cost benefits.

12. Another associated program to "buy out" the nearshore fishing permits of local fishermen would help make the possibility of having additional catch and effort

adjacent to marine reserves less likely. It would also benefit the local fishing industry by replacing at least some of the income they would have made by fishing in the nearshore habitat affected by the power plant.

13. Implementation of marine reserves requires several critical steps, including gathering information on habitats (habitat surveys), a socio-economic study, post performance monitoring, and a dedicated process managed by professionals with adequate funding, as discussed later in this paper under Process for Establishing Marine Protected Areas.

Applicability of Marine Protected Areas to Entrainment Losses

As noted above, entrainment losses may occur over a large area, on the order of hundreds of kilometers of coastline or hundreds of square kilometers of ocean habitat. Note that when the spatial extent of the impact is large the intensity tends to be low (also note the reverse is often true). Importantly, the estimated area is different for each species. Certain benefits of marine reserves also may occur over a similar geographic scale. These benefits would mainly result from increased export of larvae from protected areas.

Although the ecological effects of entrainment losses cannot be precisely identified or measured, staff and the Regional Board's independent scientists have concluded that entrainment losses affect the overall ecosystem (essentially lowering larval production, with uncertain secondary effects). Properly placed and designed marine reserves should increase or maintain larval production, thereby offsetting (to some extent – on a species-specific basis) entrainment and contribute to the restoration and maintenance of natural ecosystems that would otherwise be impacted by other anthropogenic pressures.

The match (entrainment losses to marine reserves) is clearly not perfect; indeed, Marine Protected Areas would benefit some entrained species, but not all. In addition, certain species not subject to entrainment might also be enhanced (e.g. surfperch which do not produce larvae). It is possible that predation pressure on some nearshore fish taxa may increase in reserve areas due to more abundant and larger forage species that prey on nearshore taxa (although the resulting ecosystem within reserves would likely be a more "natural" system). The overall effect of marine reserves is to benefit the marine ecosystem on a large scale; this approach avoids micromanagement of individual species or groups of taxa (as would be the case with fish hatcheries or small scale habitat work).

Another consideration is the real-world likelihood of actually establishing marine reserves. If a potential project is impossible to implement, the project has no real value. Marine reserves have been established by the Fish and Game Commission, and there is legislation requiring the establishment of additional reserve areas (Shelley Bill: Marine Life Protection Act). Accordingly, establishment of Marine Protected Areas on the Central Coast is a realistic option.

The independent scientists considers it unreasonable to expect PG&E to solely fund a Marine Protected Area process for the entire State of California. We think it would be more reasonable for PG&E to contribute funds toward a Marine Protected Area process focused on the Central Coast. Regional Board staff and the Board's independent scientists think PG&E's contribution would be scaled to the Area of Production Foregone (Area of Production Forgone is a way of expressing the entrainment impact in area of habitat, as discussed in the next section), plus consideration for the uncertainty related to the 316b study and the imperfect match between mitigation and entrainment loses.

Scaling Marine Reserve Habitat to Entrainment Losses

Entrainment losses are difficult to interpret in a simple currency. Entrainment losses are the product of both an affected area and an estimate of the intensity of impact over that area. One way to simplify the currency is through the use of "Area of Production Forgone," as discussed in Dr. Raimondi's testimony to the Regional Board for the July 10, 2003 hearing. Area of Production Forgone is the theoretical amount of habitat that would be necessary to produce the entrainment losses. The best estimate comes for calculations similar to those established for the artificial reef, as discussed above. As opposed to those calculations here we included sandy habitat species and came up with a source water body of an area 70 km long and again 3 km wide (see table 2). In addition, the average loss rate of larvae over all targeted species, is estimated at 8.59% (see table 2). The product of these terms is the area of *new* habitat that would be required to offset the entrainment losses; here an area 6 km along shore by 3 km offshore. This hypothetical area would be comprised of the same mixture of sandy and rocky habitat as the source water body. Clearly the additional larval contribution from marine reserve designation would not be the same as that from entirely new habitat, hence a multiplier needs to be used to scale the contribution. For example if the reserve was expected to produce 20% more larvae than a non reserve, then an area 30 km (6/0.2) by 3 km would be required to produce the number of larvae lost to entrainment. [note there is another way to calculate area required. This would rely on estimates of species specific larval production per area. These values could then be used with entrainment estimates and estimates of reserve effect (the additional contribution caused by reserve status) to produce reserve area needed. However, we have few good estimates of larval production per unit area].

In scaling the mitigation to entrainment impacts (Area of Production Forgone to marine reserve area), four main factors should be considered:

1. There is uncertainty in the entrainment study (as with any such study), and there are no practical means of reducing the uncertainty.
2. The conversion of entrainment losses to Area of Production Forgone is not exact; it provides an <u>indication</u> of applicable scale.
3. The reserve effect (in terms of additional larval production) is unknown and would need to be estimated (probably through models)
4. There are no practical means for directly mitigating or compensating for all entrainment losses; only partial mitigation is possible.

5. Marine reserves will not replace entrainment losses, but will provide the benefits discussed in the Potential Benefits of Marine Reserves, above.

Given the above factors, Regional Board staff and the independent scientists think that if marine reserves are the preferred option, it is reasonable to err on the side of over-mitigating for the entrainment losses. This can be accomplished by leveraging mitigation funds and cooperating with a larger, regional effort to establish Marine Protected Areas on the Central Coast, which is discussed in the next section.

The actual benefit to impact ratio would depend on the ambient and/or future level of impact to the protected areas that would be reduced. Marines reserves established in an area that is highly impacted would provide the greatest benefits (by eliminating the impact). It is important to note that the benefits are not strictly "replacement" of larval losses. Rather, the benefits result from general improvement to the ecosystem (see discussion of these benefits, above) and permanent resource protection.

Process for Establishing Marine Reserves

Establishing marine reserves on the Central Coast will require a comprehensive approach, sound management, and assistance from leading experts in the various fields of study. To this end, Regional Board staff and Dr. Raimondi met with the Resources Legacy Foundation Fund (RLFF), a non-profit organization whose mission is to conserve or restore natural landscapes, protect and enhance marine systems, and preserve wildlands and wilderness. RLFF is currently implementing the California Coastal and Marine Initiative (CCMI), a re-granting program of the David and Lucile Packard Foundation. . The goal of the CCMI is to ensure the health and resilience of California's coastal and marine environment through ecosystem-based conservation and management. A key component of this goal is to focus intensively on the Central Coast, with the intention of creating significant, tangible, and permanent ecosystem benefits in this specific region. The goal of the CCMI should directly coincide with mitigation goals for Diablo Canyon. .

The Regional Board could establish a working relationship with RLFF to develop a proposal for establishment of marine reserve areas on the Central Coast. This proposal would be presented to the California Fish and Game Commission. RLFF has indicated that they may provide matching funds toward this effort. The major steps involved in developing a marine reserves proposal to the California Fish and Game Commission would be:

1. The Regional Board enters into an agreement with RLFF, establishing goals, tasks to achieve the goals, responsibilities, matching funds, etc. (similar to the Memorandum of Agreement between the Regional Board and the Elkhorn Slough Foundation).
2. Regional Board and RLFF establish a process for developing the Marine Protected Area proposal. The process should include a mechanism for participation by other agencies and parties.

3. Regional Board and RLFF establish an estimated schedule for developing the proposal (a multi-year schedule is certain).
4. Regional Board and RLFF implement the tasks necessary to develop the proposal, which could include:
   a. Habitat surveys necessary to design a preferred reserve size and layout, and possible alternative designs.
   b. A socio-economic study for the preferred reserve design(s), as well as options to mitigate local impacts to the fishing community.
   c. A stakeholder process to gain public input on the final design.
   d. A CEQA (or functional equivalent) document for consideration by the Department of Fish and Game and a public participation process (including a scope of work and budget).
   e. A performance monitoring plan.

5. Regional Board and RLFF form an advisory group, including independent scientists, to guide the design, implementation, and evaluation of the marine reserve areas. Measures of success for the marine reserves should include:
   a. Providing resources that have been lost as a result of impacts at DCPP
   b. Increased number and size of fish
   c. Conservation benefits

The Boards independent scientists recommend performance monitoring to evaluate the effectiveness of any marine reserves that are established. The cost for such monitoring will scale with the size of the reserve. Costs are discussed in the next section. An adaptive management approach is needed to increase the likelihood of success.

The independent scientists also recommend that all surveys and research funded by the Diablo Canyon settlement be overseen and managed by an independent panel of scientists with experience in the relevant field of study.

Costs Associated with Establishing Marine Protected Areas

The estimated costs for developing a marine reserve proposal for the Fish and Game Commission include planning and design (initial habitat surveys, a socio-economic study, etc.), local projects (relief for fisherman, permit buyouts, etc.), process management (coordination, agency outreach, drafting reports etc.), and patrolling/management of the reserves for a limited time after they are established. Based on discussions with RLFF, we estimate the cost of these tasks to be less than $10 million (probably $6 to $8 million).

In addition, performance monitoring should be required. Costs associated with performance monitoring for 316b purposes, based on other similar work at SONGS, will likely be based on a variable effort. The purpose of performance monitoring is to determine whether the size and density of fish taxa are greater in the reserve versus no-reserve areas. The first year will be more comprehensive than subsequent years (prior to reserve being established), followed by reduced monitoring for a number of years, with another more comprehensive effort at the end of the period. One possible scenario based on CFG CRANE survey methods could be:

Year 1:	$150,000
Year 2:	$75,000
Year 3:	$75,000
Year 4:	$75,000
Year 5:	$75,000
Year 6:	$75,000
Year 7:	$75,000
Year 8:	$75,000
Year 9:	$75,000
Year 10:	$150,000
Total	**$900,000**

These costs are estimates based on the work done at PISCO (UC Santa Cruz), which use methods that are the BASIS of CRANE surveys, and are in 2004 dollars.

These estimates assume that the 316b performance monitoring will be coordinated closely with existing efforts to minimize costs. Also, monitoring will be done on a limited spatial scale to minimize costs, and will serve as a proxy for other reserve areas.

The number and size of reserves in the proposal is not expected to have a large linear effect on the total project cost estimate because the same tasks must be done whether the proposal calls for one or multiple reserves, or various size reserves.

Note that additional funds would be necessary over the long term to oversee and patrol the marine reserves. However, this relatively minor cost would eventually be borne by the Department of Fish and Game.

Regional Board/PG&E settlement calls for the following (among other things):

Dedicated Fund for Projects:	$4,050,000
CCAMP Funding:	$1,500,000 (150,000/year for ten years)
Abalone Research Funding:	$ 350,000
Use of Lab Facilities:	$ 150,000 ($100,000 start-up plus $5,000/yr/10 yrs)
Total:	$6,050,000 (2004 dollars)

The $6.05 million listed above could be directed toward development of marine reserves on the Central Coast. RLFF has indicated that they may provide matching funds up to $2.5 million. If these matching are provided, the total, $8.55 million, would likely cover the total cost of developing a comprehensive proposal for the Fish and Game Commission (including all of the elements mentioned above).

Practicality of Establishing Marine Protected Areas

The practicality or real-world likelihood of establishing Marine Protected Areas can be considered on three levels:

1. Likelihood of developing a scientifically and legally defensible proposal.
2. Likelihood of the Fish and Game Commission adopting the proposal, or some variation of the proposal.
3. Likelihood that the Marine Protected Areas accomplish what is intended (performance criteria).

There are no guarantees of success with any option; however, the practicality and likelihood of success on all three levels above is high relative to other projects. This assumes that the performance criteria are carefully crafted and recognize the limitations (only some species will benefit from marine reserves) and strengths (conservation benefits) of Marine reserves. This is because there is precedent for establishing Marine Protected Areas in California, there is strong scientific support for the establishment of marine reserves particularly for conservation, and with the exception of artificial reefs, no other restoration option offers these strong points (nexus, benefits, feasibility, and scientific support).

3.3 Terrestrial Conservation Easement

With respect to marine habitat, the conservation easement defined in the RWQCB/PG&E settlement provides benefits mainly to intertidal taxa via permanent resource protection (while power plant effects are temporary). From a quantitative perspective, the marine benefits of the conservation easement cannot be realistically scaled to entrainment impacts, and the benefits provided would only apply to intertidal taxa. From a qualitative perspective, many species affected by the power plant (entrainment and thermal effects) use this intertidal habitat, so there is a direct nexus. Protection of this intertidal habitat is accomplished by preventing future degradation. Dr. Raimondi's testimony to the Regional Board for the July 10, 2003 hearing discusses the types of intertidal degradation that can occur in unprotected intertidal areas, as illustrated by the University of California's PISCO monitoring program. Where access is allowed, such as at Montana De Oro State Park, intertidal degradation includes decreases in habitat forming species, such as foliose algae, and decreases in density and diversity of associated intertidal taxa. The easement will prevent these types of impacts from occurring. The easement includes 5.7 miles of coastline (measured along the coastline contour, not line of site). This is a relatively large amount of habitat that will be permanently protected. The amount of habitat protected, and the nexus between the intertidal zone and the power plant impacts makes this project appropriate, though not quantitatively scalable to entrainment losses. The easement offers major ecological benefits and should be included in the settlement agreement.

3.4 Fish Hatchery: This option would only potentially benefit one, or perhaps very few, species, would not benefit the overall marine environment, would likely be very costly, and would potentially mitigate entrainment losses to only a fraction of the hundreds of species that are entrained. There are also significant issues with respect to the benefits and impacts of fish hatcheries, such as the introduction of diseases and degradation of natural genetic stocks. Hence, a fish hatchery does not seem to be defensible project for mitigation of entrainment losses, although there may be value in an experimental approach with a few defined and economically important species.

3.5 Restoration of Marine Habitat: Restoration of marine habitat of the sort that would lead to enhanced larval production of affected species is not available on the Central Coast. The nearshore habitats of such species are not in need of restoration (from a physical perspective – but see section on marine reserves, above). That is, from a practical perspective we cannot identify areas of ocean habitat where "restoration" would increase larval productivity. There are examples of degraded ocean habitat in other areas, such as the so-called "dead zones" where pollution runoff from terrestrial sources accumulates in the benthic environment, usually offshore from the mouths of major tributaries like the Mississippi River. The solution to these problems is to minimize pollutant runoff, which will allow the degraded areas to recover over time; there is no practical "restoration" type work that could be implemented to correct the problem. In addition, there are no large-scale degraded areas of ocean habitat off the Central Coast of California (in the relevant geographic area for this case). Therefore, ocean habitat restoration is not applicable in this case.

3.6 Abalone Research (RWQCB/PG&E Settlement): Research to develop disease resistant abalone is speculative at best, and even if successful, would benefit only one species. Abalone are probably not impacted by entrainment, but are impacted by the thermal discharge. The independent scientists do not recommend this type of research as mitigation for thermal impacts. However, other projects intended to enhance black abalone populations could be possible. In addition, research or projects directly intended to help restore red abalone populations (that were impacted by thermal discharge) might also be possible and supportable.

3.7 Use of PG&E Lab Facilities (RWQCB/PG&E Settlement): The use of PG&E's lab facilities by county educational organizations may be beneficial to the community, but it is not mitigation for impacts. There is no nexus to the impacts, or relevant benefit to the environment. This project is not recommended. Note that we have recently been informed that the lab facilities are being torn down.

3.8 Central Coast Ambient Monitoring Program Funding (RWQCB/PG&E Settlement): The Central Coast Ambient Monitoring Program (CCAMP) appears to be an important and useful program for the Regional Board. However, general ambient monitoring is not mitigation for impacts. We do not recommend ambient monitoring as mitigation. We do recommend adaptive performance monitoring, with oversight by independent experts from the relevant fields of study, for any implemented mitigation projects. Adaptive performance monitoring would be done to answer specific questions or address specific hypothesis that determine the degree of success for mitigation projects. Performance monitoring can be expensive, and given its importance in this case, should take precedence over ambient monitoring. CCAMP may provide the organizational structure to manage the adaptive performance monitoring, as long as independent experts from the relevant fields of study oversee the work.

3.9 CALCOFI Program: The California Oceanic Cooperative Fisheries Investigations (CalCOFI) are a unique partnership of the California Department of Fish and Game, the NOAA Fisheries Service and the Scripps Institution of Oceanography. The organization was formed in 1949 to study the ecological aspects of the collapse of the sardine populations off California. Today its focus has shifted to the study of the marine environment off the coast of California and the management of its living resources. CALCOFI is the longest running oceanographic and near shore monitoring program in California. Data collected in these surveys have been used to detect long-term change in zooplankton communities, icthyoplankton spatial patterns and detailed current patterns. The CALCOFI program is costly and the State is not providing funding at anywhere near historic levels. While this program is certainly a worthy effort, the data collected are mainly from much further offshore than the estimated area of entrainment influence, and, as a research project, there is no mitigation or restoration nexus to the power plant impacts. This option is therefore not recommended.

Comparison of All Projects
All options should be considered relative to each other for perspective. Table 7 lists all options and their relative rankings with respect to nexus, availability, likelihood of success, relative benefit, and relative cost. Artificial Reefs are the highest ranked project.

Table 7: Matrix Showing Relative Ranking of Potential Entrainment Mitigation Projects Based on Best Professional Judgment

Project	Nexus	Availability	Relative Likelihood of Success	Overall Relative Benefit	Relative Cost
Offshore Reefs	High	High	High	High	High
Marine Protected Areas	High	High	High*	High**	Moderate
Terrestrial Reserve (intertidal zone protection)	Medium	High (certain)	High (certain)	Medium	Low
Fish Hatchery	Low	Low	Low	Low	High
Physical Restoration of Marine Habitat	Unknown	None	Unknown	Unknown	Unknown
Abalone Research	Low	Low	Low***	Low	Low
PG&E Lab Facilities	None	Low (access)	Unknown (access)	Low	Low
RWQCB CCAMP	Low	High (certain)	High (certain)	Low	Low
CAL COEL Research	Low	High	High	Low	High
Technology Alternatives****	High	None	None	High	Extreme

*assumes that success criteria are crafted with an understanding of the limitations of marine reserves as mitigation for entrainment impacts for non-harvested species
** assumes benefit for conservation is included in calculation
*** for black abalone
**** as discussed in 316B

4.0 Potential Projects Related to Thermal Impacts

4.1 Marine Reserves: The discussion above regarding marine reserves applies here because intertidal and shallow subtidal habitats (such as those affected by the thermal discharge) would be protected. The only practical way to scale the benefits to the impacts is by comparing the amount of habitat affected by the thermal plume to the amount of similar habitat protected in a marine reserve. The thermal discharge impacts a relatively small amount of intertidal and shallow subtidal habitat compared to what would be protected in a marine reserve. The marine reserve would not necessarily replace losses caused by the thermal discharge, but would protect the intertidal and shallow subtidal habitat that supports the thermally impacted taxa.

4.2 Terrestrial Conservation Easement: The Regional Board/PG&E conservation easement would provide permanent protection for 5.7 miles of intertidal habitat against future degradation, which is direct mitigation for many thermal impacts in the intertidal zone. Given current plans, degradation of intertidal habitat would come mainly from public access. Recently PG&E has entered into an agreement with the California Coastal Commission that will open access to areas north of DCPP (the same area designated in the easement. The access rules are not fully understood at the time of writing this document, and the value of the easement as a mitigation alternative is uncertain until we are able to assess the implication of the agreement with the CCC.

4.3 State Parks Docent Program: The Regional Board directed the independent scientists to consider mitigation projects that would provide more immediate benefits than the conservation easement. This would require "restoring" degraded nearshore marine habitat. As noted above, the University of California's PISCO program illustrates intertidal degradation in areas with major public access, such as State Parks. A State Parks docent program may help reduce degradation in these areas by using field-based volunteers to educate and monitor visitors. This would be a "passive" restoration approach, rather than active, physical restoration. This effort could be scaled to the area of thermal impact by including a similar amount of habitat in the docent program. Reduced degradation may be observed over time via existing PISCO sampling. The relative cost of a docent program should be low, consisting mainly of training for volunteers.

The drawback of this type of program is that even with field docents, the areas may continue to be degraded simply because visitation is high. Concentrating visitors in specific areas acts to limit the spatial extent of degradation while allowing the public to experience the resource first hand, and would be preferred to an 'open access' policy.

5.0 Thermal Effects Monitoring

The Regional Board directed the independent scientists to develop a reduced thermal effects monitoring program. As discussed above regarding other programs (CALCOFI and CCAMP), monitoring does not mitigate for impacts. Therefore, staff and the independent scientists do not recommend that thermal effects monitoring be considered "mitigation" for impacts. However, a reduced thermal effects monitoring program could be useful to detect major biological changes above and beyond the impacts documented to date. The purpose of a reduced program would <u>not</u> be to continue verifying <u>known</u> changes, but to detect major additional changes, such as large shifts in algae, invertebrates, and fish, and detect diseases or other major ecological events, outside of Diablo Cove. Accordingly, the independent scientists recommend implementation of a modified thermal effects monitoring program at intertidal and subtidal stations.

6.0 Other Considerations

The independent scientists also considered additional projects/issues that do not directly mitigate impacts, but may be useful, including:

1. Allow access to the conservation easement for the purpose of monitoring intertidal areas. This will be necessary if a Marine Protected Area is established offshore of the easement.
2. The thermal effects in Diablo Cove and the vicinity provide a valuable opportunity for marine research projects; however, access must be approved by PG&E (and possibly federal agencies for security reasons). The independent scientists recommend allowing qualified researchers access to Diablo Cove and the vicinity, including boat launching in the Cove and maintenance of physical access ways (present roads and stairways) to rocky intertidal areas used in PG&E thermal effects studies.

7.0 CONCLUSIONS

We conclude that the most direct mitigation for entrainment losses would be provided by artificial reef habitat. As currently estimated, this alternative would require 85 to 200 hectares, at a cost of $10.6 to $26 million. This is also the best estimate for the "value' of the entrainment losses. We realize that the cost of an artificial reef is not equivalent to the "value" of entrainment losses as estimated from a resource economy model. However, creation of artificial reef habitat would be *direct* mitigation for entrainment losses, and the estimated scale and cost is based on comprehensive research done at SONGS using independent scientific oversight. This type of habitat-based valuation method is also similar to the approach used by the Regional Board at the Moss Landing and Morro Bay Power Plants.

Marine reserves would also provide major benefits to the marine ecosystem, but are more difficult to scale to entrainment impacts. The cost for developing a Central Coast marine reserve proposal to the Fish a Game Commission, in compliance with CEQA and the Marine Life Protection Act, would cost less than $10 million (likely between $6 and $8 million). This effort would include several major tasks such as a habitat survey, a socio-economic study, performance monitoring, local project funding, and a public input process.

We recommend that the conservation easement be included in the settlement agreement because it provides protection for a significant amount of nearshore marine habitat, which is directly scalable to the thermal effects, and partially related to entrainment losses. Also, intertidal areas are degraded in some State Park areas on the Central Coast due to public access (trampling). Funds could be directed to a docent program designed to minimize this impact. We recommend that this project be considered, but secondary to the terrestrial easement.

Other elements of the settlement agreement are not currently recommended (but some could be with further explanation, such as abalone research), because they do not provide mitigation for impacts or direct protection of the marine environment.

Selected references for Marine Reserves, with emphasis on West Coast

Airamé, S., J. E. Dugan, K. D. Lafferty, H. M. Leslie, D. A. McArdle, and R. R. Warner. Applying ecological criteria to marine reserve design: a case study from the California Channel Islands. Ecological Applications 13 (Supp.): S170-S184.

Allison, G., S. Gaines, J. Lubchenco, and H. Possingham. 2003. Ensuring persistence of marine reserves: Catastrophes require adopting an insurance factor. Ecological Applications in press

Bergen, L.K and Carr, M.H. 2003. Science as a catalyst for policy: Informing the development of marine reserves. Environment. 45:8-19.

Berkeley, Chapman, and Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology 85:1258-1264.

Carr, M., J. Neigel, J. Estes, S. Andelman, R. R. Warner, and J. Lagier. Comparing marine and terrestrial ecosystems: implications for the design of coastal marine reserves. Ecological Applications 13 (Supp.): S90-S107.

Carr, M.H. and Raimondi, P.T. 1999. Marine protected areas as a precautionary approach to management. California Cooperative Oceanic Fisheries Investigations Reports. 40:1-6.

Caselle, J. E., S. L. Hamilton, and R. R. Warner. The interaction of retention, recruitment, and density-dependent mortality in the spatial placement of marine reserves. Gulf and Caribbean Research 14: 107-118.

Gaines, S. D., B. Gaylord, and J. Largier. 2003 Avoiding current oversights in marine reserve design. Ecological Applications. In press.

Halpern, B., and R. R. Warner. Matching marine reserve design to reserve objectives. Proceedings of the Royal Society B 270:1871-1878. DOI 10.1098/rspb.2003.2405

Palumbi, S.R., S. D. Gaines, H. Leslie, and R. R. Warner. New wave: high-tech tools to help marine reserve research. Frontiers in Ecology and Evolution 1:73-79.

Roberts, C., S. Andelman, G. Branch, R. Bustamante, J. C. Castilla, J. Dugan, B. Halpern, K. Lafferty, H. Leslie, J. Lubchenco, D. McArdle, H. Possingham, M. Ruckelshaus, and R. R. Warner. Ecological criteria for evaluating candidate sites for marine reserves. Ecological Applications 13 (Supp.): S199-S214.

Roberts, C., G. Branch, R. Bustamante, J. C. Castilla, J. Dugan, B. Halpern, K. Lafferty, H. Leslie, J. Lubchenco, D. McArdle, M. Ruckelshaus, and R. R. Warner. Application of ecological criteria in selecting marine reserves and developing reserve networks. Ecological Applications 13 (Supp.): S215-S228.

Shanks, A.L, Grantham, B. and Carr, M.H. 2003. Propagule dispersal distance and the size and spacing of marine reserves. Ecological Applications 13:S159-169.

Yoklavich, M., G. Cailliet, R.N. Lea, H.G. Greene, R. Starr, J. de Marignac, and J. Field. 2002. Deepwater habitat and fish resources associated with the Big Creek Marine Ecological Reserve. CalCOFI Reports, 43:120-140.

Also see http://www.pewoceans.org/reports/pew_marine_reserves.pdf , which is a PEW commission report on the utility of Marine Reserves

The Science of Marine Reserves, PISCO – a web page devoted to bringing forward current scientific information on the utility, and design of Marine Reserves: http://www.piscoweb.org/outreach/pubs/reserves/

A Review of

Final Report: "Benefits Valuation Study for Diablo Canyon Power Plant," prepared for PG&E by Matthew Bingham et al, Triangle Economic Research, February 21, 2005

by

Prof. Charles D. Kolstad[1]

17 July 2006

[1] For identification only: Bren School of Environmental Science & Management, University of California, Santa Barbara. Email: ckolstad@sbceo.org. Website: http://www.ckolstad.org.

INTRODUCTION.

The subject report from Triangle Economic Research (referred to here as "TER Report" or "TER Analysis") presents an estimate of the economic benefits of reducing impingement and entrainment (I&E) losses of marine life in the cooling water intake system at Diablo Canyon Power Plant (DCPP), pursuant to procedures in Section 316(b) of the Clean Water Act and its implementing regulations.

In particular, the regulations allow a site-specific determination of "best technology available" for mitigating adverse effects of I&E. One option for obtaining such a determination is to develop a cost-benefit analysis of I&E reduction. Such an analysis must be supported by a benefits valuation study (as well as other supporting analyses not considered here). The TER Report constitutes the benefits valuation study required under Section 316(b).

Although the estimate of benefits must stand on its own two feet, there is a significant amount of guidance that the EPA has provided in preparing the benefits study. Specifically, in part because EPA must conduct it's own benefit-cost analysis of the proposed regulation, the EPA has conducted its own estimate of benefits in California. Furthermore, in its Federal Register publication of Final Regulations (July 9, 2004), the EPA provides considerable insight into its conclusions regarding how a benefits study in this context should be conducted – what steps are reasonable and what steps are not.

The TER analysis is based on the premise that marine life lost (due to water intake at DCPP) has direct and indirect use-based impacts on commercial fisheries and recreational fisheries. The authors also consider non-use losses but in the end conclude that non-use losses are negligible. The authors also conduct an analysis of the effect of uncertainty on their conclusions.

Several caveats regarding this review of the TER Report are in order. One is that just because EPA does something in its own analysis[2] of the 316(b) rules does not necessarily mean that the EPA approach is economically correct or consistent with "best practice" in economics (though for the most part, the EPA analyses are very good). Another caveat is that I have assumed the biologic components of the TER analysis are correct -- this reviewer is not a biologist. Having said this, the TER work does seem to parallel EPA's own biologic analysis done is support of the 316(b) rules.

One of the TER authors' general conclusion is that eliminating all losses from I&E at DCPP would have an annual benefit of $26,000 to $49,000. Converting a stream of these annual losses (through 2053) into a net present value yields $563,000 to $1,035,000 (with smaller numbers for a shorter period or less complete elimination of I&E losses).

In general the TER analysis is competently done, to a large extent paralleling the analyses of I&E in California done by the EPA.[3] This is not to say the report is perfect; however, it is unlikely (though always possible) that addressing the criticisms in this review will result in dramatic changes in the conclusions.

---

[2] "Economic Benefits Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule," EPA Report EPA-821-R-02-001 (February 2002); and "Economic Benefits Analysis for the Final Section 316(b) Phase II Existing Facilities Rule," EPA Report EPA-821-R-04-005 (February 2004).

[3] The California analyses are in the same reports as the general analysis of the 316(b) Phase II Existing Facilities rules: EPA Report EPA-821-R-02-001 (February 2002) and EPA Report EPA-821-R-04-005 (February 2004).

GENERAL COMMENTS

These general comments parallel the specific questions in the Peer Review Charge. Each of the points raised here is further elaborated in the subsequent section on Specific Comments.

1. Is the organization of the report appropriate and does it present the material in a clear and concise manner? Are there any changes that are recommended?

The organization of the report is good; the report is easy to follow. My primary suggestion for revision would be to tighten up the presentation, more completely documenting assumptions. There is an informality of presentation that makes it difficult to check some assumptions made by the authors. The report should be written in such a way that a reader can go directly to important data sources and even so a third party could reproduce the analysis.

2. Is the report consistent with economic principles of measuring benefits? Are there any changes that would make it more consistent with accepted economic principles?

To a very large extent, the economics used in the report is good. As will be discussed below, some of the background discussion of fisheries and welfare do not appear to be correct; however, the background discussion is not pivotal to the analysis. Another problem has to do with how commercial benefits are calculated. There are other modest issues that will be raised in the next section on specific comments.

3. Is the report consistent with the EPA Phase II 316(b) regulations for measuring benefits? Are there any changes that would make it more consistent?. The authors are careful to parallel the EPA analyses closely in preparing the DCPP assessment. From my reading of the EPA requirements, the authors have met the requirements. Perhaps the one

area with which I have some concern is non-use benefits. It would appear from the EPA regulations that only a qualitative discussion of non-use benefits is required, which is what TER provides. However the TER qualitative discussion is short and in my opinion could be strengthened. This is not to say they have not met the EPA requirements, only that there is room for improvement.

<u>4. Are the potential economic effects of I&E addressed in a manner consistent with standard principles and practices for conducting benefits studies?</u> All potentially important beneficial effects of I&E reduction appear to be included in the analysis. The authors correctly mention the secondary effects on fishing effort from a larger stock but do not include it in their analysis (nor does EPA). This effect is likely to be negligible. I have some concerns with the methodology of the commercial benefits calculation and some other minor concerns; all are detailed in the specific comments part of this review.

<u>5. Are all of the relevant benefit categories included in the analysis? Are any significant categories omitted? If there are omitted categories, what methods could be used to reliably assess their value?</u> All relevant categories of impacts appear to be included in the TER analysis. As mentioned above, I have some concern about the completeness of the non-use benefits discussion; however, that category of benefit is not omitted from the analysis.

<u>6. Are potential nonuse benefits addressed in a way that is consistent with economic principles and benefits practices? Are they addressed consistent with the EPA Phase II 316(b) regulations? Are any changes necessary?</u> Nonuse benefits appear to be handled consistent with EPA regulations in that the regulations appear to only require a qualitative discussion of these benefits. I believe the qualitative discussion could be

strengthened somewhat though that is unlikely to change the conclusions. I would not say that the nonuse benefits are addressed in a manner consistent with best economic principles. This would require a more extensive analysis than is found here. But since that is not required by the EPA, I see no reason to do it.

7. Is the empirical analysis consistent with standard statistical and econometric procedures? Specifically, are the data appropriate for the task or could better data have been used? Are the benefit calculations performed in a manner that is consistent with standard economic practices? Are there improvements that should have been implemented? Although there are small issues which I detail below, the empirical analysis is generally good. I think it is unfortunate that the RUM analysis that the TER report relies upon is unpublished; peer-reviewed and published work is the ideal. Furthermore, the TER authors were unable to develop a model to show how increased catch rates will increase recreational fishing. The reason given for omitting this from the TER report is that EPA didn't do it for California, which is not necessarily a valid excuse. Finally, the assumption of unitary elasticity of demand for fish in the commercial demand section is not supported; in fact, the commercial benefits section may be flawed.

8. Is the uncertainty analysis consistent with standard statistical principles and practices? Have the relevant sources of uncertainty been accounted for? Have the appropriate confidence intervals and other statistical principles been calculated and used in the appropriate manner? Are there any improvements that should be implemented? The uncertainty analysis could be improved. Some sources of uncertainty (such as non-use value) are omitted in favor of uncertainty with respect to a limited set of parameters. The use of ranges instead of standard errors is not explained well and is not ideal. There

is nothing wrong with what has been done except that the approach probably understates uncertainty. Furthermore, many of the biologic parameters are undoubtedly correlated, which will affect the results of the analysis.

9. Does the study provide a reliable estimate of the potential benefits of reducing I&E impacts at DCPP? If so, why so? If not, would it be reliable if the proposed changes you have recommended were implemented in appropriate fashion? My opinion is that the authors have included the most important benefits categories in their analysis. Furthermore, I expect that if they addressed all of the concerns raised here the qualitative conclusions of the analysis would not be substantially changed. I would expect the uncertainty in the bottom line to increase somewhat.

SPECIFIC COMMENTS.

These specific comments correspond to the specific sections of the report.

Section 2. Background. Generally, the background section is accurate. However, there is a discussion of fishery markets in section 2.4 (pp 9-10) which is not really accurate or at best, incomplete. The authors discuss the welfare economics of a fishery in the same way they would any commodity market. The important complicating factor in a fishery is *access*. If the fishery is *open access* (unregulated), there is no surplus or rent accruing to producers – the cost of fishing equals revenue. There may still be an upward sloping supply curve but the area between the price and the supply curve is not generally producer surplus (including rent). If the authors are distinguishing between rent and producer surplus, that should be made more explicit. On the other hand, if the fishery is efficiently regulated, then there are rents that accrue, possibly to the producer.

Producer surplus is a more complex issue than in standard markets. This is one reason the EPA[4] assumes that producer surplus is 0%-40% of gross revenues (based on the literature) rather than actually measuring it.

I would like to see the discussion qualified; it is probably not necessary to launch into a full discussion of fishery economics, in part because EPA does a good job of this in their report. The consumer surplus discussion is fine but there really should be a discussion of the nature of regulation (or absence thereof), particularly in the vicinity of DCPP, and how it affects producer surplus and rents. The effect of I&E losses on an open access fishery will be quite different from an efficient fishery which will be quite different from a partially regulated fishery.

In section 2.5, several documents are mentioned (the two California studies and the ASA prior study). These should be completely referenced in such a way that the reader can access the documents. This comment applies in many parts of the TER report. If the authors are relying on an analysis or piece of data, the source should be fully referenced.

Section 3.1 Description of Valuation Methodologies. This is a well-written and clear section. I do have some issues however with recreational as well as commercial valuation.

The worked-through example of the Brown Rock Crab is a nice addition to the report. The TER authors should try to document the example sufficiently so that someone could duplicate the analysis. This is not done. For instance, in Step 4 (p 24), it is approximately clear where the 75:25 split came from but it is not easy to find the appropriate data on the California Department of Fish and Game website.

[4] Section A10-11 of EPA Report EPA-821-R-04-005 (February 2004).

Recreational Values. Step 5 of section 3.1.1 (p 17) concerns the recreational valuation component. The TER report uses a Random Utility Model (RUM) of recreational fishing to estimate the benefits per fishing day of an increase in the catch rate. The TER authors use the parameters from the RUM developed by EPA for the California regional analyses (a sensible step). But EPA recommends a second step, calculation of increased trip frequency from increased catch. This turns out to be significant in other regions[5] though EPA was unable to estimate such a participation model for California. TER neglects this second step, perhaps for good reason. I would like to see this explicitly accounted for in the analysis. TER should include either a treatment of participation or a rationale for why it is omitted.

Commercial Values. The authors of the TER analysis take an approach to commercial benefits that is different from the approach of the EPA and actually quite innovative. TER assumes a downward sloping demand curve for fish/shellfish which implies that decreased I&E has an effect on the price of fish with consequent effects on consumer surplus from this change. Because of the assumptions TER makes, they do not even have to consider changes in producer surplus. This is in contrast to EPA, which ignores changes in consumer surplus in favor of changes in producer surplus. Although TER's approach is innovative, it may not be correct.

One of the problems of evaluating effects on a fishery is what to do with producer surplus. As mentioned earlier, if the fishery is open access, there will be no rents and probably no producer surplus. If we perfectly represent the way in which the fishery is regulated, then we may be able to actually compute the surplus accruing to producers.

[5] EPA Report EPA-821-R-04-005 (Feb, 2004), Part D, Chapter D-4.

The EPA takes the approach of assuming a certain percentage of gross revenues is producer surplus (based on studies by others).

In the TER Report, the authors assume that the price elasticity of demand for a particular species is -1. It happens that for demand curves with price elasticities of -1, revenue is the same no matter what the price. Thus the TER authors effectively constrain gross revenue to be constant as supply changes. If producer surplus is some fraction of gross revenue then no change in gross revenue implies no change in producer surplus. This assumption allows TER to focus on consumer surplus and not worry about producer surplus.

Mathematically, this is convenient and correct. But is it an accurate representation of the markets in question? The TER authors simply assume the demand elasticity is -1, rather than concluding it is -1. They should at minimum provide some support for this. Furthermore, it is not clear what the geographic market is that they are working with – the local market, the California market or something larger? The smaller the market, the more elastic the demand is. There are numerous studies of the demand elasticity for fish and seafood. However, if the affected market is part of a much bigger market, then it is unlikely the increased supply from reduction in I&E will have much effect on price. In fact, EPA assumes that decreased I&E will not affect the price.[6] There probably is a geographic market for which the price elasticity of demand is -1 but we would need to know what that market is before applying the approach outlined by TER.

The significance of this assumption is illustrated in the Brown Rock Crab example (p. 25). The example shows that the additional surplus from avoided I&E comes from the reduction in the price of crab. For other species, the effect on price is

[6] Refer to section A10-11 of EPA Report EPA-821-R-04-005 (February 2004).).

probably much lower (though maybe not -- the data are not provided) and thus the surplus gain very low. If on the other hand, demand were more elastic (and thus price stayed more constant), the revenues would rise from reduced I&E and a portion of the producer surplus would be counted as a benefit.

The bottom line is that the TER authors take a different approach from the EPA in valuing commercial benefits from reduced I&E and do not sufficiently support the validity of their approach. My recommendation would be to either more fully support their analysis or adopt an approach more similar to what has been done by EPA. However, it should be pointed out tht according to TER's figures at the top of p18, the significance of this error may not be great.

Indirect Effects. In footnote 18 on the bottom of page 18, the authors should mention other indirect effects, including those that are excluded – such as the stock effect that makes fishing easier (as discussed in the Background section).

Section 3.2 Analysis of the Effects of Uncertainty. The uncertainty analysis appears methodologically correct. My primary suggestions have to do with documentation and specific assumptions about uncertainty.

According to the description of the uncertainty analysis in section 3.2 (p 26), most parameter uncertainty appears to be represented by a range of values around a central tendency. The authors should point out that this amounts to assuming a uniform distribution over a range rather than a distribution that looks like the examples in Figure 6. There is nothing wrong with using a uniform distribution (though it may not always be appropriate) but the discussion should be clear. Furthermore, the focus on parameter uncertainty is a bit narrow. Not only are the ranges of uncertainty detailed in Appendix B sometimes very small (for example, recreational values are ± 2.5%) but not all parameter uncertainty is represented. The uncertain parameters of the RUM induce uncertainty in the recreational value estimates; non-use value estimates are surely very uncertain.

I would suggest the authors move away from a uniform distribution of uncertainty, at least in some cases, and also move to including more variables with a wider range of uncertainty. Moving away from the uniform should reduce the spread of results; including more variables with wider ranges of uncertainty will increase the spread. A look at Table 3 illustrates that the underlying parameter uncertainty does not induce a very large spread in final benefits figures.

The uncertainty section relies on Appendix B, which could be improved. It is difficult to understand what is being done from the discussion in the Appendix. The concept of "range" is never defined, though I suspect it is ±x%. Footnote 39 is not too helpful. The method for obtaining the ranges is also not well explained. Table B.2 uses standard deviation. How does that connect to range?

Section 3.3 Results. Table 5 on p 31 is very helpful in that it is an attempt to show how the results of the TER analysis compare to other analyses (specifically the EPA California studies). This is a nice addition to the report. However, I would prefer to see this table fleshed out a little more so that a comparison is easier. About the only thing a reader can do is divide the benefits numbers by the number of facilities and compare. Using that approach, the TER figure is quite a bit smaller than the other studies. Perhaps there is a better way of comparing?

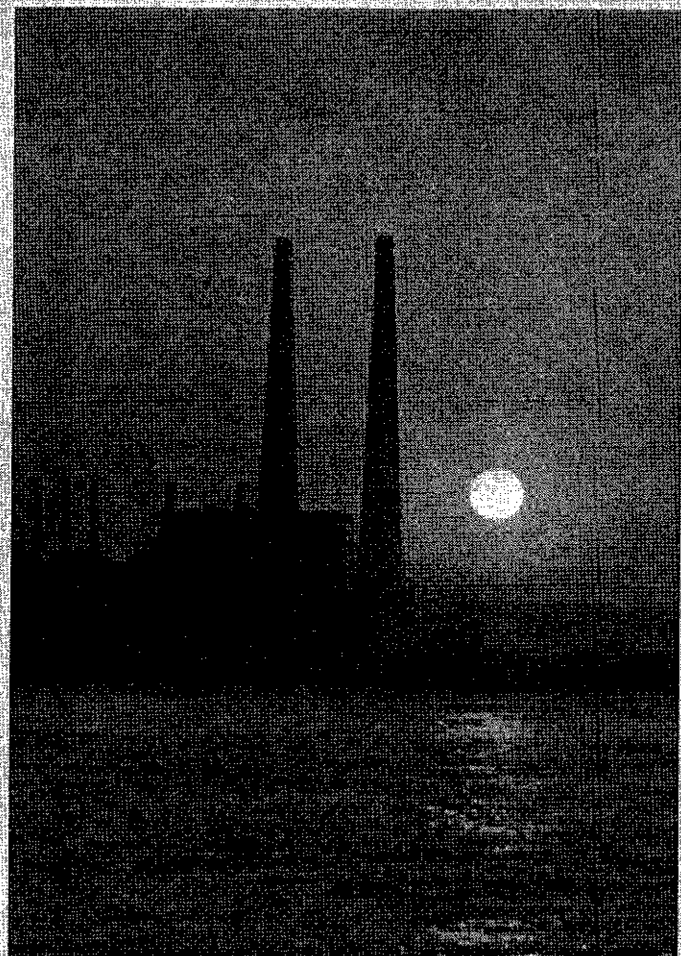
Section 4 Non-use Values. Non-use values are always tough to estimate, as is made clear by both the EPA and TER. Because of the uncertainty in this arena, EPA has generated specific guidelines regarding when a monetization of non-use benefits is needed. Although I am not convinced that there are no non-use benefits of I&E reduction, it does appear that TER is following EPA's guidelines in concluding that a qualitative discussion of these impacts is all that is needed.

I see two different discussions of non-use benefits in the lengthy Federal Register report on the final 316(b) rule. One pertains to what EPA is relying on for their national cost-benefit analysis of the rule. The other pertains to what should be included in benefits assessments in support of site-specific best available control technology. This section of the TER Report is a little confusing to the reader and the TER authors may wish to clarify this. For instance, EPA concludes (quoted by TER on p32) that "none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits." This does not mean that qualitative discussion of nonuse benefits is always adequate for site-specific benefits assessments, as is made clear on page 41648 of the Federal Register (July 8, 2004) and quoted by TER on p37.

Although I have not examined the "impingement mortality and entrainment characterization study" -- the TWG I&E study – I assume that it did not identify I&E as resulting in substantial harm to a threatened or endangered species, the sustainability of populations of important species of fish, shellfish or wildlife, or to the maintenance of community structure in the vicinity of DCPP. In this case, the EPA rules are clear that a monetization of non-use benefits is not necessary. A qualitative discussion is adequate.

The qualitative description of non-use values in the TER Report is brief – perhaps too brief. Furthermore, most of it is a recounting of the theory of non-use values. The purpose of this section is to argue that the non-use benefits of I&E reduction are negligible. I believe the authors could be more convincing. Most people know there are significant wildlife on the Central Coast south of Big Sur that *could* have significant value to the general public – pelicans, seals and otters to mention a few. I would urge the authors to more fully dispose of the notion that "important species of wildlife" will be substantially affected by I&E reductions.

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



Michael S. Foster
Moss Landing Marine Laboratories

review supported by the
California Energy Commission

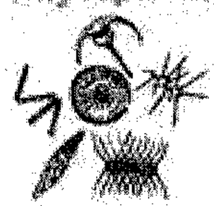
MAJOR MARINE IMPACTS

-pollution (nutrients, toxins, sediment)
-over fishing & by catch
-habitat destruction
-invasive species
-ocean warming & sea level rise
-once-through cooling?

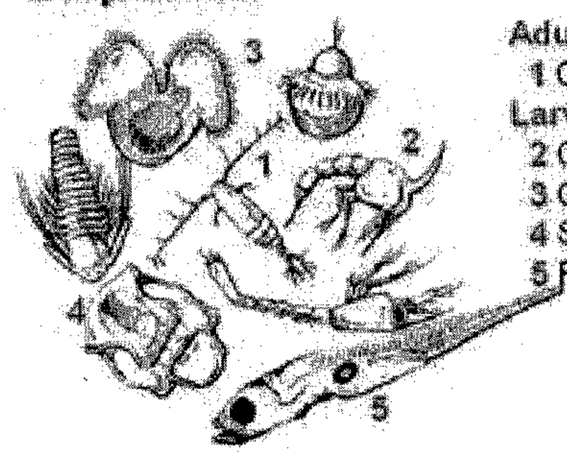
SEAWATER IS A COMMUNITY, NOT JUST SALTY WATER

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

Phytoplankton 10^2 SPP 10^9 #



Zooplankton



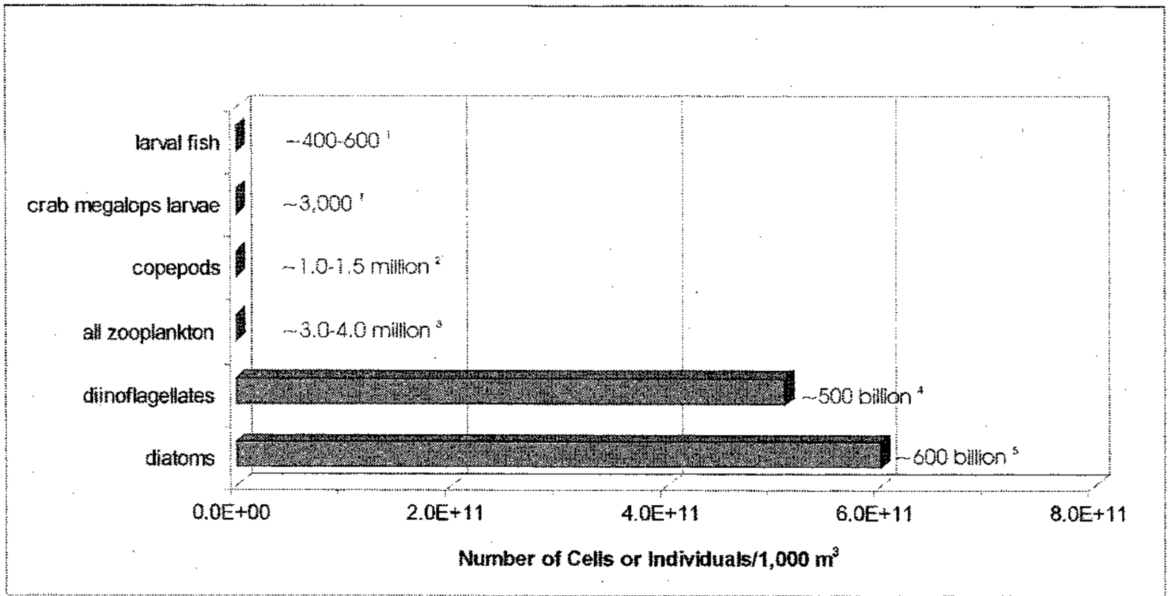
	SPP	#
Adults		
1 Copepods and related animals	10^2	10^6
Larvae		
2 Crabs	8	$3x10^3$
3 Clams & mussels	> 5	$1.8x10^6$
4 Sea urchins	2	$6x10^2$
5 Fish	44-200	400 – 600

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

~ 50 Million Marine & Estuarine Fish Entrained Per Day in CA

$1000\ m^3 \times 100{,}000 \approx 17$ Billion Gallons

Plankton Abundance



[1] various 316b entrainment studies
[2] Kimmerer 1993
[3] Hopcroft et al. 2002
[4] Buck et al. 1992
[5] Fielder 1982

Citations for Plankton Abundance:

[1]. Tenera Environmental. 2000. Diablo Canyon Power Plant 316(b) Demonstration Report. Prepared for Pacific Gas and Electric.

[1]. Tenera Environmental. 2000. Moss Landing Power Plant Modernization Project 316(b) Resource Assessment. Prepared for Duke Energy Moss Landing, LLC.

[1]. Tenera Environmental. 2001 Morro Bay Power Plant Modernization Project 316(b) Resource Assessment. Prepared for Duke Energy Morro Bay, LLC.

[2]. Hopcroft, R R, Clarke, C, and F P Chavez. 2002. Copepod communities in Monterey Bay during the 1997-1999 El Nino and La Nina. Progress in Oceanography 54: 251-264.

[3]. Kimmerer, W J. 1993. Distribution Patterns of Zooplankton in Tomales Bay, California. Estuaries 16(2): 264-272.

[4]. Fiedler, P C. 1982. Zooplankton Avoidance and Reduced Grazing Responses to *Gymnodinium splendens* (Dinophyceae). Limnology and Oceanography 27(5): 961-965.

[5]. Buck, KR; Uttal-Cooke, L; Pilskaln, CH; Roelke, DL; Villac, MC; Fryxell, GA; Cifuentes, L; Chavez, FP. 1992. Autecology of the diatom *Pseudonitzschia australis* , a domoic acid producer, from Monterey Bay, California. Mar. Ecol. Prog. Ser. 84(3): 293-302.

Phytoplankton Distribution:

Taxa	Distribution
Diatoms	
Pseudo-nitzschia pungens & *P. multiseries*	"cosmopolitan"
Pseudo-nitzschia australis C	warm water and temperate Pacific
Dinoflagellates	
Alexandrium acatenella	coastal north Pacific US and Canada, north of Japan and Argentina
Alexandrium catenella	coastal areas along Pacific Ocean of North America, south and central Chile, southern Argentina, western South Africa, Japan, Kamchatka peninsula in the Soviet Union, Tasmania, and south of Australia.
Gymnodinium catenatum	temperate waters of North America, Europe, Australa and Japan

Citations:

Tomas, C.R (editor). 1997. Identifying Marine Phytoplankton. Academic Press. 858 pages.

Zooplankton Distribution

Copepods made up about 79% of the macro-invertebrates collected of Diablo Canyon Power Plant during the 1985-1986 sampling. *Acartia tonsa* was one of the common copepod species found off DCPP during 1974-1975 sampling. *A. tonsa*'s is distributed along the Atlantic and Pacific coasts of North and South America and the Indian Ocean.

Citations:

Tenera Environmental. 1998. Diablo Canyon Power Plant Cooling Water Intake Structure 316(b) Demonstration. Prepared for Pacific Gas and Electric Company.

Icanberry, J.W. and J.W. Warrick. 1976. Seasonal Distribution of Plankton in the nearshore environment of Diablo Canyon Nuclear Power Plant. Pacific Gas and Electric Report #7846.13-76.

http://www.sea.ee/Sektorid/merebioloogia/MASE/Plankton.htm

Phytoplankton Generation Time

- Generation time ranges from a few hours to a few days.

Citations:

GA Cangelosi, AM Hamlin, R Marin and CA Scholin. 1997. Detection of stable pre-rRNA in toxigenic *Pseudo-nitzschia* species. Applied and Environmental Microbiology 12:4859-4865.

Kiefer, DA; Lasker, R. 1975. Two Blooms of *Gymnodinium speldens* (Lebour). A large naked dinoflagellate. Research on the marine food chain, Progress Report UCSD 10P20-202, for the period July 1974-June 1975. pages 223-235.

Eppley, R W, Rogers, J N, and J J. McCarthy. 1969. Half-Saturation Constants for Uptake of Nitrate and Ammonium by Marine Phytoplankton. Limnology and Oceanography, 14(6): 912-920

Mann, K H, and J R N Lazier. 1991. Dynamics of Marine Ecosystems. Blackwell Science, Inc. 466 p.

http://www.nwfsc.noaa.gov/hab/habs_toxins/phytoplankton/algal_dynamics.html

Weiler. C.S. 1980. Population structure and in Situ division rates of Ceratium in the oligotrophic waters of the North Pacific Central Gyre. Limnology ans Oceanography 25: 610-619.

Zooplankton Generation Time

- Generation time ranges from 3-53 days depending on species and water temperature.

Citation:

Gillooly, J F. 2000. Effect of body size and temperature on generation time in zooplankton. Journal of Plankton Research 22: 241 - 251.

Chapter 12

PLANKTON*

Zooplankton

Zooplankton are small animals that drift in the water. They feed mainly upon the tiny plants - the phytoplankton - that are the basis of the marine food web (although some zooplankton feed on other zooplankton). In turn, zooplankton are fed upon by fish and other organisms that ultimately support most of the sport and commercial fish species in the oceans.

The zooplankton may be subdivided into three groups: 1) those that spend all their lives as plankton (holoplankton), 2) the early stages of species (such as barnacles and clams) whose adult stages live on the ocean floor (meroplankton), and 3) the larvae of many fish species. The last group is sufficiently important that it was studied in a separate program (see Chapter 13); the first two groups are discussed together here. A more detailed account of the results (including those for phytoplankton) is given in the *Interim Technical Report: 4. Plankton.*

As noted in Chapter 2, experts at the public hearings predicted severe and widespread declines in the abundance of zooplankton, and especially of meroplankton, mainly because of their possible transport offshore by SONGS' discharge plume. This concern was the major motivation for the creation of the MRC. In a report to the CCC *(Predictions of the Effects of San Onofre Nuclear*

* Dr. Arthur Barnett (Marine Ecological Consultants) carried out the scientific studies of plankton on which this report is based, and also prepared the Contractor's Final Report. The Interim Technical Report 4 to the CCC was prepared by Dr. Jon Kastendiek and Mr. Keith Parker.

Generating Station, and Recommendations (1980)), the MRC concluded that the evidence was not adequate to make firm predictions that such adverse changes in abundance would occur.

The zooplankton were sampled at an Impact site 0.3 km north of the Unit 2 diffuser, and at a Control site 12 km south of the plant (Figure 12.1). Samples were taken using the BACIP design at Impact and Control both in the Before and After periods (Chapter 5).

The zooplankton were sampled over a 5-year period before Units 2 and 3 became operational, and for three years afterwards [ITR 4: Appendix C]. During the operational period we concentrated samples into those periods when SONGS was operating well above its average level, so if an effect were to occur we should be more likely to catch it.

Intake Losses

We estimate that about 1350 tons dry weight of zooplankton are taken into the intakes each year. This total is made up of 1000 tons of the zooplankton groups analyzed in our samples, plus an estimated 350 tons of very small individuals - the microzooplankton, which we do not sample [ITR 4: 20-21, Appendix K]. The latter estimate is based on results of sampling for this group in the nearshore near La Jolla. The 1000 tons estimate matches the MRC 1980 prediction. Although this is a large loss, it is clearly not sufficient to cause a local depression in the zooplankton, as we discuss below.

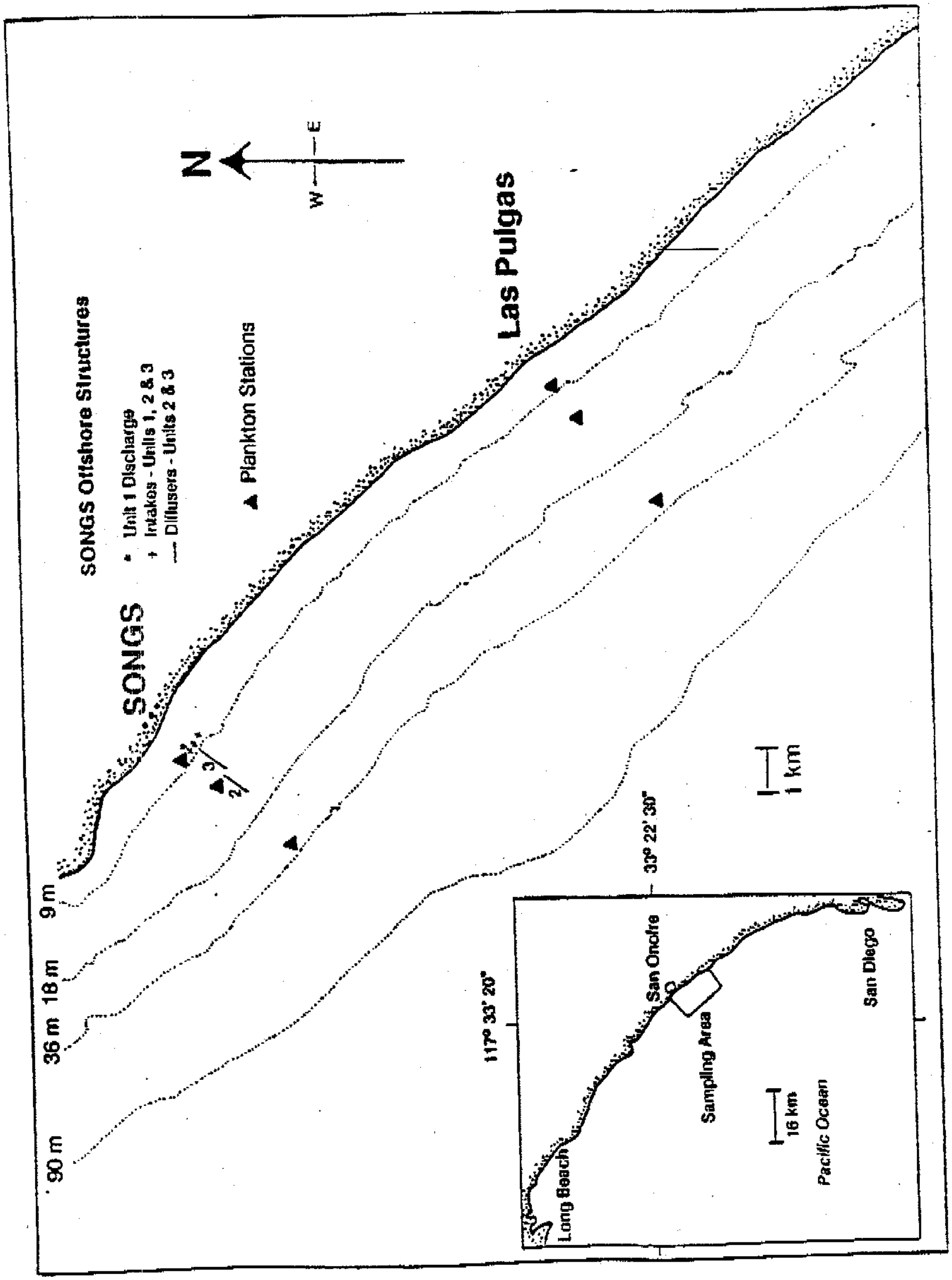


Figure 12.1. Locations of stations sampled for plankton.

Changes in Abundance[1]

Contrary to expectations, the plant appears to have increased the local abundance of meroplankton, and to have had no effect on the remaining zooplankton - the holoplankton.

The abundance of meroplankton (which comprise about 6% of the zooplankton) increased at SONGS relative to Control by about 60% on average (Table 12.1) [ITR 4: 12-13). Within meroplankton, the three subgroups examined tended to increase (Table 12.1). Our confidence that these increases are SONGS effects is increased by the fact that they remain when we examine data only from dates, both before and after operation, when the plume was passing over the Impact area, and sometimes disappear when the plume was moving in the opposite (south) direction.

Table 12.1

Statistically significant, (or nearly significant), changes in abundance of zooplankton at SONGS relative to the Control site in the operational period. The second column gives the percentage that each group contributes to the total zooplankton abundance.

SPECIES OR GROUP	RELATIVE % CHANGE	% OF TOTAL
Meroplankton	+64	6.3
Barnacle nauplii	+ >100	0.4
Bryozoan larvae	(+38)	2.4
Unidentified meroplankton	(+68)	3.5

[1] Dr. Fay does not agree with the conclusions in this section.

The holoplankton constitute the remaining 94% of the zooplankton [ITR 4: 13]. SONGS had no effect on the holoplankton as a group. This result was independent of the direction of the current. Eighteen species or species groups of holoplankton were studied individually, and statistically significant changes were observed in one uncommon genus of holoplankton (*Evadne*) [ITR 4: Table 2]. The changes seen in this genus may be unrelated to the plant's operation and are discussed in *Interim Technical Report 4*.

No other species showed statistically significant changes, although nine showed a tendency towards a relative increase and three showed a tendency towards a relative decrease [ITR 4: Table 2]. Early predictions were for a greater than 50% local decline in abundance of zooplankton populations; but for the holoplankton as a group and the meroplankton as a group, we can state with statistical confidence that a 50% decline did *not* occur. The same can be said, individually, for a set of 12 species and species groups [ITR 4: Appendix J].

Reasons for the Absence of a Reduction in Zooplankton

As noted in Chapter 2, the primary motivation for the creation of the MRC was a concern that severe and widespread reductions in zooplankton abundance would occur as a result of SONGS' operation, and that this in turn would result in a nearshore marine "desert." The results discussed above show that in fact no substantial changes have occurred in the zooplankton, and we provide here the likely reasons why this is so.

Two mechanisms by which SONGS might reduce the zooplankton were envisaged at the original hearings. The first was direct killing of zooplankton taken into the plant. It is now clear that this is not a feasible mechanism for producing local depressions. For example, under typical conditions, a sample of seawater taken from the discharge plume about 1 mile downstream of the plant will consist almost entirely of unaffected water; only about one-fortieth of the sample will have passed through the plant. If we think of the plant as removing all organisms from the water that passes through it, thus diluting the concentration of organisms in the area, the dilution is thus only a few percent one mile downstream. No feasible sampling program would be likely to detect such a reduction amidst natural variation.

The second and major mechanism by which SONGS was expected to reduce zooplankton abundance was by transporting them offshore to an inhospitable environment where they would die. There are now two reasons for believing that this is not a cause for concern. First, the zooplankton data were examined to see whether the distribution shifted offshore in the diffuser zone and beyond it (such a shift would not prove there was transport, but it would be consistent with it). In fact, the only changes observed were in the opposite direction; i.e., they were increases in the diffuser zone relative to the zone just offshore. Second, studies of the plume (Chapter 6) show that the movement of water offshore is less than was expected; thus plankton do not appear to have been transported to unsuitable habitat.

Similar arguments should apply to fish larvae, and this is a reason that we have difficulty in explaining the effects that were observed in a small fraction of these species (Chapter 13).

Phytoplankton[2]

The MRC also looked for effects on the phytoplankton (the single-celled plants that are the basis of much of the life in the oceans), by measuring the concentration of the plant pigment, chlorophyll, in sea water. This study used the BACIP design, and the sampling stations were the same as for zooplankton. There is good evidence that SONGS has not reduced the local abundance of phytoplankton: no statistically significant change was detected [ITR 4: 16] and, ignoring statistical considerations, there was an increase in relative concentration near SONGS [ITR 4: H-27].

[2] Dr. Fay does not agree with the conclusions on phytoplankton.

Rockfish Resources of the South Central California Coast: Analysis of the Resource from Partyboat Data, 1980–2005.

John Stephens[1,2], Dean Wendt[1], Debra Wilson-Vandenberg[3], Jay Carroll[4], Royden Nakamura[1], Erin Nakada[1], Steven Rienecke[1], and Jono Wilson[1]

[1]California Polytechnic State University, San Luis Obispo

[2]Vantuna Research Group, Occidental College, Los Angeles

[3]California Department of Fish and Game

[4]Tenera Environmental, Inc.

John Stephens, Calpoly SLO

2550 Nightshade Pl. Arroyo Grande, CA

93420 (805)546 8310

Stephens2@earthlink.net 6,315 words

ABSTRACT

Rockfishes (*Sebastes* spp.) have historically comprised a large proportion of catches in the nearshore recreational fishery in California but declining populations of some species have led to increasingly restrictive management of the resource. This report summarizes new and existing data on rockfishes of the south central coast of California. In 2003 the California State Polytechnic University, San Luis Obispo placed observers on commercial passenger fishing vessels (partyboats) from the region.. By the end of 2005, we had observed catches from 258 trips (8,839 fisher hours). We appended these data to partyboat catch statistics collected by California Department of Fish and Game from 1988 to 1998 and calculated annual CPUE's and mean sizes by species and year. The CPUE data by species fluctuates annually but rarely shows consistent trends. The overall CPUE for 2004 and 2005 ranks in the top five of the twenty sampled years. Mean sizes have been consistent by species, generally just above the size of 50% maturity. Comparing these sizes to historical data shows decreases in some species but not in others. A review of NOAA/NMFS triennial trawl data for the Point Conception area in the southern part of the study region suggests that the deeper shelf and slope species, with a few exceptions, show little evidence of long-term declines. In general, the south central coast rockfish resources, with the exception of bocaccio (*S. paucispinis*), have not shown strong evidence of a declining trend over the past 25 years.

.INTRODUCTION

Elements of the rockfish (*Sebastes* spp.) resource of California have been in a depleted condition for many years. Fishery-related problems have been diagnosed by many researchers including Lenarz (1987), Ralston (1998), Gunderson (1998), and Love et al. (1998, 2002). Rockfish are long-lived, slow to maturity (iteroparous), and therefore subject to pre-spawning mortality (Leaman 1991). Two factors, overfishing and climate change, are considered primarily responsible for the declining marine fish populations in much of California.. Climate change, including El Nino Southern Oscillation (ENSO) events and Pacific Decadal Oscillation (PDO) reversals (Chavez et al. 2003), has been emphasized by many, including Beamish (1995), Brooks et al. (2002), Francis and Hare (1994), and Holbrook et al. (1997). Fishing pressure has also been implicated as a major factor (Mason 1995, Jackson et al. 2001, Myers and Worm 2003) and in the media. Recently, the interrelationship between these two forcing functions on California partyboat catches has been analyzed by Bennett et al. (2004) while Tolimieri and Levin (2005) have looked at their effects on bocaccio (*S. paucispinis*). Possible detrimental effects of warmer climatic conditions on rockfish include nutrient-poor water and declines in adult condition factors or gonadal growth (Ventresca et al. 1995, Harvey 2005), and increased mortality in larvae and young-of-year (YOY) related to their thermal requirements in enhanced water stratification (Boehlert et al. 1985, Ross and Larson 2003). Besides density-related decreases in catch data (CPUE), there has been an indication that relative sizes of species have also declined over the years (Mason 1998) and that the lack of large females in the population could lead to reduced recruitment through loss of fecundity or the loss of highly competent larvae produced by such females (Berkeley et al. 2004).

This paper examines changes in CPUE and mean sizes of the rockfish species taken in the nearshore environment of the south central coast (SCC) of California (fig. 1), an area not specifically examined in previous studies and an area that marks the transition between the warm-temperate southern California bight to the south, and the cool-temperate "Oregonian" oceanic province to the north. The latter is the center of distribution for the majority of eastern Pacific rockfish species (Love et al. 2002).

The earliest published data on fishes of the SCC was Heimann and Miller's (1960) comparison of trawlers and partyboat fisheries from 1957 to 1958 while Miller and Gotshall (1965) included the area in their partyboat survey of 1957–1961. Miller, Odemar, and Gotshall (1967) reported on blue rockfish while Miller and Geibel (1973) reported on lingcod, as well. Love et al. (1991) discussed aspects of the biology of nearshore rockfish of the central coast. Our partyboat monitoring (Cal Poly, 2003-2005) makes use of these as well as previously unpublished CDFG data for the region for 1988–1998, which is partially available as administrative reports (Reilly et al.1998, Wilson et al. 1996, Wilson-Vandenberg et al. 1995, 1996), as well as unpublished partyboat studies (Pacific Gas and Electric Company (PG&E) Diablo Canyon (1980–1986)), *in situ* YOY recruitment observations (PG&E/Tenera Environmental (1976-2004)), and recruitment module (SMURF) studies (Cal Poly (2004-2005)). These data are discussed along with the available results of the NOAA/NMF Triennial Trawl Surveys (1977–2004) for the Conception region.

METHODS

The Cal Poly partyboat observer program, which began July 2003 and is ongoing, follows the methods developed by CDFG (Reilly et al. 1993) with some exceptions. Both protocols have the observer select a sample of anglers to observe at the start of the trip, usually between 6 and 15. The number of the sampled anglers fishing at each drop is recorded along with the fishing time for that drop, its maximum/minimum depth, and the number of fish caught by species. Localities are recorded for each site. We measured the total length of each fish as they were landed and then recorded their fate, either kept or returned. CDFG recorded the species as they were landed as well as their fate but measured them from the fisher's bags at the end of the fishing day (kept fish only). They may also measure fish not included in the observer's sample. The CDFG protocol does not allow accurate determination of the relationship of size to depth. The Cal Poly data was limited to rockfishes (*Sebastes*), hexagrammids (greenlings and lingcod), and cabezon (*Scorpaenichthys marmoratus*) though other species were noted. CDFG recorded all fish. The catch per unit effort (CPUE) statistic is the total number of fish caught by the observed sample divided by the effort. The effort variable (man hours) is developed from actual fishing time in minutes for each drop multiplied by the number of anglers in the observed sample. Data from the field sheets were checked by each observer and entered into a Microsoft Access® database, with subsequent quality control. Comparative data were made available on Microsoft Access® by CDFG from their 1988–1998 partyboat surveys for the same sites. Similar data for 1980–1986 were available from PG&E's Diablo Canyon surveys.

Recruitment data (1976–2004) from diver transects at a PG&E control station for Diablo Canyon (Patton Cove), outside the influence of the power plant's thermal discharge plume, was supplied by Tenera Environmental.

We initated SMURF collections of settling larvae (Ammann 2004) in 2004. SMURFs, 1.0m by 0.35m mesh plastic cylinders filled with larger mesh plastic grids, act as settlement "traps" for many nearshore fish species. Ours were attached to buoys just below the surface and sampled biweekly at three stations, three SMURFs per station..

Further data for the region was available from the NOAA/NMFS Triennial Trawl publications (1977, 1995, 1998, 2001) and we received data from 2004 from NOAA Northwest Fisheries Science Center and the NOAA Alaska Fisheries Science Center's Racebase database (Beth Horness, NOAA/NMFS, pers. comm.).

RESULTS AND DISCUSSION

For 2003, 2004, and 2005 we observed partyboat catches from Patriot Sportfishing and Virg's Sportfishing operating out of Port San Luis and Morro Bay, respectively. A total of 258 trips was observed: 68 in 2003, 126 in 2004, and 62 in 2005. The number of trips was evenly dispersed between the two ports. In 2005, fishing was allowed only at depths of 20 fm (36.6 m) or shallower and the season lasted from July 1st until the middle of December (5+ months). For 2004, the season opened January 1st, closed for the months of March, April, and July, and was open for the remainder of the year (9 months). That year fishing was allowed as deep as 30 fm (54.7 m) for about one-third of the period, and restricted to 20 fm the remainder of the time. For 2005, the season opened on May 1st and ended September 30th (5 months). Fishing was open to 40 fm (80m) or less for the entire season.

The Cal Poly partyboat data (tab. 1) presents the catch and take of species of interest for each year with mean size and standard deviation for each category. There was a total of 23 species of rockfishes, 3 hexagrammids, and cabezon for a total of 27 species of interest taken in our samples for these three years. Of these, eleven rockfishes and the two greenlings represent elements of the nineteen species complex included in the California Resources Agency Nearshore Fishery Management Plan. Catch per unit effort is considered to be a reliable measure of fish density in the habitat. The overall partyboat CPUE by year (fig. 2) has remained relatively constant over the years even though recreational regulations have reduced the overall bag limit, number of hooks per line, reduced the take and increased size limits on some species while excluding others from take, altogether. A number of factors could reduce the effects of these changes including improved fish finding (sonar) and new technology in artificial lures. The recent Cal Poly data do not show evidence of decline and the CPUE (2003-2005) ranks in the top five in the 20 years sampled.

Species CPUE's are much more informative than generic ones. Because partyboats fish deeper than the major distribution of several of our species of interest (grass, black & yellow rockfish, treefish, kelp greenling, and cabezon) and as they are not sampled well by this methodology, we will not discuss them further. Most of the other species that were taken are available to fishers at shallow depths but many are more numerous and are larger in size at greater depths. Thirteen species made up more than 1% of the catch in at least one year of sampling. In order of decreasing total abundance they were: blue, gopher, vermillion, lingcod, brown, yellowtail, olive, rosy, copper, starry, canary, black, and bocaccio. The assemblage rank order did not differ significantly over these three years (Kendall's tau, p =.05) even though different depths were fished over different years. During 2005, because fishing was allowed to depths of 40 fm (80 m), we were able to test the effect of this depth range on species distributions. Five of the thirteen rockfish species increased regularly in CPUE with greater depth: canary, copper, olive, rosy, and yellowtail, while two species, brown and gopher, decreased in density with depth. Changes in CPUE and size are shown (fig. 3) for relevant species.. Two species, blue and starry, increased in CPUE in depths below 20 fm but decreased or stayed constant in depths greater than 30 fm while vermillion and bocaccio increased in the deepest fishable strata of 30–40 fm. Five species increased in size (mean length) in deeper water: blue, canary, copper, olive, and yellowtail. These data suggest that it is important to consider depth when describing changes in abundance and size of rockfishes through time.

As CPUE's and size data measured outside the preferred habitat of a species may not be typical for that species (MacCall 1990), we compare species that occupy similar depth strata and depict CPUE from all depths as well as data from 20 fm or less (figs. 4 and 5). Species that seem to center their distribution around 20 fm (black, blue, brown, china, gopher, olive, and lingcod) are compared (fig. 4). Here, CPUE is generally higher for the shallow (<21 fm) data which more accurately reflects the preferred habitat. For a number of species (black, brown, china, and olive) the highest CPUE of the 14 year sampling period occurred in 1990–1991, which were "normal" years for oceanographic conditions between the ENSO events of 1983–1984 and 1992–1993. Black and china rockfish have been in low abundance recently which may reflect a northern displacement of these species from their southern limits in response to the warm PDO (1977–1998). Olives have not been abundant the last three years but apparently were very abundant between 1998 and 2002 (Steve Moore, Patriot Sportfishing, pers. com.,) when sampling had been discontinued. All these shallow species appear to decrease in CPUE during 2005 but this is the result of decrease fishing in shallow water and expanded fishing outside their depth range. Only 21% of the drops in 2005 were in shallow water. Blues, browns, gophers, olives, and lingcod appear to have strong populations. Blues are unique in showing peaks in abundance that coincide with ENSO events which probably relates to increased catchability when their planktonic nutrient resources are low (Ventresca et al. 1995).

As cited earlier, seven species: bocaccio, canary, copper, rosy, starry, vermillion, and yellowtail, though often common in depths less than 20 fm, increase in density in deeper water (fig. 5). The 2005 CPUE for copper and vermillion is the highest of the time series while that for rosy and starry ranks in the top five Bocaccio have been in decline since at least 1989, a well-described phenomenon (Ralston et al. 1998, MacCall et al. 1999) and are still depleted as evidenced by their low CPUE. Their density increased slightly in our 40 fm data but it appears that their density has not changed much in the last 12 years, since their major collapse (1989–1992). Recent work by Tolimieri and Levin (2005) suggests that the balance between reproductive success (recruitment) and population growth in the bocaccio is tenuous at best and that any fishing pressure could push the population towards extinction. The present bag limit for bocaccio is two fish per angler which is an increase over the no-take regulation in 2003, but is still conservative.

Densities of most species do not appear to change dramatically or consistently with ENSO years. This may reflect the relatively low fishing intensity in the SCC, as well as its' cool water habitat. Bennett et al (2004) discussed differing reactions to ENSO events in the warm, heavily fished southern California bight (decreases) as opposed to the cool water, low fishing intensity sites north of San Francisco (increases). This reasoning could apply here.

Besides reduction in CPUE (density), fish size is an important indicator of possible population problems. Reduction in fish size due to fishing pressure reducers the number of large mature individuals in the population (Cushing 1975). Long lived and slow growing species are especially vulnerable to this effect. The loss of large females from the population can have an especially strong effect on larval production and survival (Berkeley et al. 2004). Thus, growth and recruitment overfishing can be closely related. The annual change in mean length as a measure of size since 1988 (fig.6) does not indicate a major trend by species in the SSC. The mean lengths of most species are above the fifty percent maturity size though yellowtail and black are not. Yellowtail caught in deeper waters (2005) did exceed this size level and the smaller size of the shallow water catch reflects ontogenetic movements in this species. Blacks generally have not done well on the SCC since the change to a warm PDO, and were small for the species, even in the 1980–1986 data (Karpov et al. 1995). The SCC is the southern limit of their range.

The CDFG size data (1988-1998) were from fish that were kept by fishers in the partyboat fishery and the depths from which they were taken were uncertain. Our data (2003-2005) includes both caught and kept fish as well as depth of capture. We have used kept fish size to make our data comparable to previous studies but the use of size from only kept fish biases (increases) the fish size estimate of the fished population because fishers sometimes released smaller fish. The difference between mean size of caught versus kept data is presented in table 1. Certain species (e.g., brown, gopher, and vermillion) are rarely discarded regardless of size and the kept/catch ratio is close to unity.

The lingcod data demonstrate the effect of minimum size regulations on the kept/catch ratio. Rockfish regulations rarely specify minimum size limits because survival of released fish is estimated to be very low due to swim bladder distension. Lingcod, however, lack swim bladders and show little effect from being brought to the surface so that releasing smaller fish is a viable option. In 2003, the minimum size was 60 cm TL and only about twenty five percent of landed fish were kept. In 2004, the minimum size was raised to 76cm and only ten percent were retained while in 2005, the minimum size was reduced to 60 cm and more than thirty percent were kept. Certainly, in this case, the kept data is not a reflection of the fish size in the population.

The relationship of size to depth of capture for 2005, the year when regulations allowed fishing to depths of 40 fm (fig. 3), certainly suggests that changing the allowable depth of the fishery can lead to increases in size. The mean lengths for fish from 2005 were higher for species that inhabit deeper strata. The closure of partyboat fishing in 2003 to waters deeper than 20 fm would not account for size differences observed in 2005. It is therefore not possible to accurately relate historical size differences to today's catch without depth data from each source.

Karpov et al. (1995) discussed decrease in rockfish size using Miller and Gotshall's 1957–1961 data and comparing it to MRFSS data from the 1980's. Mason (1998) described a decremental trend in rockfish size from partyboat catches, 1959–1994, in the Monterey region. She used logbook data to estimate total catch and catch per angler day, and CDFG sampling surveys to estimate species composition and lengths. Neither estimates are without question but her general description of trends seems reasonable. She used data with depth limits for species groups, and her ten most abundant species included bocaccio, chilipepper, greenspotted and greenstriped from the deep group, canary, widow, and yellowtail from the mixed-depth group, and blue and olive from our shallow group. We can compare our length data for 2005 to her last data point (1994) for blue, yellowtail, bocaccio, olive, rosy, and canary and with the exception of the canary, our mean lengths (tab. 1) are equal to or higher than these. It is probable that there is a latitudinal trend in size for rockfishes (but see Laidig et al. 2003) and that growth patterns as well as fishing intensity are not the same between sites. The PG&E Diablo Canyon partyboat sampling data from 1980 to 1986 (Gibbs and Sommerville 1987) include size frequency histograms for seven species. If we compare their 1982 data to ours from 2005, four species, gopher, blue, canary, and copper, have higher mean lengths in 1982 while three species, olive, bocaccio, and yellowtail, were smaller. Blue rockfish data from the early 1960's (Miller et al 1967) for Avila samples show means that fluctuate between 33.6 cm (1960) and 28.0 cm (1964). The years 1959, 1960 and 1963 had higher means than 2005 while the means for 1962 and 1964 were lower. There is considerable annual fluctuation in catch size of rockfishes which must be related to site specific and historical factors such as recruitment success and fishing intensity.

Continual fishing pressure is certain to decrease the abundance of older, larger reproductive individuals in populations of slow-growing fish like rockfish.

An additional effect of "overfishing" might be a change in the dominance of one or more species within the assemblage. Using only the shallow data (20 fm or less) to eliminate the depth problems, we present pie charts for 13 species (which rank in the top ten for any sampled year) for the 14 years of adequate sampling (fig. 7). After 1992, blue, brown, and gopher make up about 75% of the catch.(10 sampled years). Yellowtail and gopher were important in 1988; vermillion, gopher, and rosy in 1989; and black, brown, and gopher in 1990. The dominance of brown rockfish in 2005 results from the fact that the majority of the shallow fishing that year occurred at Pt. Purisima which is an exceptional habitat for browns.

We tested the rank order by year of species in the shallow water assemblage (1979–2004) using Kendall's tau statistic ($p=.05$) and >80 % of the 190 comparisons were significantly correlated (tab. 2). There was a slow, modest transformation of the assemblage over the twenty sampling years. For example, the 1979 rank order was significantly correlated to most years prior to 1992, and not to later years. 1980 was generally correlated until 1996 but not thereafter. Some years (1985, 1990, and 1991) did not significantly correlate to a number of years and these instances are not easily interpreted.

Data on recruitment to the fishery can be gleaned from annual changes in size frequency (Mason 1998). Recently, strong recruitment to the habitat (Dan Pondella, Vantuna Research Group, pers com.) and to the fishery of the SSC has occurred in vermillion rockfish, which has shown an increasing CPUE since 1996 with decreasing mean length. Since 1998, the mean size has stabilized or increased reflecting growth in the recruitment class. The best record of shallow water recruitment to the nearshore habitat in the SSC region is available from PG&E's unpublished diver transect studies of rockfish at Patton Cove near Diablo Canyon (fig. 8). Pulses of rockfish recruitment have occurred since the study began in1976 though pelagic species (bocaccio, olive/yellowtail, and blue) have not recruited strongly since the mid 1980's. The last five years have shown very limited successful recruitment at the study site. In 2004, this site became a portion of the CRANE sampling system (CDFG) for the SCC and several additional sampling sites were added. It will be interesting to compare these more diverse data to those from the Patton Cove site alone.

In 2004–2005, we initiated a study of larval settlement using 'SMURF' settlement modules which have been employed for some years at contiguous sites in the Santa Barbara area (J. Caselle, UCSB, pers. com.) and in the Santa Cruz area (M. Carr, UCSC, pers.com.). As recruitment success depends not only on larval supply but within-site predation (Hobson et al. 2001, Adams and Howard 1996) the use of SMURFs examines the settlement of recently transformed larvae and reduces the effects of subsequent predation. The two-year pattern of settlement (fig.9) shows a similar pattern for cabezon and the CGB complex (copper, gopher, and black & yellow). The BYO complex (black, yellowtail, and olive) failed to recruit in 2005. A similar pattern occurred in the Santa Cruz area (Mark Carr, UCSC, pers. com.), though not in the southern California bight. In this case, the lack of recruits reflects absence of larvae rather than post settlement predation. The lack of published time-series data at this time precludes present interpretation.

Finally, the NMFS/NOAA triennial trawl data are available which give estimates of CPUE, biomass, and fish populations on the SCC. The original survey in 1977 (Gunderson and Sample 1980) sampled less shallow strata (depths from 91 m vs. 55 m, 1995–present). They did not calculate population estimates and their CPUE was measured as kg/km trawled while later publications used kg/ha. This later area can be about 30% smaller than the former estimate (trawl width is estimated to be between 12 m and 14 m). Further, there was a hiatus of eighteen years between 1977and 1995 when no data were collected as far south as the SCC. However, the existing data can still be used as an indicator of change for shelf and slope species in the SCC. The triennial trawl surveys sample depths between 55 m and 500 m (30–275 fm). At the shallower depths they overlap partyboat strata. Depths from 50-150 fm have been closed since 2003 to all bottom fishing (RTCA) including commercial and recreational. The triennial trawl data since 1980 has been published as NOAA Technical Memoranda (1995 [Wilkens et al. 1998]; 1998 [Shaw et al. 2000]; and 2001 [Weinberg et al. 2002]). The 2004 data were collected but are not yet published, however, we have been given access to some of the unpublished SCC data. The SCC is represented by the 'Conception' site which extends from 34° 30' N to 36° 00' N. This is not the same 'Conception' site of the NPAFC which extends southward into the southern California bight (Ware and Thomson 2005) transgressing major faunal lines and environmental conditions. The estimated rockfish total biomass (tons) for the Conception region (1995-2004) is 17,318, 17,092, 22,810, and 23,726 by year. The 2001 estimate in the report (12,898) is obviously an error and we calculated this figure as a total of presented data.. These biomass totals are small compared to the estimates for most other regions. The Conception region, however, is the smallest of the regions and the resultant differences in estimated biomass are the result of these differentials. If we standardize by unit area, the standardized biomass of Conception ranks first or second by year among the five U. S. sites.

The CPUE estimates for selected species in the Conception region (tab. 3A) includes limited data on 23 species (1977, 1995, 1998, and 2001 [2004 not as yet available]). Estimated total biomass (tab. 3B) has increased since 1977, even if only species reported in 1977 are included. Similarly, the estimated species abundance (tab 3C) has increased though not in a linear fashion. Extremely large catches of one species have large effects on these data: shortbelly in 1998, chilipepper in 2001, and splitnose in 2004. The coefficients of variation are large for these data though the trends or lack of trends shown may be valid. There has been no significant change in rank order of important species based on yearly CPUE or estimated abundance between 1995 and 2004 (Kendall's tau, p=.05). The 1977 data was not significantly correlated to the other years, but the species list was probably incomplete. When tested for rank concordance using the six top ranked species from 1977, the concordance (Kendall's rank concordance test) is significant (p=.01). These data suggest that the rockfish assemblage in the triennial trawl depth range has not shown negative trends since the late 1970's. We have not as yet been granted permission to sample these depths experimentally with partyboats although the data could potentially corroborate such trends.

In conclusion, it does not appear that the major decline in rockfish abundance or biomass which has been observed for some species in the Northeast Pacific since the late 1970's can be documented for fish from the south central coast of California, with the exception of bocaccio. Existing trends may be masked by sampling error as well as by technological improvements in the sportfishing boats ability to locate and capture fish. Nevertheless, this site is the southernmost area of the cool temperate zone (Oregonian) and is isolated from large human population centers (Monterey and San Francisco to the north, and Santa Barbara, Los Angeles, and San Diego to the south). This combination of nutrient-rich upwelling, cool temperatures, and lower levels of exploitation, coupled with vigorous fishery regulations (CDFG, PFMC), is likely responsible for the persistence of this rockfish assemblage.

LITERATURE CITED

Adams, P. B. and D. F. Howard. 1996. Natural mortality of blue rockfish, *Sebastes mystinus*, during their first year in nearshore benthic habitats. Fish. Bull. 94:156–162.

Ammann, A. J. 2004. SMURFs: standard monitoring units for the recruitment of temperate reef fishes. J. Exp. Mar. Biol. Ecol. 299(2):135–154.

Beamish, R. J. (ed). 1995. Climate Change and Northern Fish Populations. Canadian Special Publication of Fisheries and Aquatic Sciences 121. 739 pp.

Bennett, W. A., K. Roinestad, L. Rogers-Bennett, L. Kaufman, D. Wilson-Vandenberg, and B. Heneman. 2004. Inverse regional responses to climate change and fishing intensity by the rockfish (*Sebastes* spp) fishery in California. Can. J. Fish. Aquat. Sci.. 61:2499–2510.

Berkeley, S. A., M. A. Hixon, R. J. Larson, and M. S. Love. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries 29(8):23–32.

Boehlert, G. W., D. M. Gadomski, and B. C. Mundy. 1985. Vertical distribution of ichthyoplankton off the Oregon coast in spring and summer months. Fish. Bull. 83:611–621.

Brooks, A. J., R. S. Schmitt, and S. J. Holbrook. 2002. Declines in regional fish populations: have species responded similarly to environmental change? Mar. Freshwater Res. 53:189–198.

Chavez, F. P., J. Ryan, S. E. Lluch-Cota, and M. Niquen. 2003. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299: 217–221.

Cushing, D. L. 1975. Marine Ecology and Fisheries. Cambridge University Press. 278 pp.

Francis, R. C. and S. R. Hare. 1994. Decadal scale regime shifts in the large marine ecosystem of the northeastern Pacific: a case for historical science. Fish. Oceanogr. 3:279–291.

Gibbs, S. E. and D. C. Sommerville. 1987. Diablo Canyon sportfish monitoring program, progress report for 1986. *In* Environmental Investigations at Diablo Canyon, 1986. Vol. 1, Marine Ecological Studies. D. W. Behrens and C. O. White, eds. San Ramon, CA.

Gunderson, D. R. and T M. Sample. 1980. Distribution and abundance of rockfish off Washington, Oregon, and California during 1977. Marine Fisheries Review 42:2–16.

Gunderson, D. R. 1998. A call for a change in managing our rockfish resources. *In* Marine Harvest Refugia for West Coast Rockfish: A workshop. M. Yoklavich, ed. NOAA Tech. Mem. NMFS-SWFSC-255, p. 156.

Harvey, C. H. 2005. Effects of El Niño events on energy demand and egg production of rockfish (Scorpaenidae: *Sebastes*): a bioenergetic approach. Fish. Bull. 103:71–83.

Heimann, R. F. G. and D. J. Miller. 1960. The Morro Bay otter trawl and partyboat fisheries, August 1957 to September 1958. Calif. Fish and Game 46:35–58.

Hobson, E. S., J. R. Chess, and D. F. Howard. 2001. Interannual variation in predation on first-year *Sebastes* spp. by three northern California predators. Fish. Bull. 99:292–302.

Holbrook, S. J, R. J. Schmitt, and J. S. Stephens, Jr. 1997. Changes in an assemblage of temperate reef fishes associated with a climate shift. Ecological Applications 7(4):1299–1310.

Jackson, J. B.C., M. X. Kirby, W. H. Berger, K. A. Bjorndal, L. W. Botsford, B. J Bourque, R. H Bradbury, R. Cooke, J. Erlandson,. J. A. Estes, T. R. Hughs, S. Kidwell, C. B. Lange, H. S. Lenihan, J. M. Pandolfi, C. H. Peterson, R. S. Steneck, M. J. Tegner, and R. R. Warner 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293:629–637.

Karpov, K. A. ,D. P. Albin, and W. H. Van Buskirk 1995. The marine recreational fishery in northern and central California: a historical comparison (1958–86), status of stocks (1980–86), and effects of changes in the California current. California Department of Fish and Game, Fish Bull. 176. 192 pp.

Laidig, T. E., D. E. Pearson, and L. L. Sinclair. 2003. Age and growth of blue rockfish (*Sebastes mystinus*) from Northern and Central California. Fish. Bull. 101:800–808.

Leaman, B. M. 1991. Reproductive styles and life history variables relative to exploitation and management of *Sebastes* stocks. Envir. Biol. Fishes 30: 253–271.

Lenarz, W. H. 1987. A history of California rockfish fisheries. *In* Proceedings of the International Rockfish Symposium, p. 35–41. Alaska Sea Grant Rep. 87-2. Fairbanks, AK.

Love, M. S., R. N. Lea, R. D. MacAllister, and D. A. VenTresca. 1991. Biological aspects of nearshore rockfishes of the genus *Sebastes* from central California. Cal. Dept. Fish Game, Fish Bull. 177:1–109.

--------------, J. E. Caselle, and K. Herbinson. 1998. Declines in nearshore rockfish recruitment and populations in the southern California bight as measured by impingement rates in coastal electric power generating stations. Fish. Bull. 96:492–501.

---------------, M. Yoklavich, and L. Thorstienson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley. 405 pp.

___________, S. Ralston, D. E. Pearson. and E. Williams 1999. Status of the bocaccio off California and outlook for the next millennium. Appendix to Status of the Pacific coast groundfish fishery through 1999 and recommended acceptable biological catches for 2000. Pacific Fishery Management Council, Portland, Oregon.

MacCall, A. D. 1990. Dynamic geography of marine fish populations. Washington Sea Grant / University of Washington Press, Seattle, Washington. 153 pp.

----------------1998. Declining rockfish lengths in the Monterey Bay, California, recreational fishery, 1959–94. Fish. Rev. 60(3):15–28.

Mason, J. E. 1995. Species trends in sport fisheries, Monterey Bay, California, 1959-1986. Fisheries Review 57(1):1–16.

Miller, D. J. and J. J. Geibel. 1973. Summary of blue rockfish and lingcod life histories; a reef ecology study; and giant kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California. Cal. Fish and Game, Fish Bull 158. 130 pp.

Miller, D. J. and D. W. Gotshall. 1965. Ocean sportfish catch and effort from Oregon to Point Arguello, California, July 1, 1957–June 30, 1961. Cal. Fish and Game, Fish. Bull. 130. 135 pp.

Miller, D. J., M. W. Odemar, and D.W. Gotshall. 1967. Life history and catch analysis of the blue rockfish (*Sebastodes mystinus*) off central California, 1961–1965. Cal. Fish and Game. Mar. Res. Operations Ref 67-14. 130 pp.

Myers, R. A. and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423:280–283.

Ralston, S. 1998. The status of federally managed rockfish on the west coast. *In* Marine Harvest Refugia for West Coast Rockfish: A workshop. M. Yoklavich, ed. NOAA Tech. Mem. NMFS-SWFSC-255, 6–16.

-------------, J. N. Lanelli, R. A. Miller, D. E. Pearson, D. Thomas, and M. E. Wilkins. 1996. Status of the bocaccio in the Conception/Monterey/Eureka INPFC areas in 1996 and recommendations for management in 1997. Appendix to Status of the Pacific coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997. Pacific Fishery Management Council, Portland, Oregon.

Reilly, P. N., D. Wilson-Vandenberg, C. E. Wilson, and K. Mayer. 1998. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1995. Marine Region, Admin. Rep. 98-1. 110 pp.

Ross, J. R. M. and R. J. Larson. 2003. Influence of water column stratification on the depth distributions of pelagic juvenile rockfishes off central California. CalCOFI Rep. 44:65–75.

Shaw, F. R., M. E. Wilkins, K. L. Weinberg, M. Zimmerman and P. R. Lauth. 2000. The 1998 Pacific west coast bottom trawl survey of groundfish resources: estimates of distribution, abundance, and length and age composition. U. S. Dept. Commerce, NOAA Tech. Mem. NMF-A FSC-114. 137 pp.

Tolimieri, N and P. S. Levin. 2005. The roles of fishing and climate in the population dynamics of bocaccio rockfish. Ecol. Appl. 15(2):458–468.

Ventresca, D. A., R. H. Parrish, J. L. Houk, M. Gingras, S. D. Short, and N. C. Crane. 1995. El Nino effects on the somatic and reproductive condition of blue rockfish, *Sebastes mystinus*. CalCOFI Rep. 36:167–173.

Ware, D. M. and R. E. Thomson 2005. Bottom-up ecosystem trophic dynamics determine fish production in the Northeast Pacific. Science 308:1280–1284.

Weinberg, K. L., M. E. Wilkins, F. R. Shaw, and M. Zimmermann. 2002. The 2001 Pacific west coast bottom trawl survey of groundfish resources: estimates of distribution, abundance, and length and age composition. NOAA Tech. Mem. NMFS-AFSC-128. 141 pp.

Wilkins, M. E., M. Zimmermann, and K. L. Weinberg. 1998. The 1995 Pacific west coast bottom trawl survey of groundfish resources: estimates of distribution, abundance, and length and age composition. NOAA Tech. Mem. NMFS-AFSC-89. 138 pp.

Wilson, C. E., L. A. Halko, D. Wilson-Vandenberg, and P. N. Reilly. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, 1992. Marine Resources Div., Admin. Rep. 96-2. 103 pp.

Wilson-Vandenberg, D., P. N. Reilly, and L. Halko. 1995. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1993. Marine Resources Div, Admin. Rep. 95-2. 122 pp.

----------------------, P. N. Reilly, and C. E. Wilson. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1994. Mar. Res. Div. Admin. Rep. 96-6. 96 pp.

ACKNOWLEDGEMENTS

We thank the following for supporting this study: The Marine Interest Group of San Luis Obispo, Patriot Sport Fishing (Steve Moore), Virg's Sport Fishing (Darby Neil), Central Coast Fisheries and Conservation Coalition, Steelhead Recovery Coalition, Port San Luis Harbor Commission, Port San Luis Commercial Fisheries Organization, and CCMI-Resources Legacy Fund Foundation.

Figure 1. Map of the south Central Coast Region. of California.

Figure 2. Partyboat CPUE, 1980-2005, all species of interest, South Central Coast.

Figure 3. Rockfish that change in abundance and/or mean size with increasing depth to 40 fathoms. Solid lines show CPUE, dashed lines show mean size. A.. blue B. bocaccio C. brown D. canary E. copper F. gopher G. olive H. rosy I. starry J. vermillion K. yellowtail

Figure 4. Changes in CPUE by year (Partyboat data, SCC) Fish that are abundant in waters shallower or equal to 20f. Diamonds=fish caught in 20f or less, squares= fish caught at all depths.. A. black B. blue C. brown D china E gopher F. olive G. lingcod.

Figure 5. Changes in CPUE by year (Partyboat data, SCC). Fish that commonly exceed 30f but are common in shallower water (legend as in fig. 4) A. bocaccio B. canary C. copper D. rosy E. starry F. vermillion G. yellowtail

Figure 6. Changes in mean length by year for nine species caught by partyboats, SCC. Diamonds= kept fish, triangles=all fish caught, dashes= line of 50% maturity, A. black B. blue C. brown D. gopher E. olive F. rosy G. vermillion H. yellowtail I. Lingcod

Figure 7. Pie charts, 1988-2005, relative abundance of the top 13 species, Partyboat data, SCC.

Figure 8. Recruitment of YOY/juvenile rockfish at Patton Cove, 1976-2003. Water column and benthic fishes.combined.

Figure 9.. Larval settlement to SMURF's on the SCC. 2004-2005. Solid line CGB (copper, gopher, black&yellow) complex, dashed line, BYO (black, yellowtail and olive) complex, dotted line, cabezon.

ELSEVIER

Environmental Science & Policy 3 (2000) S341–S348

Environmental Science & Policy

www.elsevier.com/locate/envsci

Impacts of power-plant cooling systems on estuarine fish populations: the Hudson River after 25 years

Lawrence W. Barnthouse*

LWB Environmental Services, Inc., 105 Wesley Lane, Oak Ridge, TN 37830, USA

Abstract

In the early 1970s, impacts of power-plant cooling systems on fish populations were a major source of controversy. The most thoroughly studied and controversial power plants were the Indian Point, Bowline, and Roseton generating stations on the Hudson River. The assessments performed for these three plants were unique in employing river-wide sampling data and mathematical models designed to predict the effects of cooling-water withdrawals on the short- and long-term abundance of striped bass and other important fish populations. A Settlement Agreement in 1981 led to the establishment of a long-term monitoring program that continues to generate valuable information concerning the impacts of power-plant cooling systems on estuarine ecosystems. This paper evaluates the results generated by the past quarter century of Hudson River, with the objective of evaluating the utility of the information for future 316(b) assessments. Specific recommendations are made concerning: (1) methods for quantitative assessment of cooling-system impacts at new vs operating facilities; (2) research that would improve the efficiency and accuracy of assessments; and (3) the need to integrate cooling system impact studies into a general framework for management of aquatic ecosystems.

Keywords: 316(b); Entrainment; Impingement; Impact assessment; Hudson River

1. Introduction

What is an "adverse environmental impact?" What is "best available technology?" These issues were among the earliest to be debated at the beginning of the modern environmental movement in the late 1960s. It may seem curious to many that the definition of an adverse environmental impact under Section 316(b) of the Clean Water Act is being revisited more than a quarter century after the enactment of the legislation. However, the scientific issue underlying the regulations — the immediate and long-term ecological consequences of mortality imposed on natural populations by man's activities — is still a fundamental issue in applied population biology.

Even before the enactment of the National Environmental Policy Act in 1969, lawyers and scientists were already debating the impact of water withdrawals on striped bass and other fish populations in the Hudson River. In 1964, the first lawsuit opposing Consolidated Edison (Con Ed)'s proposed Cornwall Pumped Storage Facility was filed. A few years later, similar controversy and litigation accompanied Con Ed's operating license applications for Indian Point Units No. 2 and 3. The assessment studies performed between the initial Cornwall lawsuits and the signing of a comprehensive Settlement Agreement in 1981 provide valuable lessons for those who are still grappling with the question of how to define an adverse environmental impact under Section 316(b).

2. The Hudson River studies, pre-1980

The scientific and methodological issues framed during the early years of the Hudson River studies are

* Tel.: +1-865-483-0100; fax: +1-865-483-0115.
E-mail address: lwb.env@worldnet.att.net (L.W. Barnthouse).

1462-9011/00/$ - see front matter
PII: S1462-9011(00)00037-X

the same ones that concern assessment scientists and regulators today. From the very beginning, there were two key issues: the fraction of the young fish spawned each year that would be killed by entrainment or impingement, and the long-term effects of that excess mortality on the productivity and viability of the vulnerable populations, especially striped bass.

At the time the first quantitative assessments were performed the approximate location and season of striped bass spawning was known, but the detailed spatial and temporal distributions of the early life stages of striped bass within the Hudson had never been studied in detail. Such information was essential for determining the fraction of the eggs and larvae spawned that might be entrained or impinged. Whether or not any of the entrained or impinged organisms might survive the experience was a matter of pure conjecture.

Concrete information concerning the potential long-term impacts of mortality imposed on young fish was similarly lacking. Long-term consequences of mortality related to water withdrawals would be determined in large part by the extent to which compensatory, or density-dependent processes could offset the imposed mortality. Data concerning the types and importance of compensatory processes that might operate within the Hudson River striped bass population did not exist.

In the virtual absence of data, the above issues were addressed through simulation modeling exercises documented by Barnthouse et al. (1984). These models were featured prominently in hearings held in 1972–73 by the Atomic Safety and Licensing Board and in 1974 by the Atomic Safety and Licensing Appeals Board pursuant to Con Ed's application for an operating license for Indian Point Unit No. 2. A model of estuarine circulation developed by the AEC staff suggested that up to 50% of each striped bass year class could be entrained at Indian Point. An alternative model developed by consultants to Con Ed suggested that, considering the effects of both estuarine circulation and density-dependence, the impact would be <5%. Not surprisingly, the AEC was unable to make a definitive finding and sent both sides back to collect more data and refine their assessments.

Comprehensive data collection began in 1973. This was no easy task. The study area was defined to be the entire 243 km tidal reach of the Hudson, from the southern tip of Manhattan Island to the federal lock and dam at Troy, New York. The primary biological monitoring studies consisted of weekly riverwide surveys of striped bass ichthyoplankton and juveniles conducted using a stratified random sampling design and a variety of gears (Boreman and Klauda, 1988). An adult stock characterization program was also initiated, with the intent of defining the age, size, and sex composition of the striped bass spawning stock in the Hudson (Hoff et al., 1988) and estimating the contribution of the Hudson to the Atlantic coastal fishery for striped bass (Berggren and Lieberman, 1978; Van Winkle et al., 1988). Once Indian Point Unit No. 2 came on line in 1974, studies of the survival of entrained and impinged fish were initiated (Muessig et al., 1988a,b). Similar studies were soon initiated at the new oil-fired generation stations located at Bowline Point and Roseton and at the older Lovett and Danskammer Point stations.

When jurisdiction over cooling-system impacts passed from the Atomic Energy Commission (AEC) and its successor agencies to the Environmental Protection Agency (EPA), studies of white perch (Klauda et al., 1988), Atlantic tomcod (McLaren et al., 1988), and other fish species were initiated.

Assessments prepared to support the National Pollutant Discharge Elimination (NPDES)-permitting processes for the three stations relied extensively on data collected between 1974 and 1976 and emphasized empirical data rather than theoretical models (Barnthouse et al., 1984; Christensen and Englert, 1988). Although the emerging data forced the assessments produced by agency and utility scientists to converge (Englert and Boreman, 1988), they did not end the controversy. The assessments indicated that the combined operation of all three plants could impose an impact of roughly 10–20% on each striped bass year class. This magnitude of impact is small by fisheries standards, where an annual take of 30–50% or more is common, but large enough that regulatory agencies were unwilling to find it "negligible" or "insignificant." The long-term implications of the mortality could not be quantified, because neither side could develop defensible estimates of the degree to which compensatory processes might offset the mortality caused by power plants (Fletcher and Deriso, 1988).

In view of that fact that yet more data were unlikely to resolve the remaining scientific issues in a timely manner, EPA, the State of New York, and utilities negotiated a settlement. The utilities agreed to implement a variety of measures intended to reduce entrainment and impingement. The also agreed to fund a long-term monitoring program for the estuary, intended to determine the effectiveness of the mitigating measures mandated by the settlement, and to establish a research foundation to sponsor scientific, economic, and public policy research related to the Hudson.

The Hudson River Foundation was established with an endowment designed to ensure its perpetuity, but the monitoring requirements were initially mandated only for the ten-year duration of the Settlement Agreement. Since the expiration of the settlement in 1991, the utilities and the New York State Department of

Environmental Conservation (NYSDEC) have continued to negotiate the terms of a renewed license. While negotiations have continued, river-wide monitoring has also continued.

Coincidentally, study of the coastwide population of striped bass accelerated during the 1980s, providing today's assessment scientists with a wealth of empirical information beyond the wildest fantasies of the scientists who labored for the contesting parties 20 years ago.

3. The Hudson River studies, post-1980

The continuing utility-sponsored sampling components since 1980 have included both survey programs and mark-recapture programs. The mark-recapture program, initiated as a means of evaluating the effectiveness of the striped bass hatchery, also has provided valuable information concerning the abundance and composition of the component of the population that overwinters in upper New York Harbor. In recent years, the number of fish of length ≥200 mm has varied between approximately 300,000 and 1,000,000, with no discernible trend (Normandeau Associates, 1995). Approximately half of the 379,000 fish ≥200 mm in length estimated to be present in the winter of 1993–94 consisted of 1-year-olds, and about 2% consisted of fish ≥3-years-old.

Three river-wide survey programs continue under the sponsorship of the Hudson River utility companies (EA Engineering, Science, and Technology, 1995). The Longitudinal River Ichthyoplankton Survey and Fall Shoals Survey provide estimates of densities and standing crops of eggs, larvae, and juveniles of various fish species. Although designed primarily to obtain data concerning the seven species included in the Settlement Agreement (striped bass, white perch, Atlantic tomcod, bay anchovy, American shad, alewife, and blueback herring), these surveys also provide information concerning the distribution and abundance of other species that utilize the same habitats. Combined with in-plant sampling programs conducted at the Hudson River power plants, these data are used to estimate annual fractional losses of striped bass and other fish species. The beach seine survey is intended to provide annual relative abundance indices for these same species. Gear and deployment methods for the beach seine survey are similar to those used by the NYSDEC and by fisheries agencies in other states to estimate relative abundance indices for striped bass. The beach seine time series for the Hudson now includes 25 years of observations.

Analyses of these data sets have provided important insights into the population biology of striped bass. Pace et al. (1993) analyzed relationships between the abundance indices for eggs, yolk-sac larvae, post yolk-sac larvae, and juveniles over the years 1974–90. They found that the abundance of striped bass eggs in the Hudson was only weakly correlated with the abundance of yolk-sac larvae, implying either high sampling error or a high degree of unexplained environmental variability affecting the survival of eggs. Abundances of yolk-sac larvae and post yolk-sac larvae were much more strongly correlated, implying relatively constant survival over these two life stages. Abundances of post yolk-sac larvae were, however, essentially uncorrelated with the beach seine indices. Although the lack of correlation could have been due to measurement error, beach seine indices are accepted by fisheries scientists as valid measures of year-class strength in striped bass. Both the Maryland striped bass index and the two Hudson River beach seine indices have been accepted by the Atlantic States Marine Fisheries Commission (ASMFC) as valid indicators of year-class strength in striped bass (SARC, 1998). On this basis it might be concluded that year-class strength of striped bass in the Hudson is determined by a combination of density-independent and density-dependent process occurring prior to transformation to the juvenile stage.

The possibility that a substantial fraction of this mortality may be density-dependent is suggested by the stability of the beach seine indices over time. Values of the utility and NYSDEC surveys, as reported by the inter-agency Stock Assessment Review

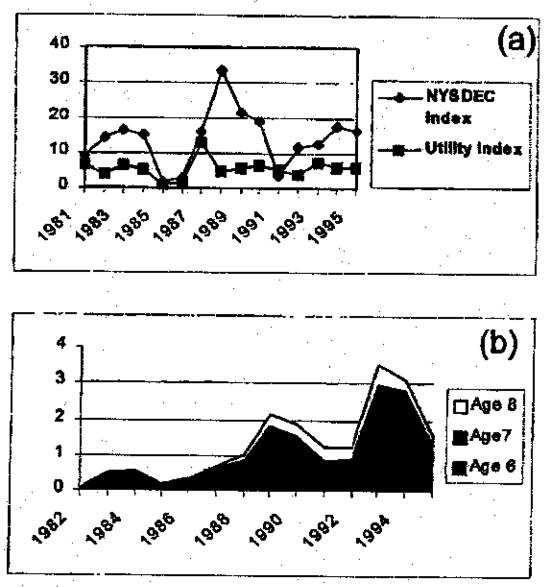


Fig. 1. Indices of striped bass abundance in the Hudson River. (a) Young-of-the-year indices from beach seine surveys conducted by the Hudson River utilities and the NYSDEC. (b) CPUE for age 6–8 striped bass caught as bycatch in the gillnet fishery for American shad. Data from SARC (1998).

Committee (SARC, 1998) are plotted in Fig. 1(a). Although variability is high, there is little discernible trend in either index. This lack of trend contrasts markedly with the highly significant increase in size of the striped bass spawning stock since 1985, when stringent coast-wide regulations on harvesting striped bass were enacted. The SARC uses data on the abundance of striped bass in caught as bycatch in the commercial gillnet fishery for American shad in the Hudson as an index of the size of the spawning population in the Hudson. As shown in Fig. 1(b), the catch-per-unit effort (CPUE) of age 6–8 striped bass has increased by more than a factor of 10 since the early 1980s. These indices provide fairly strong circumstantial evidence that the size of the striped bass spawning stock in the Hudson has increased, and that this increase has not been accompanied by an increase in subsequent recruitment. Although not conclusive, this result certainly suggests a significant degree of density-dependence.

Throughout the post-settlement period, the impacts of entrainment and impingement have held steady. Although actual values of impacts for these years are still being updated and are not currently available, nothing about either the distribution of striped bass early life stages or the operation of the facilities has changed since the settlement. Hence, one would expect that annual cropping by Indian Point and the other power plants still falls in the 10–20% range that prevailed in 1980. The relative stability of the population in spite of this added mortality may seem surprising to some, however, it must be remembered that the annual mortality imposed by Indian Point and the other Hudson River power plants, which affects only on young-of-the-year striped bass, is substantially lower than the mortality routinely imposed by fisheries over most of the lifetimes of the adult fish. The current ASMFC target fishing rate for striped bass is 0.31 (SARC, 1998), corresponding to an annual take of 25% of all striped bass older than about 5 years. Even this level of fishing is believed to be significantly lower than the level that could ultimately be sustained by the fishery. Power-plant-related mortality imposed on striped bass could only become an issue if fishing intensity increases significantly above the level that is currently projected.

4. Implications for future Section 316(b) determinations

With the above understanding as background, let us look at some of the specific questions posed in the Call for Papers.

> Noting your experience relative to CWIS, what were the range of impacts observed on fish populations and other aquatic resources? How significant is the issue of site-specificity in evaluating CWIS impacts?

Numerical estimates of annual reductions in year-class abundance for the principal Hudson River fish populations that were available at the time of the Settlement Agreement ranged from <5% to >35% (Boreman and Goodyear, 1988; Barnthouse and Van Winkle, 1988). However estimates for some species, especially bay anchovy, were known to be biased high because of failure of the riverwide sampling program to include the entire population. Of those species for which the most credible data were available, the impacts on striped bass (~20% per year) were the highest. These values reflect the operation of all generating units on the Hudson; the Indian Point plant has historically accounted for about half of the total impact. Site-specific considerations have major influences on the observed values. The relatively high impact of Indian Point is in part due to the size of the facility, which accounts for about 40% of the total cooling water withdrawals on the Hudson (Hutchison, 1988). The impact of Indian Point is magnified, however, because of its position within the highly productive transition zone between fresh and salt water (Cooper et al., 1988).

It must be emphasized that the impact predictions discussed above refer to short-term reductions in abundance. There is no evidence that any of the species that have been investigated have suffered long-term declines. To the contrary, many species may have benefited from continued improvements in water quality and reductions in fishing pressure.

> What types of data may be used (i.e., resource or fishery management and facility-related) for assessing the potential environmental impacts? How can the potential for environmental impacts instream be evaluated independent of facility impingement and entrainment data?

The following categories of data would appear to be the most useful for assessing potential impacts

4.1. *Descriptions of the life history and spatial distribution of potentially vulnerable species*

Especially important are the boundaries of the local populations and the spatiotemporal distributions of vulnerable life stages. Acquisition of these data was a crucial step in bounding the range of credible predictions obtained from assessment models applied to Hudson River fish populations.

4.2. Descriptions of the cooling-water withdrawal rates of the facility, and the volume or flow rate of the source water body supplying the cooling water

In some cases, the spatial boundaries of the region of interest are fairly obvious (e.g., lakes or reservoirs). In estuarine or open coastal systems, however, there may be no obvious physical boundaries. Where feasible, the region of interest should be defined by the distributions of the populations of interest, not by jurisdictional (e.g., state lines) or other artificial limits.

4.3. Data on the distribution and dynamics of exploited fish populations

If exploited species are found in the vicinity of a facility, they are virtually certain to receive considerable regulatory attention. Information on the abundance, natural mortality, spawning stock biomass or reproductive potential, and fishing rates for such species provide a valuable context for interpreting potential cooling-system impacts. For most managed coastal stocks, the quantity and quality of fisheries data have improved greatly since the 1970s.

> What are the important indicator/representative species or trophic levels for impact assessment? What are reasonable decision making endpoints, and metrics to evaluate the endpoints? To what extent do these endpoints or metrics depend on site- or species-specific considerations?

There are no specific species or trophic levels that are universally suited for impact assessments related to Section 316(b). Experience with Hudson River power plants suggests, however, that certain life history traits increase the vulnerability of species to cooling-system impacts. The Hudson River fish species that are most vulnerable to entrainment and impingement are migratory species that are seasonally abundant in the pelagic zone of the estuary. Most of these species spawn in open water and have pelagic early life stages. Gladden et al. (1988) found that year-round resident species, which (except for white perch) are relatively invulnerable to entrainment and impingement, are found primarily in the shorezone and in benthic habitats. These species tend to feed on benthic and epibenthic organisms, and none except for white perch has a pelagic life stage.

Of the various measures of impact that have been applied to fish populations in the Hudson, the "conditional mortality rate" (Barnthouse et al., 1984; Vaughan, 1988) has been the most important. This measure of impact is derived directly from Ricker's Type II fishery model (Ricker, 1975). Provided that reasonably accurate estimates of either: (1) the spatio-temporal distribution of vulnerable life stages over the range occupied by the affected population (Boreman and Goodyear, 1988); or (2) the total size of the vulnerable population (Barnthouse and Van Winkle, 1988) are available, the conditional mortality rate is a measure of the reduction in year-class abundance attributable to entrainment and impingement. Estimates of conditional mortality rates provided the principle technical basis for selection of alternative mitigating measures included in the Settlement Agreement (Barnthouse et al., 1988).

The conditional mortality rate does not account for the operation of compensatory mechanisms, and therefore is a conservative estimator of population-level impacts. A more important limitation of the methodology is its requirement for accurate estimates of distribution or abundance. Estimates of conditional mortality rates for species such as bay anchovy, for which an unknown fraction of the spawning population resides outside the Hudson, clearly cannot be interpreted as reductions in year-class abundance. At best, they are measures of localized reductions in abundance and potential losses of biomass available to higher trophic levels.

Applications of stock-recruitment models to Hudson River fish populations have been documented elsewhere (Barnthouse et al., 1984; Lawler, 1988; Savidge et al., 1988; Christensen and Goodyear, 1988; Fletcher and Deriso, 1988). These applications were highly controversial, and in retrospect it is clear that the stock-recruitment data available at that time were insufficient to support credible use of this approach. At least for striped bass, sufficient data are now available to support stock-recruitment models, and a model of the coast-wide striped bass population has been developed by the ASMFC (SARC, 1998).

Perhaps the most generally applicable assessment methodology is comparison of entrainment and impingement losses to losses related to fishery exploitation or even to predation. For comparative purposes, these losses must be adjusted to account for natural mortality. This adjustment is required because the relative importance of entraining 1,000,000 eggs vs impinging 100,000 juveniles depends on the probability of survival of each egg to the juvenile stage. The significance of the entrainment and impingement losses, as compared to losses of subadult fish due to hook-and-release mortality by recreational fishermen or bycatch in the shrimp fishery, is similarly dependent on the expected rate of survival of entrained and impinged fish to the age when they become vulnerable to exploitation-related mortality.

> What concerns or issues come to mind when examining impacts associated with intake velocity or flow, and any potential de minimis values (or

thresholds) associated with the impacts (i.e., are there thresholds of velocity or flow below which aquatic resource effects would likely be predicted to be minimal?).

Available evidence suggests that it may not be possible to identify thresholds of velocity or flow below which effects of a cooling-water withdrawal can be assumed to be invariably negligible. The greatest impingement of both white perch and striped bass at Hudson River power plants occurs during winter, when semi-dormant fish are resident in the vicinity of the Indian Point and Bowline Point plants. During this season the ability of the fish to avoid an intake current is minimal. The definition of a de minimis impact necessarily requires consideration of the water body and the species in question, not simply the technology.

What is the range of appropriate assessment methods/models for quantifying and characterizing environmental impacts? Specifically, what works well, and under what circumstances?

As noted above, comparisons of cooling-system impacts to other forms of anthropogenic mortality provide the most generally applicable assessment approach. The utility of this approach is limited, however, to facilities for which entrainment and impingement estimates can be made and to species for which there is a fishery. At least in theory, estimates of entrainment or impingement losses of unfished forage species could be compared to prey requirements of predator populations, but this approach would require more information concerning the trophic structure of the affected fish community than is available for most ecosystems.

What species have compensatory mechanisms that may offset Cooling Water Intake Structure (CWIS) impacts? What are the nature of these compensatory mechanisms?

Simply on theoretical grounds, all species must be assumed to be subject to compensatory processes that can offset CWIS impacts. Among the general types of processes that have been documented are density-dependent starvation of first-feeding larvae, density-dependent growth and mortality of larvae and juveniles, size-dependent mortality, cannibalism, and size or density-dependent reductions in reproductive success. Recently, the advent of so-called "individual-based" population models has lead to new approaches to understanding and quantifying many of these specific processes (DeAngelis et al., 1991; Rose and Cowan, 1993; Cowan and Rose, 1993). The question of how much mortality can be offset in this way is still difficult to answer.

What are the major uncertainties in assessing environmental impacts and how can they be effectively dealt with?

With regard to the Hudson, the principal remaining uncertainties are related to future management actions and to the possible occurrences of rare events that cannot be predicted from the historical record. Given the stability of the affected populations over a quarter-century of continuous plant operation, uncertainties concerning CWIS-related impacts would appear to be relatively inconsequential.

The most important uncertainties related to impact assessment in general concern new facilities for which no operational history is available. Lack of knowledge about the spatial distribution, abundance, and life-history characteristics of the potentially vulnerable species is especially critical. Credible quantitative assessments of the impacts of power plants on Hudson River fish populations were not possible until this information was acquired. However, unlike impacts of toxic chemicals, which can involve sublethal effects that are not observable until irreparable harm is done, potentially significant rates of entrainment and impingement can be identified from relatively inexpensive in-plant monitoring data. The key challenge for assessors is to identify facilities with potentially significant impacts as early as possible in the design and siting process, so that costly retrofitting of mitigation technology can be avoided.

What specific recommendations, if any, do you have regarding future R&D needs?

The Electric Power Research Institute (EPRI) COMPMECH Program has greatly advanced our understanding concerning both the types of compensatory mechanisms that operate in fish populations and the influence of life history on the response of populations to power-plant-related mortality. A continuing need exists to expand this knowledge base with new empirical data on the life history and distribution of other species that are potentially vulnerable to entrainment and impingement. Relatively little is known, for example, about interactions between power plants and early life stages of Atlantic sturgeon (proposed for listing under the Endangered Species Act) and shortnose sturgeon (already listed). These species are rarely collected during routine monitoring, and it may well be that their life histories render them relatively invulnerable to CWIS impacts. However, the information needed to validate this conjecture (e.g., entrainment and impingement monitoring records at power plants cited on estuaries supporting sturgeon populations) has never been synthesized. It may well be that high vulnerability to power plants is limited primarily to species with pelagic early life stages. Monitoring programs and 316(b) demonstrations could be more efficiently designed if life-history-based criteria for identifying especially vulnerable or invulnerable species could be identified.

Beyond life history studies, another pressing need is for a critical evaluation and synthesis of the three decades of information that already exist concerning the impacts of cooling water withdrawals on aquatic ecosystems. The Hudson River studies have been especially well documented, but large quantities of data are undoubtedly available for other facilities sited on other water bodies. This information could be used to develop criteria for identifying facility/source water body combinations associated with high or low potential impact. Such criteria would greatly facilitate the initial permitting process for new cooling-water intake structures. Monitoring and assessment requirements could be determined by the "potential impact profile" of a new or proposed withdrawal source. The profile would include information on the ecological characteristics of the potentially affected ecosystem, not just the design of the facility.

The final need, and perhaps the most important, is to develop continued monitoring and characterization of the major systems upon which power plants and other industrial facilities are likely to be sited in the future. The value of a long-term data set is nowhere more clearly demonstrated than in the case of the Hudson River. Twenty-five years of continuous observation have established a baseline against which future facility sitings or unanticipated environmental changes can be readily addressed. Without such a baseline, one or two years of ecological monitoring data are often virtually impossible to interpret.

5. Concluding remarks

Throughout this paper, I have avoided proposing either a specific definition of "adverse environmental impact" or a specific criterion for determining when such an impact has occurred. I do not believe that the ecological significance of cooling water withdrawals can be productively addressed in the abstract, isolated from other human influences. The relative stability of the Hudson River striped bass population in spite of the presence of several large power plants with once-through cooling systems contrasts markedly with the responses of other striped bass populations to large-scale human disturbances. When fishing for striped bass in Chesapeake Bay was virtually uncontrolled during the 1970s, the Chesapeake Bay stock was severely depleted. When fishing was restricted, the population rebounded. Striped bass are now spawning in regions of the Delaware River from which they were absent 30 years ago because of poor water quality (Weisberg and Burton, 1993), and native striped bass stocks in many southeastern and gulf coast rivers have been extirpated by dams that block upstream migration (Wooley and Crateau, 1983). Impacts of any single cooling water intake, no matter how large, appear small by comparison. However, the above observation does not imply that such impacts are invariably negligible. There can be no doubt that the Hudson River striped bass population has benefited from the fishing bans and consumption advisories imposed to control human exposure to PCBs. Had exploitation of Hudson River striped bass in the late 1970s equaled or exceeded the exploitation of the Chesapeake Bay population, the incremental impact due to cooling-water withdrawals might have had serious consequences.

In recent years, the EPA Office of Water has sponsored several research initiatives intended to move the agency away from source-by-source, chemical-by-chemical regulation of pollutant discharges and toward integrated management of watersheds influenced by multiple chemical and nonchemical stresses. Biological indicators of environmental quality are already used in many states as supplements to, or even in place of, traditional water-quality criteria. It seems reasonable to consider cooling-system impacts within the same type of integrated framework. Rather than promulgating generic technology-based or even biologically-based standards (e.g., a numerical limit on the allowable numbers or fraction of a population that may be lost), EPA and its state counterparts should consider establishing criteria for measuring the health of aquatic ecosystems and for establishing goals and management actions that could enable ecosystems to meet or exceed those criteria. This recommendation is not simply wishful thinking. EPA and collaborating state agencies have already established a number of programs aimed at restoration and management of entire watersheds; the Chesapeake Bay Program is perhaps the best-known example. All that is needed is to expand these programs to agency-wide initiatives and to widen their scope to include cooling-water withdrawals among the sources of impact to be managed.

References

Barnthouse, L.W., Boreman, J., Christensen, S.W., Goodyear, C.P., Van Winkle, W., Vaughan, D.S., 1984. Population biology in the courtroom: the Hudson River controversy. Bioscience 34, 14–19.

Barnthouse, L.W., Boreman, J., Englert, T.L., Kirk, W.L., Horn, E.G., 1988. Hudson River settlement agreement: technical rationale and cost considerations. American Fisheries Society Monograph 4, 267–273.

Barnthouse, L.W., Van Winkle, W., 1988. Analysis of impingement impacts on Hudson River fish populations. American Fisheries Society Monograph 4, 182–190.

Berggren, T.J., Lieberman, J.T., 1978. Relative contribution of Hudson, Chesapeake, and Roanoke striped bass, *Morone saxatilis* stocks to the Atlantic coast fishery. Fishery Bulletin 76, 335–345.

Boreman, J., Goodyear, C.P., 1988. Estimates of entrainment mortality for striped bass and other fish species inhabiting the Hudson River estuary. American Fisheries Society Monograph 4, 152–160.

Boreman, J., Klauda, R.J., 1988. Distributions of early life stages of striped bass in the Hudson River estuary, 1974–1979. American Fisheries Society Monograph 4, 53–58.

Christensen, S.W., Englert, T.L., 1988. Historical development of entrainment models for Hudson River striped bass. American Fisheries Society Monograph 4, 133–142.

Christensen, S.W., Goodyear, C.P., 1988. Testing the validity of stock-recruitment curve fits. American Fisheries Society Monograph 4, 219–231.

Cooper, J.C., Cantelmo, F.R., Newton, C.E., 1988. Overview of the Hudson River estuary. American Fisheries Society Monograph 4, 11–24.

Cowan Jr, J.H., Rose, K.A., 1993. Individual-based models of striped bass young-of-the-year dynamics. II. Factors affecting recruitment in the Potomac River, Maryland. Transactions of the American Fisheries Society 122, 439–458.

DeAngelis, D.L., Godbout, L.L., Shuter, B.J., 1991. An individual-based approach to predicting density-dependent populations in smallmouth bass populations. Ecological Modelling 57, 91–115.

EA Engineering, Science, and Technology, 1995. 1995 year class report for the Hudson River Estuary Monitoring Program. Prepared for Consolidated Edison Company of New York, Inc.

Englert, T.L., Boreman, J., 1988. Historical review of entrainment impact estimates and the factors influencing them. American Fisheries Society Monograph 4, 143–151.

Fletcher, R.I., Deriso, R.B., 1988. Fishing in dangerous waters: remarks on a controversial appeal to spawner-recruit theory for long-term impact assessment. American Fisheries Society Monograph 4, 232–244.

Gladden, J.B., Cantelmo, F.R., Croom, J.M., Shapot, R., 1988. Evaluation of the Hudson River ecosystem in relation to the dynamics of fish populations. American Fisheries Society Monograph 4, 37–52.

Hoff, T.B., McLaren, J.B., Cooper, J.C., 1988. Stock characteristics of Hudson River striped bass. American Fisheries Society Monograph 4, 59–68.

Hutchison Jr, J.B., 1988. Technical description of Hudson River electricity generating stations. American Fisheries Society Monograph 4, 113–120.

Klauda, R.J., McLaren, J.B., Schmidt, R.E., Dey, W.P., 1988. Life history of white perch in the Hudson River estuary. American Fisheries Society Monograph 4, 69–88.

Lawler, J.P., 1988. Some considerations in applying stock-recruitment models to multiple-age spawning populations. American Fisheries Society Monograph 4, 204–218.

McLaren, J.B., Peck, T.H., Dey, W.P., Gardinier, M., 1988. Biology of Atlantic tomcod in the Hudson River estuary. American Fisheries Society Monograph 4, 102–112.

Muessig, P.H., Young, J.R., Vaughan, D.S., Smith, B.A., 1988a. Advances in field and analytical methods for estimating entrainment mortality. American Fisheries Society Monograph 4, 124–132.

Muessig, P.H., Hutchison, J.B., King, L.R., Ligotino, R.J., Daley, M., 1988b. Survival of fishes after impingement on travelling screens at Hudson River power plants. American Fisheries Society Monograph 4, 170–181.

Normandeau Associates, 1995. Hudson River striped bass stock assessment program November 1993–April 1994. Prepared for New York Power Authority, 123 Main Street, White Plains, New York, 10601.

Pace, M.L., Baines, S.B., Cyr, H., Downing, J.A., 1993. Relationships among early life stages of *Morone americana* and *M. saxatilis* from long-term monitoring of the Hudson River estuary. Canadian Journal of Fisheries and Aquatic Science 50, 1976–1985.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Rose, K.R., Cowan Jr, J.H., 1993. Individual-based model of young-of-the-year striped bass population dynamics.I. Model descriptions and baseline simulations. Transactions of the American Fisheries Society 122, 415–438.

Savidge, I.R., Gladden, J.B., Campbell, K.P., Ziesenis, J.S., 1988. Development and sensitivity analysis of impact assessment equations based on stock-recruitment theory. American Fisheries Society Monograph 4, 191–203.

SARC, 1998. Consensus summary of assessments, 26th Northeast Regional Stock Assessment Workshop. Northeast Fisheries Science Center Reference Document 98-03. National Marine Fisheries Service, Woods Hole, Massachussetts.

Van Winkle, W., Kumar, K.D., Vaughan, D.S., 1988. Relative contribution of Hudson River and Chesapeake Bay striped bass stocks to the Atlantic coastal population. American Fisheries Society Monograph 4, 255–266.

Vaughan, D.S., 1988. Introduction to entrainment and impingement impacts. American Fisheries Society Monograph 4, 121–123.

Weisberg, S.B., Burton, W.H., 1993. Spring distribution and abundance of ichthyoplankton in the tidal Delaware River. Fishery Bulletin 91, 788–797.

Wooley, C.M., Crateau, E.J., 1983. Biology, population estimates, and movement of native and introduced striped bass, Apalachicola River, Florida. North American Journal of Fisheries Management 3, 383–394.

Lawrence W. Barnthouse is the President of LWB Environmental Services, Inc. He was formerly a Senior Research Staff Member in Oak Ridge National Laboratory's Environmental Sciences Division. During 19 years at Oak Ridge National Laboratory he was involved in environmental research and assessment projects involving development of new methods for predicting and measuring environmental risks of energy technologies. He is an internationally recognized authority on applications of population modeling techniques to problems involving power-plant cooling systems, toxic chemicals, and watershed management.

Environmental Science & Policy 3 (2000) S283–S293

Environmental Science & Policy

www.elsevier.com/locate/envsci

Historical overview of the efficacy of two decades of power plant fisheries impact assessment activities in Chesapeake Bay

William A. Richkus[a,*], Richard McLean[b]

[a] Versar, Inc., 9200 Rumsey Road, Columbia, MD 21045, USA
[b] Power Plant Research Program, Maryland Department of Natural Resources, Tawes State Office Building, Annapolis, MD 21401, USA

Abstract

The Chesapeake Bay is world renowned as an estuary that historically yielded large harvests of a wide variety of fish and shellfish species. Thirteen power plants are located on the mainstem of the Bay and its tributaries in Maryland, drawing out of and discharging into the Bay eight billion gallons per day of the Bay's waters for cooling purposes. Maryland DNR's Power Plant Research Program (PPRP) has, since 1974, funded a wide variety of fisheries assessment, entrainment and impingement studies. PPRP's Potomac River Fisheries Program (PRFP) encompassed multi-year, statistically rigorous, quantitative studies of all life stages of striped bass, from egg to adult, together with estuarine hydrodynamics modeling and water quality assessments, all yielding data integrated to project potential entrainment impacts from a proposed nuclear power plant. PPRP and utility-sponsored monitoring programs at BGE's Calvert Cliffs NPP, PEPCO's Chalk Point SES and DP&L's Vienna SES, as well as other generating facilities throughout the state have provided comprehensive data on impingement, entrainment and receiving water populations of all life stages of potentially impacted resource species. These studies have resulted in unusually complete and long term data sets being available for impact assessment applications, and provide a basis for confirming and validating impact assessment findings and conclusions based on much shorter time series. The state/federal Chesapeake Bay Program has extensively characterized the status and trends of all important resource species in the Bay. We compare and contrast impact conclusions and projections from studies conducted in the 1970s and 1980s with current data and information on the status of and trends in affected fish stocks in Chesapeake Bay. We use that comparison to establish the role that power plant impacts play as factors driving changes in species abundance over time. These comparisons and contrasts between historical and current data and information also illustrate and confirm the methodologies that have proven to be most and least useful for assessing entrainment and impingement impacts. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Aquatic impacts; Modeling; Fisheries; Cooling water; Chesapeake Bay

1. Introduction

For centuries, Chesapeake Bay has been one of the most productive estuaries in the world for fish and shellfish. Of the more than 200 species of fish and shellfish found in the Bay during some stage of their life cycles, as many as 40 have supported widespread and economically important fisheries in both Maryland and Virginia (Richkus et al., 1992). The Chesapeake Bay region has also for centuries been home to a wide range of industries, including power generation. Eighteen power plants greater than 90 MW in size are currently present in Maryland (Fig. 1). Most of these facilities employ once-through cooling systems. The extensive use of the Bay's waters for power plant cooling has been of concern and interest to the state's environmental and resource agencies for more than 30 years.

Extensive public debate regarding the potential effects the Calvert Cliffs Nuclear Power Plant might

* Corresponding author. Tel.: +1-410-964-9200; fax: +1-410-964-5156.
E-mail address: richkuswil@versar.com (W.A. Richkus).

1462-9011/00/$ - see front matter
PII: S1462-9011(00)00068-X

have on the Chesapeake Bay arose in the late 1960s. Calvert Cliffs was a source of elevated concern because the plant uses a once-through cooling system that withdraws 3500 million gallons of water per day from the Bay and discharges the water back to the Bay with a temperature elevation of about 12°F. The magnitude and diversity of potential environmental impacts that came to light during the licensing of Calvert Cliffs prompted the creation in 1971 of the Maryland Department of Natural Resources Power Plant Research Program (PPRP). PPRP's purpose was to ensure a complete evaluation and resolution of such issues before future decisions were made regarding whether and where to build other generating facilities.

Today, PPRP continues to conduct research on power plant impacts to Maryland's natural resources, including air, water, biota, as well as to the human population and the economy. PPRP investigations into the effect of power plants on aquatic life in the Chesapeake Bay that have been conducted continuously since 1971 have complemented and augmented other intensive and extensive studies funded by the utilities that own and operate the generating facilities in the state, including BGE, PEPCO and DP&L, as has been described by Ringger (2000) and Bailey et al. (2000). The decades of PPRP study, together with data and information from utility studies, provide unusually long-term data sets useful for the evaluation of the effects power generating facilities have had on important fish stocks in the Chesapeake Bay, and the value of a wide range of types of studies for assessing power plant impacts. They also provide a sound foundation from which PPRP can work to ensure that the Chesapeake Bay and other of Maryland's outstanding natural resources will be protected and enhanced as the electric power industry moves into the era of deregulation. Here we provide a review of the range of work performed to assess entrainment and impingement in several decades of work in Maryland, and some of the lessons learned in the process.

2. Maryland power generating facilities

With the exception of Brandon Shores, Vienna, and two of the four units at Chalk Point, all of Maryland's steam-generating power plants identified in Fig. 1 use once-through cooling systems. Once-through systems require large volumes of water — a fossil fuel fired plant uses about 1.4 million gallons of cooling water per day for each megawatt of electricity produced. Nuclear power plants, such as the Calvert Cliffs plant, generate more waste heat than fossil fuel plants and therefore must use more water per megawatt for cooling. Fig. 2 shows water use rates of power plants in Maryland, given in millions of gallons per day (mgd). The Maryland Department of the Environment grants a surface water appropriation permit to each power plant based on a forecast of the plant's water needs over a period of several years. This permitted withdra-

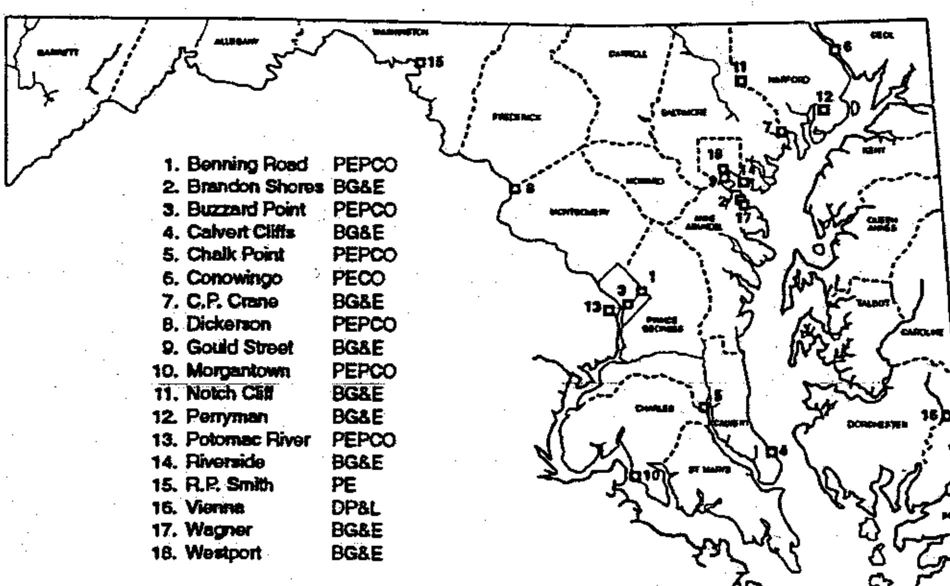


Fig. 1. Location of power plants in and around Maryland (with capacity greater than 90 MW) (Power Plant Cumulative Environmental Impact Report, 1982).

wal, also shown on Fig. 2, represents the estimated maximum amount of water that each plant could withdraw.

2.1. Modes of impact and assessment approaches

All plants using surface water for cooling have intake structures that include some type of trash rack at the entrance, to prevent large debris from disrupting cooling water flow. Nearly all plant intakes also include traveling screens, with relatively fine mesh that keeps small objects, including fish, from entering the cooling system and clogging condenser tubes. The screens are rotated at varying time intervals so that the material impinged on them can be washed off and, in most cases, be discarded into the receiving waters. Objects and biota small enough to pass through the traveling screens, such as phytoplankton, zooplankton, and ichthyoplankton are entrained in the plant's cooling system flow. Biota impinged on traveling screens are subject to stress from immobility (e.g., preventing respiration) and physical abrasion. Entrained organisms are subject to stress due to rapid temperature change, turbulence and shear forces, and biocides.

PPRP and utility impingement and entrainment impact assessments have in all cases proceeded from a first level characterization and quantification of the numbers and types of organisms being affected. Subsequent steps in assessments sometimes have consisted of a second level determination of the consequence of the effect (i.e., what percentage of the organisms entrained or impinged are killed or impaired in some way), and a third level evaluation of whether population level effects may result from the entrainment or impingement losses. Not all plants in Maryland or all species affected have been subject to these three levels of assessment. Species deemed to be of greatest value, generally because of their commercial or recreational importance, have been addressed in the greatest detail. An example of such a species in Chesapeake Bay is the striped bass (*Morone saxatilis*). For other species, less complex approaches have been employed to place within a population or ecosystem context the losses attributed to cooling water withdrawal. The results of studies of these types conducted in the 1970s and early 1980s provided a basis for the development of Maryland's regulations for cooling water intake and discharge that have ensured the protection of the state's aquatic resources. Below we provide a summary of some of the studies conducted and the manner in which the data were used to support regulatory decisions regarding Maryland's power plants.

3. Impingement

An example of annual impingement collected at power plants located on Maryland's Chesapeake Bay in the 1970s is summarized in Table 1. Similar data have been collected at nearly all plants in the 1970s and at some of these plants through the 1990s. At mesohaline facilities, a few species (Atlantic menhaden, spot, bay anchovy, hogchoker, and blue crabs) generally dominate impingement counts and the species composition of impingement is relatively similar from year to year. Year-to-year fluctuations in impingement

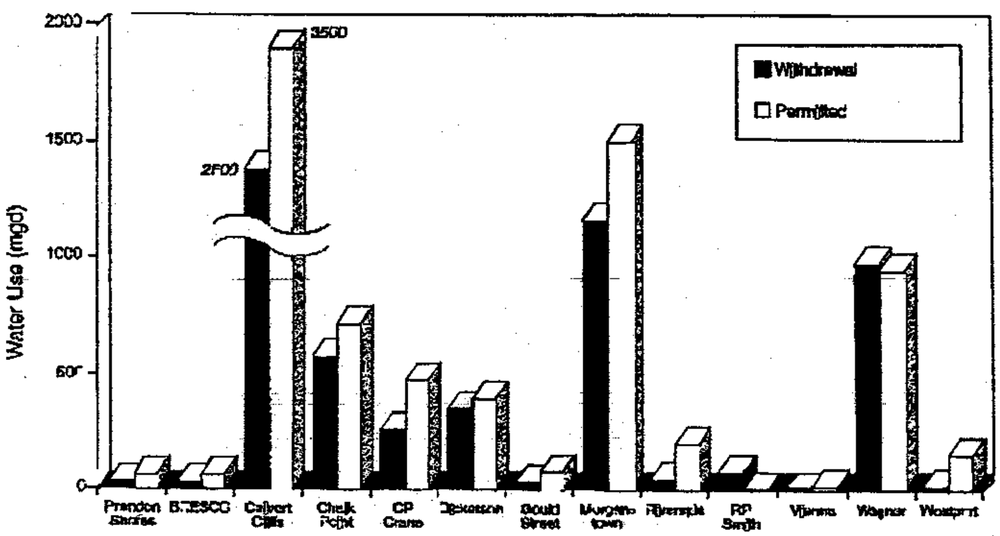


Fig. 2. Surface water withdrawals (mgd) 1991 (Power Plant Cumulative Environmental Impact Report, 1982).

Table 1
Estimated annual impingement (number of individuals) at the Chalk Point and Morgantown plants[a]

Species	Chalk Point 1976–1977		Morgantown			
	Number	Percent	1975		1976–1977	
			Number	Percent	Number	Percent
Atlantic menhaden	1,347,490	31	414,376	57	793,168	45
Spot	647,016	15	200,972	28	312,665	18
Hogchoker	191,926	5	2,510	0.3	38,095	2
White perch	41,910	1	60,648	8	91,525	5
Bay anchovy	Included with other fish		30,969	4	52,201	3
Other fish species	139,928	3	22,645	3	162,390	10
Total fish	2,368,324	55	732,081	100	1,450,044	82
Blue crabs	1,948,132	45	Not available		307,051	17
Total impinged organisms	4,316,456	100	Not available	1	1,757,101	100

[a] We note that subsequent studies suggested that these impingement figures were overestimates, and monitoring in later years yielded much lower impingement totals (Richkus et al., 1992).

catch generally reflected year-to-year fluctuations in fish and crab abundances in the intake area. The highest impingement generally occurred in late summer and fall, and the lowest values occurred in winter and spring. Juveniles dominated impingement catches, and the number of fish impinged usually was greatest at night. Mortality of the impinged fish varies from species to species. About 90% of impinged spot and hogchoker survive, whereas only about 25% of impinged menhaden and other clupeids survive (Table 2). Blue crabs had essentially no post-impingement mortality. Thus, losses of fish and crabs as a result of impingement are much less than the number impinged (Power Plant Cumulative Environmental Impact Report A, 1984). Mortality rates to impinged organisms generally were highest under intermittent screen rotation schedules (three times per day), rather than when screens were rotated frequently (once per hour) (Power Plant Cumulative Environmental Impact Report A, 1984). However, more organisms were impinged by frequent rotation schedules, and as a result, overall losses to local populations were lower if infrequent screen rotation schedules were used.

Although rigorous estimates are not available for all species, post-impingement mortalities were highest at plants where impinged organisms were returned to the receiving body along with other plant discharges which included chlorine residuals (Power Plant Cumulative Environmental Impact Report A, 1984). Subsequent changes in state discharge regulations have eliminated this additional potential source of mortality. A number of other steps were taken in the 1980s to reduce impingement mortality at some plants. A new screen wash discharge system that returned impinged organisms to the nearfield area rather than into the heated discharge canal was installed at PEPCO's Morgantown SES. A barrier net was installed across the intake canal at PEPCO's Chalk Point SES that reduced the numbers of fish and other organisms approaching the intake screens, substantially reducing the amount of impingement.

Table 2
Percent survival and percent loss of equilibrium (LOE) of major fish species impinged at Calvert Cliffs in 1979 (Richkus et al., 1992)

Species	Percent survival	Percent LOE
Atlantic menhaden	49.27	1.41
Spot	87.34	0.14
Hogchoker	> 99.00	0.0
Bay anchovy	66.82	2.66
Atlantic croaker	3.81	1.04
White perch	73.08	11.54
Blue crab	> 99.00	0.0

All studies demonstrated that high impingement episodes account for a large proportion of annual impingement at mesohaline facilities. As a result, impingement levels are not directly related to the volume of water pumped but are more a function of fish and crab abundance, as well as the behavior of the organisms and variable water quality in the vicinity of intake screens, thus reflecting its site-specific nature. At Calvert Cliffs and Morgantown, high impingement episodes were related to low dissolved oxygen (DO) levels in the intake embayment (Power Plant Cumulative Environmental Impact Report A, 1984). Removal of panels from curtain walls during periods when low DO typically occurred provided entrapped organisms with an escape route and reduced impingement levels. At Chalk Point, high impingement episodes are related to normal seasonal migration.

The six species that dominate the impingement estimates are all abundant, ubiquitous species that occur throughout mesohaline regions of the Bay and its tributaries. These species also dominate net catches made during surveys conducted at these sites, confirming the non-selective nature of cropping by power plants (Power Plant Cumulative Environmental Impact Report B, 1986). The plants appear to have impinged fish at a rate proportional to their abundance in the plant vicinity. There is insufficient knowledge of population size and dynamics of all of the listed species to predict the exact consequence of plant-induced losses, but no changes in fish density or community composition in the vicinity of these plants were observed during the 10 to 15 years over which data were collected most intensively. A relatively recent assessment of trends in important aquatic resources in different segments of the Bay found various long-term trends in the abundance of some of the major species impinged (Richkus et al., 1994), but none that could be linked to impingement effects. Figs. 3 and 4 provide summary presentations for the Patuxent River basin and the Middle Mainstem basin. In both, under finfish, it can be seen that bay anchovies, spot and menhaden, three of the species appearing in greatest numbers in entrainment and impingement estimates for the Chalk Point and Calvert Cliffs power plants over the last several decades, are characterized as being at or above the long-term reference levels established to characterize status. This information further supports the view that power plant effects are not a dominant factor in establishing the status of basin-specific fish stocks.

In lieu of complex and costly population level modeling of individual species, one simple way used by PPRP to place impingement losses in perspective was to compare them to other population losses (i.e., due to predation, fishing, natural die-offs, etc.). Such data were available for several major impinged species, and we presented the following discussion in Power Plant Cumulative Environmental Impact Report B (1986).

Menhaden is one of the major commercial finfish species in the Bay, usually accounting for over 40% of total landed weight in the 1970s. Populations are mobile, and they are distributed throughout mesohaline and oligohaline regions of the Bay. Impingement mortality for menhaden is considered to be 100%. As an approximation of a single year's impingement

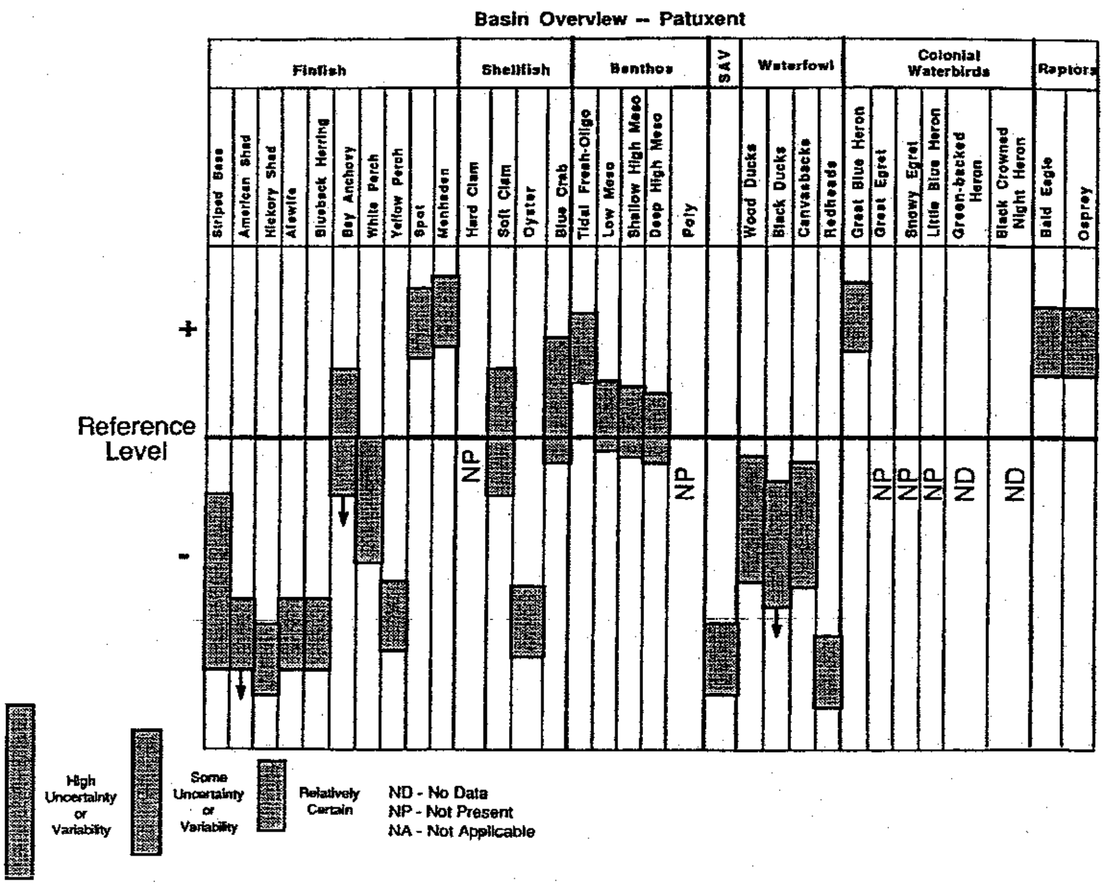


Fig. 3. Status of key species in the Patuxent basin relative to each species' respective reference level (Richkus et al., 1994).

weight total of menhaden for the three mesohaline plants, the 1976 number totals were multiplied by the average weight of menhaden impinged at Calvert Cliffs (20 g = 0.043 lbs) to give total impinged weight estimates of 76,000 lbs. This was about 1.25% of the 1976 Maryland landings of 6 million lbs. Although the mean weight of commercially harvested menhaden is not known, they are larger (older) than the juveniles being impinged. The number of juvenile menhaden impinged is, therefore, much more than 1% of the number of adult menhaden commercially caught. However, since these juveniles would have suffered considerable natural mortality (typically 90%) before reaching harvestable size, the plant-related losses would probably cause a much smaller decline in subsequent years.

Menhaden experience large natural die-offs throughout the Bay during summer months. Many of these kills are unreported or unquantified. Reported kills of menhaden in 1974 and 1975 totaled 100 million and 1.9 million individuals, respectively (Power Plant Cumulative Environmental Impact Report B, 1986). The 1976 impingement total for the three plants is estimated to be 1.8 million individuals.

Menhaden are also a favorite prey of the two major predatory fish in the Bay: bluefish, and striped bass. Daily rations for these species are about 3–5% of their body weight/day. Total stock of bluefish and striped bass in the Bay is unknown, but the amount harvested can be used to give some insight into the amounts of forage fish consumed by predators. From May to October 1976, sport fishermen landed 535,800 lbs of striped bass and 2,915,179 lbs of bluefish in the upper Bay (Power Plant Cumulative Environmental Impact Report B, 1986). If these totals are combined with commercial landings over the entire Bay during the same period, total weight of both species landed was 5,246,000 lbs. Assuming 4% of body weight consumed each day for a five-month period, total forage which would have been utilized by these landed fish is 32,525,000 lbs, much of which would have been menhaden. The estimated impinged total of 76,000 lbs is

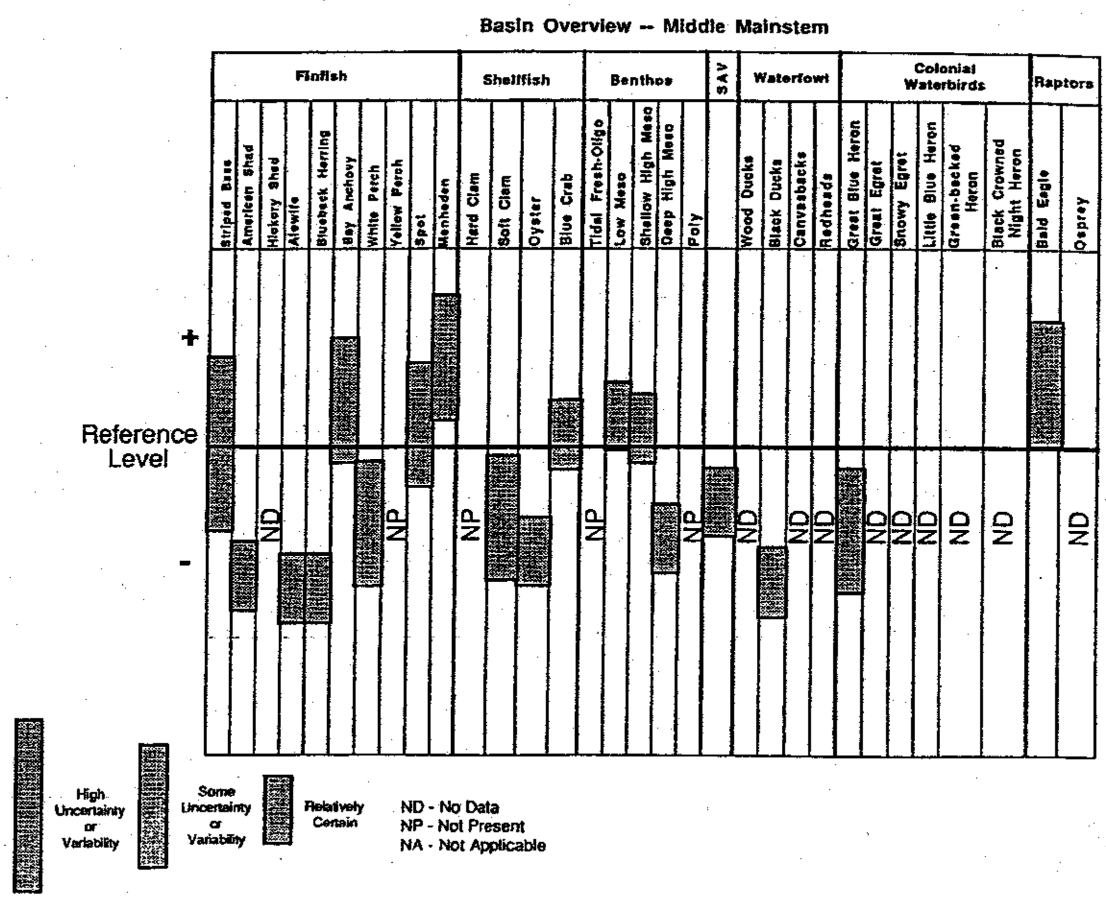


Fig. 4. Status of key species in the Middle Chesapeake Bay basin relative to each species' respective reference level (Richkus et al., 1994).

about 0.23% of that total. All of the above comparisons suggest that menhaden impingement kills represent a small perturbation on the Bay.

Crabs — in 1976, Morgantown impinged about 281,000 crabs. From June to December 1976, Chalk Point impinged approximately 1 million crabs, which was three times the commercial catch in the Patuxent and equal to the estimated sport harvest. In 1976, Calvert Cliffs impinged approximately 440,000 crabs. Mortality studies have demonstrated that crabs suffer less than 1% mortality from impingement. Thus, unless the crabs should suffer delayed mortality as a result of the impingement episode (and there is no evidence of this), no impact would result from the mechanical effects of impingement. Post-impingement mortalities could occur where crabs are washed into a discharge canal (such as at Chalk Point or Morgantown) where they are exposed to chlorinated and heated effluent. This possibility was addressed at these plants and led to reorientation of the screen wash discharge point.

These conclusions are presented in PPRP's Cumulative Environmental Impact Reports (CEIR) which are issued every two years by the Maryland Department of Natural Resources. Subsequent to these findings, the state's focus on impingement was substantially reduced, although on-going data gathering by utilities was tracked and reviewed. No impingement data or information obtained in the intervening 15 years revived concern regarding the effects of impingement on Chesapeake Bay fish stocks or prompted the state to take additional measures to reduce the magnitude of those impacts.

4. Entrainment

Phytoplankton and zooplankton entrainment effects were intensively studied at a number of Maryland power plants in the 1970s and early 1980s, in particular at Calvert Cliffs, Morgantown and Chalk Point. The early results of these studies suggested that losses of phytoplankton and zooplankton were very variable, with greatest reductions found in the summer and at plants where chlorine was used as a biocide to keep condenser tubing from being fouled. We found that phytoplankton and zooplankton populations recovered rapidly from power plant related mortalities and stresses, such that nearfield effects could not be detected except in special circumstances (Power Plant Cumulative Environmental Impact Report B, 1986). The findings from over 15 years of study at more than six plants led to no state actions, other than constraints on the use of biocides such as chlorine, to alter power plant operations to alleviate the minimal observed effects on these plankton community elements.

One major PPRP program that was solely devoted to the issue of potential power plant impacts via entrainment of eggs and larvae was the Potomac River Fisheries Program (PRFP). This program, which was implemented over a six year period, was initiated as a result of a PEPCO proposal in the 1970s to construct a large nuclear power plant at Douglas Point on the Potomac River, a location at the center of striped bass spawning in that river. PRFP was the most comprehensive fisheries program of its kind at that time, with statistically rigorous survey designs for every aspect of life history and the estuarine environment that would play a role in ultimate impact to the striped bass stock. Hydrodynamics studies, including dye studies and modeling, were performed to characterize water circulation patterns that established the proportion of the ichthyoplankton exposed to power plant entrainment. Gill net and bioacoustic studies of the spawning stock were performed to establish the age and sex composition of the stock, the abundance of the spawning stock, the location of spawning, and the factors contributing to timing and location of spawning. Extensive ichthyoplankton sampling was conducted, ultimately resulting in a stratified random sampling design over the entire river segment in which eggs and larvae could be found, using oblique bottom-to-surface tows conducted at night to minimize effects of net avoidance on density estimates. These data sets were integrated into a complex population dynamics model, with the aim of assessing the potential impacts to the adult population from entrainment-induced losses of eggs and larvae. Because the proposal to construct the Douglas Point plant was put on hold and ultimately canceled, studies to establish the accuracy and precision of estimates of impacts were not possible. However, the PRFP data did play a key role in much of the population modeling later performed to support striped bass interstate management planning by the Atlantic States Marine Fisheries Commission.

In the early 1980s, Versar, Inc. developed a population-effects model for PPRP to be used as a tool to evaluate whether Maryland power plants were in compliance with water quality regulations requiring an assessment of whether cooling water entrainment of aquatic organisms adversely affects spawning and nursery areas of consequence (SNAC) for representative important species (RIS) that are specified in those regulations. The general computational scheme for the SNAC model is shown in Fig. 5 (Polgar et al., 1979; Summers, 1989). Potential adult population losses due to the entrainment of early life stages were initially estimated for 24 RIS populations in the Potomac River, and the model was, in later years, applied to many of those same species populations in other portions of the Chesapeake Bay on which power plants were sited. The calculations were based on local and regional life stage densities, larval behavioral characteristics, estuarine transport rates, and plant cooling water withdrawal rates. The impacts of population losses were evaluated in terms of regional economics as potential relative dollar value lost to the regional fishery, and in terms of ecosystem dynamics as a potential increase in "unutilized" system net production due to the computed population losses. Table 3 presents the results of the SNAC model application for the Potomac River ecosystem, taking into account the entrainment impacts of the Morgantown and Possum Point power plants. We concluded from these analyses that while several species showed potentially significant population losses (>3%), the ecological impact of these losses on the Potomac River system was insignificant. While the SNAC model proved to be a useful tool for evaluating the entrainment effects of power plants, it was also data intensive, requiring a diverse and large amount of data and information for its application. Its application illustrates that the determination of "adverse impact" that would trigger some action on the part of the plant owner remains a societal judgment on the part of the regulatory agency. Substantial differences among estimates of impacts of the different plants also illustrate the site-specific nature of entrainment impacts.

In the various applications of the SNAC model since its initial development, only in the case of PEPCO's Chalk Point SES were entrainment impacts considered to be sufficiently significant to warrant some action being taken by the state. Utility and state agency estimates of the entrainment effects differed to some degree, but there was agreement that the most important fish population experiencing the greatest potential impact was the Bay anchovy, an important forage species in the Bay. While a complete consensus on the magnitude of the loss and its potential consequences to the population was not reached, there was sufficient agreement to achieve resolution. In this instance, following state water intake and discharge regulatory procedures, this issue was resolved by having PEPCO undertake mitigation aimed at assisting the state in the restoration of several important fish stocks in the Patuxent River, in essence an out-of-kind mitigation agreement. Such an agreement was reached in this instance because the potential costs of cooling

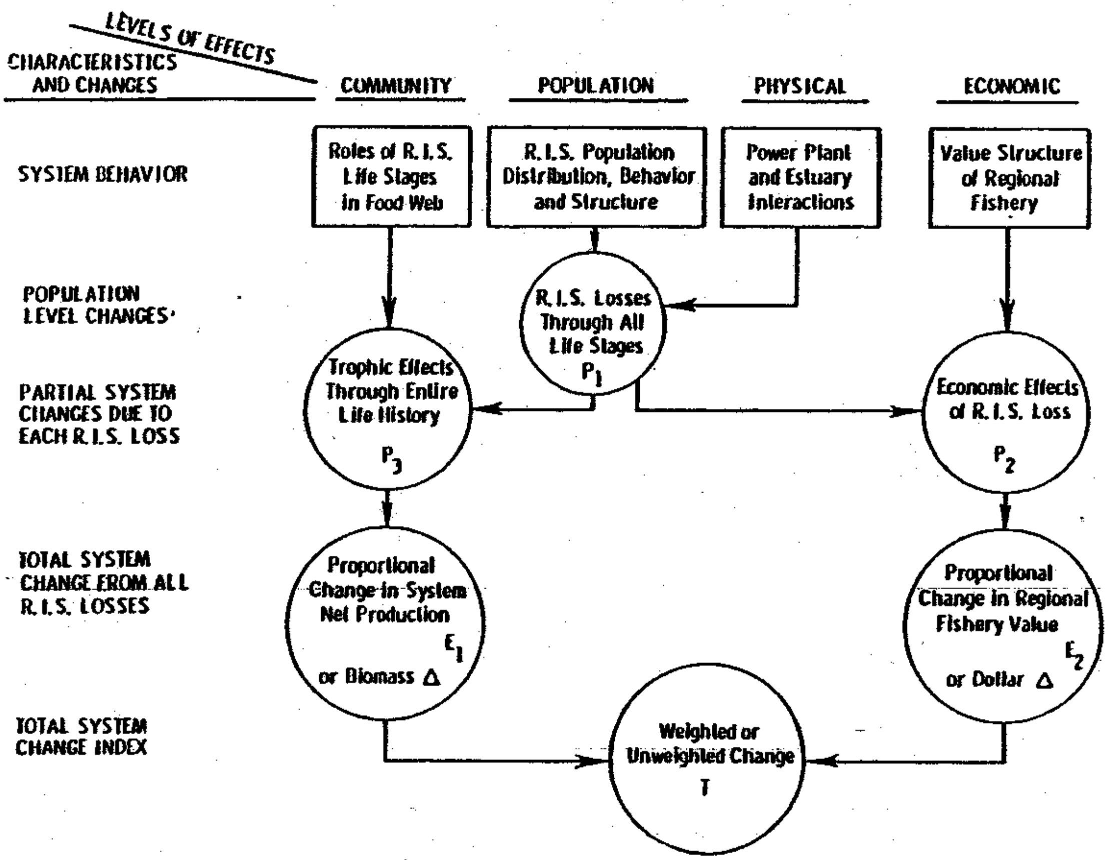


Fig. 5. The general computational scheme (Polgar et al., 1979).

alternatives, including the use of wedge-wire screens on the intake or the installation of cooling towers and reduction in water withdrawal rates, were deemed to be not commensurate with the magnitude and nature of the loss of aquatic resources.

5. Power plant impacts within the context of Chesapeake Bay fisheries management

Because of the economic and recreational value of many Bay species, declines in fish stocks in recent decades triggered both public concern and also remedial action by state and federal agencies starting in the early 1980s. One key outcome of that response was the establishment of the Chesapeake Bay Program, a multijurisdictional effort run by the US Environmental Protection Agency (EPA) and operating at both the federal and state levels. As part of the overall Bay restoration effort, state and federal resource managers developed stock assessment recommendations for the 1987 Chesapeake Bay Agreement. The agreement's purpose was to implement programs to restore depressed fish and shellfish stocks and to prevent the decline of currently abundant stocks (Richkus et al., 1992).

The assumption underlying most fisheries management is that stock abundance (population size) is regulated by internal feedback mechanisms; such that when stock abundance decreases as a result of fishing activity or any other source of mortality, the species responds with increased growth and reproduction. Theoretically, this response allows a certain level of annual harvest to be sustained indefinitely (Richkus et al., 1992). It is a complex task, however, to identify all of the factors that affect the status of exploited, or harvested, stocks and to quantitatively classify the relative impact of these factors. Fig. 6 schematically illustrates the myriad interacting natural and anthropogenic factors that bear on the size of a fish or shellfish stock. When setting harvest regulations, managers must take into account not only the biological factors but also various social, political, economic, and jurisdictional factors. These non-biological factors, many of which are not based on science, often play a major role in management decisions.

It is worth noting in Fig. 6 that cooling water withdrawal-induced mortality of various life stages of any fish population, captured in the figure as life stages "killed by man", is simply one of a large number of mortalities experienced by those life stages. As such, it has no lesser or greater importance to the ultimate fate of the affected population than any other source of mortality, and it can only be taken into account within the context of all of the other factors affecting the population. It is also notable that the Bay management plans intended to preserve and restore major fish stocks focus on environmental restoration and protection and harvest regulation, with no specific attention called to the consequences of cooling water withdrawal.

6. Conclusions

We have briefly reviewed examples drawn from more than 25 years of PPRP research conducted in the Chesapeake Bay to evaluate the effects of power plant water withdrawal on Chesapeake Bay aquatic resources. The huge volume of work performed over this time period has increased the breadth and depth of knowledge concerning how power plant cooling

Table 3
Percentage losses of Potomac RIS due to operations at Morgantown and Possum Pt, SES and their economic and ecological effects[a]

Species	Population		Economic		Ecological	
Striped bass	6.4	(1)	3.1	(1)	0.16	(7)
Alewife	6.0	(2)	0.15	(2)	0.091	(3)
White perch	5.1	(3)	0.07	(3)	0.078	(4)
Naked goby	4.4	(4)	0		0.024	(6)
Silverside	3.3	(5)	0		0.035	(5)
Bay anchovy	2.3	(6)	0		0.14	(1)
Atlantic menhaden	0.95	(7)	0.036	(4)	0.12	(2)
Atlantic croaker	0.28	(8)	4.2×10^{-4}	(5)	5.6×10^{-5}	(8)
Spot	0.073	(9)	3.8×10^{-4}	(6)	1.6×10^{-5}	(9)
Weakfish	4×10^{-4}	(10)	0		1.5×10^{-7}	(13)
Rangia cuneata	3×10^{-4}	(11)	0		1×10^{-5}	(11)
Macoma balthica	2.1×10^{-4}	(12)	0		1.5×10^{-5}	(10)
Macoma balthica Oyster	8×10^{-5}	(13)	2.7×10^{-5}	(7)	5.4×10^{-6}	(12)

[a] Rankings of losses are in parentheses; percentage of population is of equilibrium stock abundance; percentage of economic value is of the dollar value of projected annual harvest; percentage of ecological value is of contribution of biomass to higher trophic levels (Polgar et al., 1979). $E_2 = 3.4\%$ ($174,404), $E_1 = 0.51\%$ (0.57 gm/100 gm NPP).

water withdrawal impacts fish stocks, how to quantify those impacts, and how to analyze and interpret them. We have learned a number of important lessons:

- A rigorous statistical design of sampling programs to measure impingement and entrainment rates must take into account all important site specific factors (e.g., water quality fluctuations, fish behavior, seasonal migrations, spawning period) in order to accurately characterize the quantities of organisms affected.
- Some relatively simple modifications of intake operations and structures (e.g., changing screen rotation schedules; removing skimmer wall panels during periods of low DO) can result in very large reductions in the magnitude of impingement.
- The location of a water intake (e.g., relative to spawning locations) in large part establishes the potential magnitude of entrainment.
- Assessments of population level and ecosystem level impacts require that entrainment and impingement mortalities be considered within the context of all other sources of mortality, both natural and anthropogenic.
- The large number of factors that must be taken into account in population level or ecosystem level impact assessments and the large degree of uncertainty associated with quantitative estimates of many of these factors severely limits the degree of precision and reliability that can be achieved by even the most elaborate impact assessment model constructs (Richkus, 1980).

This knowledge has provided the foundation for im-

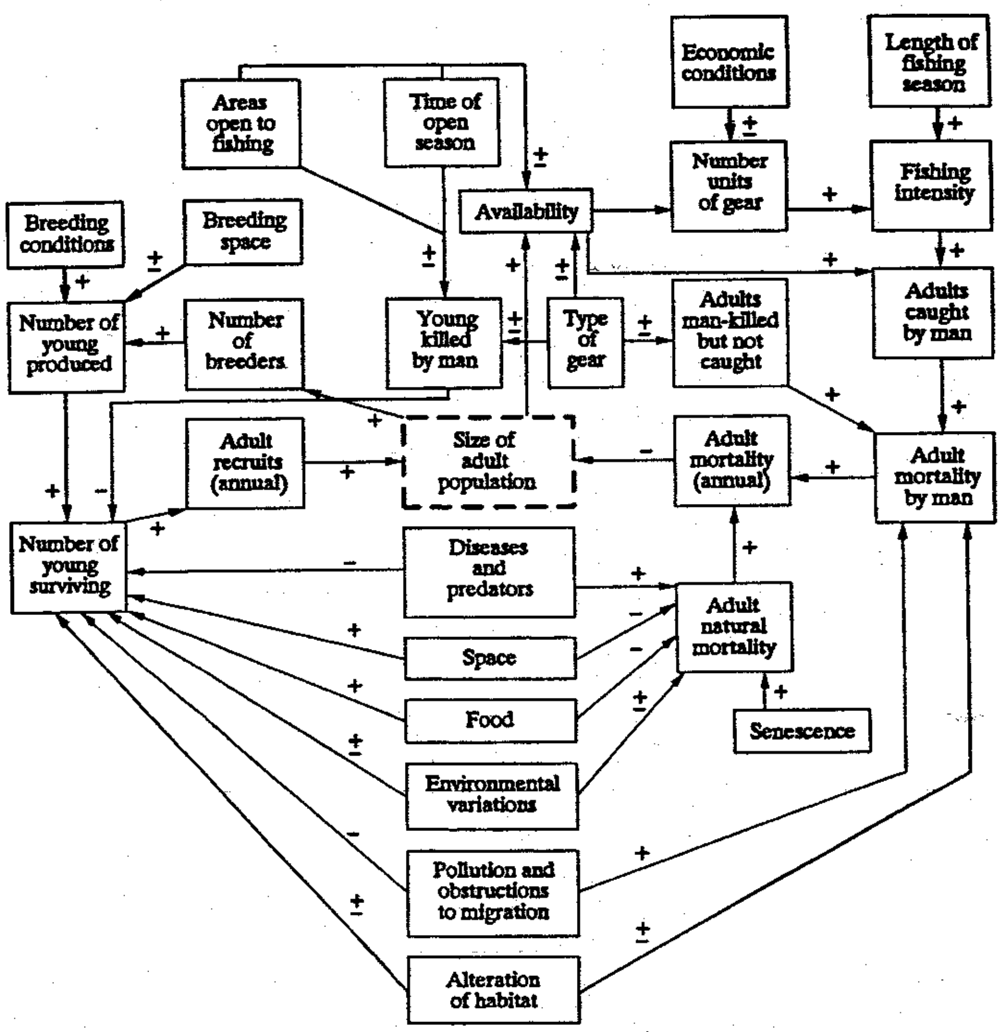


Fig. 6. Factors involved in determining population size of exploited fish or shellfish stocks. The (+) and (−) signs refer to a positive or negative effect, respectively, of one factor or another.

plementation of Maryland's regulations regarding cooling water withdrawal. In all cases, implementation can be characterized as occurring in a series of phases or stages, starting with quantifying the impacts, proceeding to the determination of the significance of those impacts, and ending with the determination of measures to be implemented by the utility to reduce impact to an extent commensurate with the significance of that impact or to mitigate for that impact. The absence of power plant water withdrawal impact issues in Maryland for more than a decade, concurrent with the intense state/federal effort to restore Chesapeake Bay and its resources, is evidence that the approaches developed and applied by PPRP have satisfied the state's needs and requirements. However, a ~~critical point to be made regarding the regulation of~~ power plants in Maryland is that the regulatory procedures successfully employed to protect the living resources of Maryland's Chesapeake Bay and to allow for the generation of electricity essential to the state's citizens and industry clearly allows for cooling water withdrawal as a valid use of the state's water resources, so long as the consequences of this use is balanced against other related sources of impacts and the state's overall environmental and social objectives.

References

Bailey, D.E., Loos, J.J., Perry, E.S., Wood, R.J., 2000. A retrospective evaluation of 316(B) mitigation options using a decision analysis framework. Environmental Science and Policy 3, S25–S36.

Polgar, T.T., Summers, J.K., Haire, M.S., 1979. Evaluation of the Effects of the Morgantown SES Cooling System on Spawning and Nursery Areas of Representative Important Species. PPSP-MP-27. Maryland Power Plant Siting Program, Maryland Department of Natural Resources, Annapolis, Maryland. 130 pp.

Power Plant Cumulative Environmental Impact Report (CEIR), 1982. PPSP-CEIR-3. Maryland Power Plant Siting Program, Maryland Department of Natural Resources, Annapolis, Maryland.

Power Plant Cumulative Environmental Impact Report A (CEIR), 1984. PPSP-CEIR-4. Maryland Power Plant Siting Program, Maryland Department of Natural Resources, Annapolis, Maryland.

Power Plant Cumulative Environmental Impact Report B (CEIR), 1986. PPSP-CEIR-5. Maryland Power Plant Siting Program, Maryland Department of Natural Resources, Annapolis, Maryland.

Richkus, W.A., 1980. Problems in monitoring marine and estuarine fishes. In: Hocutt, C.H., Stauffer, J.R. (Eds.), Biological Monitoring of Fish, Lexington Books, Lexington, MA. pp. 83–118.

Richkus, W.A., Austin, H.M., Nelson, S.J., 1992. Fisheries Assessment and Management Synthesis: Lessons for Chesapeake Bay. In Perspectives on Chesapeake Bay, 1992: Advances in Estuarine Sciences. Scientific and Technical Advisory Committee, Chesapeake Bay Program, USEPA, Annapolis, MD. pp. 75–114.

Richkus, W.A., Jacobson, P., Ranasinghe, A., Shaughnesy, A., Chaillou, J., Kazyak, P., Delisle, C., Batiuk, R., 1994. Basin-Specific Characterization of Chesapeake Bay Living Resources Status. Chesapeake Bay Program USEPA, Annapolis, MD, 1975. In: Rounsefell, G.A. (Ed.), Ecology, Utilization, and Management of Marine Fisheries, St Louis: C.V. Mosby Company. 258 pp.

Ringger, T.G., 2000. Investigations of impingement of aquatic organisms at the Calvert Cliffs Nuclear Power Plant, 1975–1995. Environmental Science and Policy 3, S261–S273.

Summers, J.K., 1989. Simulating the indirect effects of power plant entrainment losses on an estuarine ecosystem. Ecological Modelling 49, 31–47.

Dr William A. Richkus is Vice President and General Manager of Versar, Inc. Dr Richkus received his B.S. in Biology from the University of Rhode Island, an M.S. in Oceanography from Scripps Institute of Oceanography, UC/San Diego, and a Ph.D. in Oceanography from the University of Rhode Island. He has worked in environmental consulting for 27 years, with particular focus on assessment of power generating facility impact, ecological monitoring and assessment, and fisheries management.

Mr Richard McLean is Senior Administrator and Manager for Nuclear Programs for the Power Plant Research Program of Maryland's Department of Natural Resources. He received his B.S. in Biology from Pennsylvania State University, and worked subsequently in the monitoring of power plant effects with the Academy of Natural Sciences of Philadelphia before joining MDNR. He has been involved in all aspects of ecological impact assessment of power plant impacts, particularly relating to nuclear facilities, for more than 20 years.