N. San Onofre Nuclear Generating Station

Southern California Edison—San Clemente, CA

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1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at San Onofre Nuclear Generating Station (SONGS) with closed-cycle wet cooling towers is technically and logistically feasible based on this study's design criteria, and will reduce cooling water withdrawals from the Pacific Ocean by approximately 95 percent. Impingement and entrainment impacts would be reduced by a similar proportion.

The site's location alongside San Onofre State Beach and parallel to the San Diego Freeway would likely require plume-abated cooling towers to prevent public safety hazards on the freeway. The preferred option selected for SONGS includes two cooling tower complexes (one per unit), each comprising six plume-abated wet cooling towers.

Construction-related shutdowns are estimated to take approximately 8 months for both units (concurrent). As a baseload facility, SONGS would incur a substantial financial loss as a result. The configuration of SONGS might enable a staggered retrofit (one unit at a time), which will reduce the amount of generating capacity removed from the grid during construction. As a nuclear facility, SONGS is subject to the Nuclear Regulatory Commission's (NRC) oversight and approval for substantial changes to the existing system operations as described in this chapter. It is unclear how the NRC's review and approval process might affect any downtime estimates.

The cooling tower configuration designed under the preferred option complies with all identified local use restrictions and includes necessary mitigation measures, where applicable.

1.1 COST

Initial capital and Net Present Cost (NPC) costs associated with the installation and operation of wet cooling towers at SONGS are summarized in Table N–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table N–2. A detailed cost analysis is presented in Section 4.0 of this chapter.

Table N–1. Cumulative Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Total capital and start-up [a]	593,100,000	30.04	35
NPC_{20} [b]	2,620,900,000	132.74	153

[a] Includes all costs associated with the construction and installation of cooling towers and shutdown loss. The loss of revenue from shutdown is estimated to be $595 million.

[b] NPC_{20} includes all capital costs, operation and maintenance costs, and energy penalty costs over 20 years, discounted at 7.0 percent.

Table N–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Initial capital [a]	56,000,000	2.84	3.27
Operations and maintenance	8,400,000	0.43	0.49
Energy penalty	144,500,000	7.32	8.43
Total SONGS annual cost	**208,900,000**	**10.59**	**12.19**

[a] Does not include revenue loss associated with shutdown, which is incurred in Year 0 only. The loss of revenue from shutdown is estimated to be $595 million.

1.2 ENVIRONMENTAL

Environmental changes associated with the conversion of the existing once-through cooling system at SONGS to a wet cooling tower system are summarized in Table N–3 and discussed further in Section 3.4 of this chapter.

Table N–3. Environmental Summary

		Unit 2	Unit 3
Water use	Design intake volume (gpm)	795,600	795,600
	Cooling tower makeup water (gpm)	38,200	38,200
	Reduction from capacity (%)	95	95
Energy efficiency	Summer heat rate increase (%)	3.74	3.74
	Summer energy penalty (%)	6.33	6.33
	Annual heat rate increase (%)	2.88	2.88
	Annual energy penalty (%)	5.48	5.48
Direct air emissions [a]	PM_{10} emissions (tons/yr) (maximum capacity)	458	458
	PM_{10} emissions (tons/yr) (2006 capacity utilization)	397	363

[a] Does not include stack emissions from sources used to supplement the projected generation shortfall, if obtained from fossil fuel facilities.

1.3 OTHER POTENTIAL FACTORS

Considerations outside this study's scope may limit the practicality or overall feasibility of a wet cooling tower retrofit at San Onofre.

The Unit 3 tower complex will require new or amended development permits for a coastal bluff that extends several thousand feet south of the facility's current boundary. Use of this area may be restricted due to conflicts with Coastal Act provisions that protect critical habitats along the coastal bluff. In developing size and cost estimates for the Unit 3 tower complex, this study assumes the availability of this area. In the event this area is not available, the goal of retrofitting the Unit 3 cooling system with wet cooling towers becomes infeasible due to the lack of sufficient space.

The construction-related downtime required to complete a cooling system retrofit at SONGS is estimated to be approximately 6 months per unit, during which time either Unit 2 or Unit 3 would not be available to generate electricity. The net impact is the temporary removal of 1,127 MWe from the grid.

2.0 BACKGROUND

SONGS is a nuclear-powered steam electric generating facility 2.5 miles south of the city of San Clemente at the northern edge of San Diego County and is principally owned and operated by Southern California Edison (SCE). The facility's main portion is located south of San Onofre State Beach alongside the Pacific Ocean on land leased from the U.S. Marine Corps' Camp Pendleton. The San Diego Freeway (I-5) parallels the eastern boundary of this section (Figure N–1). SCE operates two pressurized water reactor (PWR) units (Unit 2 and Unit 3), each rated at 1,127 MW, for a facility total of 2,254 MW. Unit 1, also a PWR unit, ceased commercial operation in 1992 and is in the latter stages of decommissioning. The total size of this area is approximately 84 acres. (See Table N–4.)

The SONGS facility also comprises an additional area, roughly 130 acres in size, on the eastern side of the San Diego Freeway. This area, referred to as the Mesa Complex, is also leased from Camp Pendleton and houses various administrative, maintenance, and support services for the facility. No power-generating activities occur at the Mesa Complex.

Table N–4. General Information

Unit	In-service year	Rated capacity (MW)	5-year capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 2	1983	1,127	86.8%	795,600
Unit 3	1984	1,127	79.4%	795,600
SONGS total		**2,254**	**83.1%**	**1,591,200**

[a] A 5-year average capacity utilization factor is used for SONGS because 2006 output (68 percent) was substantially less than in preceding years. As a baseload facility, SONGS can be expected to operate at a higher utilization rate on average. Data were compiled from the Quarterly Fuel and Energy Report (2001–2006) published by the California Energy Commission (CEC 2001–2006).

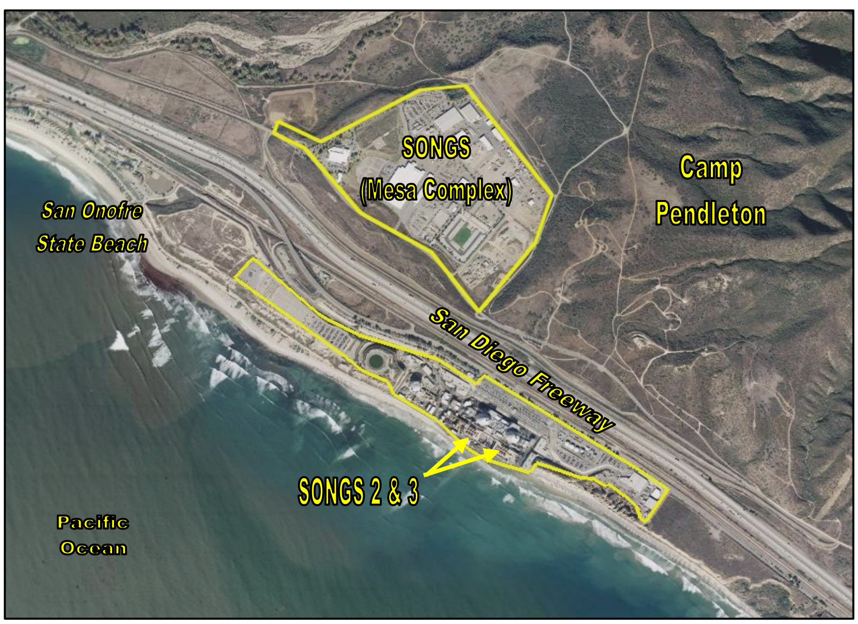

Figure N–1. San Onofre Nuclear Generating Station and Vicinity

2.1 COOLING WATER SYSTEM

SONGS operates two independent cooling water intake structures (CWISs) to provide condenser cooling water to Unit 2 and Unit 3. Once-through cooling water is combined with low-volume wastes generated by SONGS and discharged through two outfalls located 8,300 feet (Unit 2) and 5,900 feet (Unit 3) offshore in the Pacific Ocean. Surface water withdrawals and discharges for each unit are regulated by individual National Pollutant Discharge Elimination System (NPDES) permits CA0108073 for Unit 2; CA0108181 for Unit 3. Each permit is implemented by separate orders administered by the San Diego Regional Water Quality Control Board (SDRWQCB): R9-2005-0005 for Unit 2; R9-2005-0006 for Unit 3. The NPDES permit for Unit 1, which no longer produces wastewaters related to power generation, has been allowed to expire. Any remaining wastewaters produced at the Unit 1 site as a result of the decommissioning process are routed to the Unit 2 or Unit 3 outfalls and discharged under the respective permits.

Figure N–2. Site View of Oceanside Complex

Cooling water for Unit 2 and Unit 3 is withdrawn through two separate submerged conduits, each extending 3,183 feet offshore in the Pacific Ocean and terminating at an approximate depth of 32 feet. The submerged end of the conduit is fitted with a velocity cap to minimize the entrainment of motile fish into the system by converting the vertical flow to a lateral flow, thus triggering a flight response from fish.

The onshore portion of each intake consists of six vertical traveling screens fitted with 3/8-inch mesh panels. Screens are typically rotated based on the pressure differential between the upstream and downstream faces of the screen, although screens may also be rotated manually. A high-pressure spray removes any debris or fish that have become impinged on the screen face.

Captured debris is collected in a dumpster for disposal at a landfill. The through-screen velocity of water is 2.8 feet per second (fps). The vertical traveling screen assemblies are angled approximately 30o to the incoming flow that, combined with a series of vertical louvers placed in the forebay, guides fish to a quiet zone at the far end of the CWIS. A fish elevator periodically empties captured fish into a 4-foot-diameter conduit that returns them by gravity flow to a submerged location approximately 1,900 feet offshore.

Downstream of the six intake screens are four circulating water pumps, each rated at 207,000 gallons per minute (gpm), or 298 million gallons per day (mgd). Each unit has a design pump capacity totaling 828,000 gpm, or 1,192 mgd, for a facility total of 1,656,000 gpm, or 2,384 mgd. A portion of the intake flow is used for the saltwater cooling system (SWCS), which removes heat from auxiliary reactor systems and the turbine plant. Water for the SWCS is withdrawn from and returned to the main condenser flow.

2.2 SECTION 316(B) PERMIT COMPLIANCE

The CWIS currently in operation at SONGS uses velocity caps to reduce the entrainment of motile fish through the system, although the caps are commonly thought of as impingement-reduction technologies because they target larger organisms. Velocity caps have been shown to reduce impingement rates when compared with a shoreline intake structure.

Likewise, the location of the intake structure in a deep, offshore setting may contribute to lower rates of entrainment when compared with a shoreline intake if the near-shore environment is more biologically productive. Furthermore, each CWIS is angled to the incoming flow and incorporates other measures (vertical louvers) to prevent the impingement of organisms against the screens. Organisms that are diverted are returned to the source water through a combination fish elevator/return pipeline. This study did not evaluate the effectiveness of any of these measures.

The current orders for Unit 2 and Unit 3 do not contain numeric or narrative limitations regarding impingement or entrainment resulting from CWIS operation, but do require quarterly monitoring of impingement at each intake structure (coinciding with scheduled heat treatments). Because the current orders were adopted following implementation of the Phase II rule but prior to the Second Circuit Court's decision and EPA's notice of suspension, each contains a requirement to adhere to the rule's compliance schedule.

These requirements consist of various data collection provisions and studies that were to be submitted in support of an eventual best technology available (BTA) determination made by the SDRWQCB. Based on the record available for review, SONGS has been compliant with this permit requirement. No information from the SDRWQCB is available indicating how it intends to proceed with the permit requirements in light of the changes to the Phase II rule.

SONGS maintains a coastal development permit issued by the California Coastal Commission (CCC). In 1991, the CCC adopted permit conditions requiring SONGS to develop and fund various mitigation measures that address adverse impacts caused by the facility's operation, including the intake structures. These conditions include the installation and operation of fish barrier devices at the intakes as well as restoration measures to enhance the affected areas. This study did not evaluate compliance with CCC permit requirements (CCC 2005).

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

This study evaluates the use of saltwater wet cooling towers at SONGS, with the current source water (Pacific Ocean) continuing to provide makeup water to the facility. Conversion of the existing once-through cooling system to wet cooling towers will reduce the facility's current intake capacity by approximately 95 percent; rates of impingement and entrainment will decline by a similar proportion. Use of reclaimed water was considered for SONGS but not analyzed in detail because the available volume cannot serve as a replacement for once-through cooling water.

As a makeup water source, reclaimed water may be an attractive alternative when considering additional benefits its use may provide, such as avoidance of conflicts with effluent limitations or air emission standards. Securing a sufficient volume of makeup water from secondary or reclaimed sources in the vicinity (45 to 50 mgd in a freshwater configuration) is difficult and would require connections to multiple facilities. Use of reclaimed water is discussed further in Section 3.4.4.

The configuration of the wet cooling towers—their size and location—was based on best professional judgment (BPJ) using the criteria outlined in Chapter 5 and designed to meet the performance benchmarks in the most cost-effective manner. Plume-abated towers were selected based on the proximity to major infrastructure (San Diego Freeway) and potential public safety concerns.

A previous analysis of a wet cooling tower installation at SONGS, developed by PLG, Inc., for SCE in 1990, was also considered in determining the placement and general limitations of the final configuration selected for the site. Information not available to this study that offers a more complete characterization of the facility may lead to different conclusions regarding the physical configuration of the towers.

Based on a review of information provided by SCE and obtained from public records, installation of wet cooling towers at SONGS is difficult and may conflict with protected uses of adjoining state lands, but remains a logistically feasible option. This study assumes such conflicts can be overcome. Conversion to a wet cooling tower system will reduce the facility's available output by an annual average of 4.45 percent (approximately 100 MW). This is likely to be a major consideration if such a project moves forward. The final design of the plume-abated cooling towers, described below, represents the most practical installation that could be developed for the facility.

This study developed a conceptual design of wet cooling towers sufficient to meet the cooling demand for the steam turbine portion of the combined-cycle unit at SONGS at its rated output during peak climate conditions. Cost estimates are based on vendor quotes developed using the available information and the various design constraints identified at SONGS.

The overall practicality of retrofitting the combined-cycle unit at SONGS will require an evaluation of factors outside the scope of this study, such as the projected life span of the generating units and their role in the overall reliability of electricity production and transmission in California, particularly the San Diego region.

3.2 DESIGN BASIS

3.2.1 CONDENSER SPECIFICATIONS

For this study, the conceptual design of the cooling towers selected for SONGS is based on the assumption that the condenser flow rate and thermal load will remain unchanged from the current system. Although no provision is included to re-optimize the condenser performance for service with a cooling tower, some modifications to the condenser (tube sheet and water box reinforcement) may be necessary to handle the increased water pressures that will result from the increased total pump head required to raise water to the elevation of the cooling tower riser.[1] The practicality and difficulty of these modifications depend on the configuration of each unit, but are assumed to be feasible at SONGS. Additional costs associated with condenser modifications are included in the discussion of capital expenditures (Section 3.4).

If wet cooling towers were installed, SONGS, as a facility with a projected remaining life span of 15 years or more (currently licensed to operate through 2022), would likely pursue an overall strategy that included re-optimizing the condenser to minimize performance losses resulting from a conversion. Re-optimization would require extensive demolition and excavation of the existing site to gain access to the existing condensers (23 feet below grade level) and reconfigure the tubes and supply and return lines connecting to the water boxes.

Because of the complexity and level of detail required to develop an accurate estimate of a condenser re-optimization for SONGS, no attempt is made to characterize the cost or impact on facility downtime during construction in this study. A previous analysis conducted for the Diablo Canyon Power Plant notes significant increases in cost and shutdown loss to accomplish the necessary modifications (BES 2003).

Information provided by SONGS was largely used as the basis for the cooling tower design. In some cases, the data were incomplete or conflicted with values obtained from other sources. Where possible, questionable values were verified or corrected using other known information about the condenser. The condenser specification data sheets provided by SCE did not contain information detailing the total surface area or heat transfer coefficients for the condenser tubes.

In lieu of this information, a replacement value was calculated based on other known characteristics about the system (e.g., design inlet temperature, condenser rise, thermal load, tube material, etc.) using Heat Exchange Institute guidelines (HEI 2007). The resulting calculation is referred to as the "U-A" value and is substituted into the relevant equations as necessary.

Table N–5 summarizes the condenser design specifications for Unit 2 and Unit 3 used in this study.

[1] In this context, re-optimization refers to a comprehensive overhaul of the condenser, such as re-tubing or converting the flow from single to multiple passes. Modifications are generally limited to reinforcement measures to enable the condenser to withstand the increased pressures.

Table N–5. Condenser Design Specifications

	Unit 2	Unit 3
Thermal load (MMBTU/hr)	7950	7950
Surface area (ft^2)	*NA*	*NA*
Condenser flow rate (gpm)	795,600	795,600
Tube material	Titanium 338-73	Titanium 338-73
Heat transfer coefficient (U_d)	NA	NA
“U-A” value (BTU/hr·°F)	~560,800,000	~560,800,000
Cleanliness factor	0.9	0.9
Inlet temperature (°F)	64	64
Temperature rise (°F)	19	19
Steam condensate temperature (°F)	102.7	102.7
Turbine exhaust pressure (in. HgA)	2.1	2.1

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

SONGS is in San Diego County, approximately 2.5 miles south of the city of San Clemente. Cooling water is withdrawn through two submerged offshore intakes extending 3,183 feet into the Pacific Ocean. Condenser inlet temperature data were provided by SCE for January through November of 2006. Additional information to supplement this data set was obtained from the National Oceanographic and Atmospheric Administration (NOAA) *Coastal Water Temperature Guide—Dana Point, CA* (NOAA 2007).

The wet bulb temperature used in the development of the overall cooling tower design was obtained from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publications. Data for San Clemente, California, indicate a 1 percent ambient wet bulb temperature of 70° F (ASHRAE 2006). An approach temperature of 12° F was selected based on the site configuration and vendor input. At the design wet bulb and approach temperatures, the cooling towers will yield “cold” water at a temperature of 82° F. Monthly maximum wet bulb temperatures used in the development of energy penalty estimates in Section 4.6 were obtained from National Climatic Data Center (NCDC) climate normals for Oceanside, California (NCDC 2006). Climate data used in this analysis are summarized in Table N–6.

Table N-6. Surface Water and Ambient Wet Bulb Temperatures

	Surface (°F)	Ambient wet bulb (°F)
January	59.8	52.2
February	59.9	53.5
March	61.6	56.4
April	61.3	58.2
May	64.8	63.3
June	68.1	66.4
July	68.6	69.3
August	67.4	70.0
September	67.6	64.8
October	65.6	59.6
November	64.3	53.0
December	60.8	51.8

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Development in the vicinity of SONGS is regulated by the County of San Diego General Plan and the Local Coastal Plan (LCP) as well as by Camp Pendleton's guidelines or restrictions. Due to the proximity of the city of San Clemente, that city's general plan is also considered when modifications to SONGS are proposed that have the potential to affect the city. The San Diego General Plan and LCP outline narrative noise criteria to be used as a guide for future development, but do not identify numeric noise limits for new construction.

Based on consultation with the County of San Diego Department of Planning and Land Use, any measures limiting noise from a wet cooling tower at SONGS would be considered based on the project's final design criteria with respect to the relevant ordinances and development codes of San Diego County, the city of San Clemente, and Camp Pendleton. In general, noise would likely not be permitted to exceed 70 dBA at the nearest area of impact. Given the undeveloped nature of the surrounding area and the proximity to noise from the San Diego Freeway, stringent limitations on noise from wet cooling towers are unlikely. Accordingly, the overall design of the wet cooling tower installation for SONGS does not require any measures to specifically address noise, such as low-noise fans or barrier walls.

The proximity to public recreational areas (San Onofre State Beach) and protected areas may warrant measures to mitigate lower-level noise impacts, but these cannot be determined within the framework of this study.

3.2.3.2 BUILDING HEIGHT

According to the San Diego County General Plan, SONGS is within a land use zone designated as public or semipublic. Consultation with the County of San Diego Department of Planning and Land Use indicates building height restrictions would be evaluated on a conditional use basis with input from relevant agencies with oversight of the area (CCC, Camp Pendleton). Given the existing height of the current structures at SONGS, this study selected a height restriction of 75 feet above grade level for any new structures. The height of the wet cooling towers designed for SONGS, from grade level to the top of the fan deck, is 62 feet.

3.2.3.3 PLUME ABATEMENT

Local zoning ordinances do not contain any specific criteria for addressing impacts associated with a wet cooling tower plume. The proximity of SONGS to the San Diego Freeway, however, may necessitate incorporating plume abatement measures. As shown in Figure N–1, the San Diego Freeway parallels the eastern boundary of the beachfront complex for approximately 1.25 miles at a distance of fewer than 250 feet in some locations. Placement of a conventional (not plume-abated) wet cooling tower, combined with the direction of prevailing winds at the site (generally from the west), would likely create a public safety hazard on the heavily traveled freeway.

Furthermore, the proximity of SONGS to coastal recreational and protected areas, and the potential visual impact on these resources, may require plume abatement measures. California Energy Commission (CEC) siting guidelines and Coastal Act provisions evaluate the total size and persistence of a visual plume with respect to aesthetic standards for coastal resources; significant visual changes resulting from a persistent plume would likely be subject to additional controls.

For the above reasons, the cooling tower design evaluated for installation at SONGS includes plume abatement technologies for all cells.

3.2.3.4 DRIFT AND PARTICULATE EMISSIONS

Drift elimination measures that are considered best available control technology (BACT) are required for all cooling towers evaluated in this study, regardless of their location. State-of-the-art drift eliminators are included for each cooling tower cell at SONGS, with an accepted efficiency of 0.0005 percent. Because cooling tower PM_{10} emissions are a function of the rate of drift, drift eliminators are also considered BACT for PM_{10} emissions from wet cooling towers.

This efficiency can be verified by a proper in situ test, which accounts for site-specific climate, water, and operating conditions. Testing based on the Isokinetic Drift Test Code, published by the Cooling Tower Institute, is only required at initial start-up on one representative cell of each of the 12 towers, for an approximate cost of $720,000 (CTI 1994). This cost is not itemized in the final analysis and is instead included as part of the indirect cost estimate (Section 4.3).

3.2.3.5 FACILITY CONFIGURATION AND AREA CONSTRAINTS

The limited space available at the beachfront section of SONGS creates significant challenges for identifying sufficient area to accommodate the large cooling towers that will be necessary to serve Unit 2 and Unit 3. Much of this area is currently occupied by the power blocks for Unit 2 and Unit 3, the decommissioned site for Unit 1, the dry cask storage area (for spent fuel rods), the switchyard, and various support structures, parking areas, and maintenance buildings. Placement of wet cooling towers at SONGS will require removal and/or relocation of some of these structures as well as procurement of areas outside the current SCE property line.

The Mesa Complex, across the San Diego Freeway, was eliminated from consideration due to the hilly terrain that would require grading and excavation to prepare the site for cooling towers. Placement on the Mesa Complex side would require excavating tunnels under the freeway sufficiently sized to accommodate four 12-foot-diameter pipes. Even if these limitations could be overcome, the increased cost is likely to be significant, compared with an installation on the facility's beachfront side.

The north end of the SONGS property, as shown in Figure N–3, has few relatively close areas that can support a wet cooling tower complex. Area 1 comprises 510,000 square feet (1,700 feet by 300 feet) on a bluff overlooking San Onofre State Beach and is largely occupied by an employee parking lot.

Area 2 is the site of the retired Unit 1 complex and ongoing decommissioning activities occupying a 250,000-square-foot area immediately adjacent to Unit 2. This area could be used in conjunction with other areas to accommodate a portion of the cooling tower cells necessary for Unit 2 and to minimize some of the pipeline distances. However, it was eliminated from further consideration because it is not known when decommissioning activities will be completed and whether the area would be available for use at that time. Other areas were initially considered but ultimately eliminated because they currently house the spent fuel rod dry cask storage system and administration buildings (Area 3) and the facility switchyard (Area 4).

Area 1 was selected as the most practical location to accommodate the cooling towers for Unit 2. This study did not evaluate in detail the consequences of relocating the employee parking area, most likely to a location at the Mesa Complex, nor did it include the potential costs of that relocation.

The south end of the SONGS property, as shown in Figure N–4, is similarly constrained in terms of available siting locations. The combination of Area 5, occupied by the demineralizing system and employee parking, and Area 6, occupied by unidentified maintenance/support buildings, would be large enough to accommodate the cooling towers for Unit 3. These areas were eliminated from consideration, however, because their use would require removing several essential systems to other areas of the site. The disruption this would cause and the limited areas available for relocation are potentially significant issues that cannot be quantified within the scope of this study.

Area 7 is not within the boundaries of the current SCE property. It is an undeveloped coastal bluff overlooking the beach and comprises approximately 800,000 square feet (2,000 feet by 400 feet) of state park land. Use of the bluff for wet cooling towers is problematic due to the presence of Southern Coastal Bluff Scrub, which has been identified by the California Department of Fish and Game as a rare habitat type.

Thus, under the Coastal Act, this area is considered an Environmentally Sensitive Habitat (ESHA) and is subject to limits on development that encroaches upon it. The CCC has noted that the coastal development permit (CDP) issued to SCE for SONGS does not allow for significant clearing of vegetation and would require, at a minimum, an amendment to allow constructing wet cooling towers in this area.

PLG, Inc., in an analysis developed for SCE in 1990, first proposed this area as the Unit 3 cooling towers site but did not address the potential conflicts its use would entail (PLG 1990). This study (as does the PLG report) develops a wet cooling tower configuration for Unit 3 that also assumes the availability of the coastal bluff area identified as Area 7, with the strong caveat that use of this area would have to overcome substantial hurdles to comply with Coastal Act provisions. Area 7 is considered in this study only because no other areas were identified that could conceivably accommodate the towers for Unit 3. In the event Area 7 is unavailable, it is unlikely that a reasonable cooling tower configuration could be developed without significant disruption to facility operations.

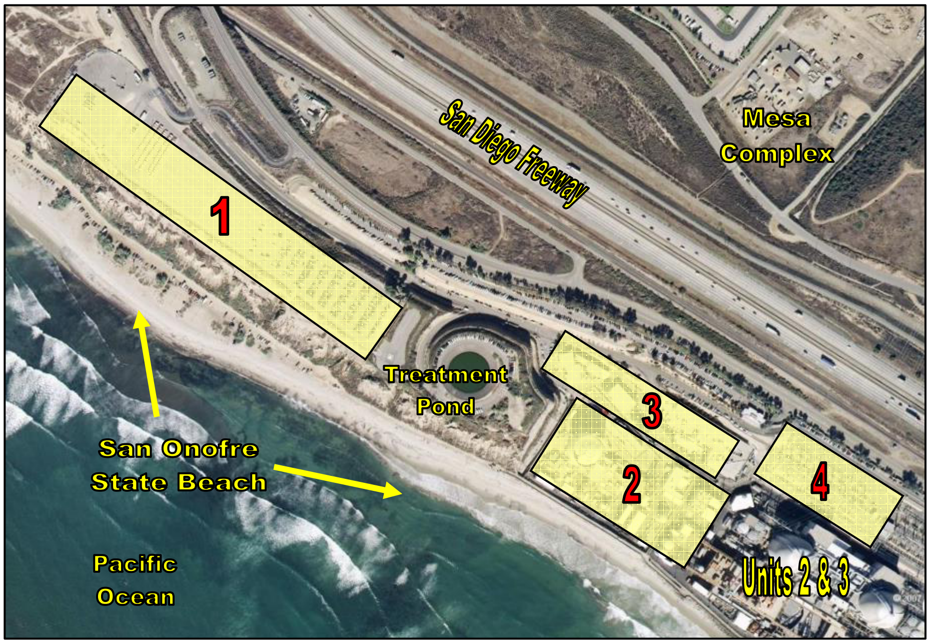

Figure N–3. SONGS Site View (North End)

Figure N–4. SONGS Site View (South End)

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above, two wet cooling tower complexes, each consisting of six towers, were selected to replace the current once-through cooling system at SONGS, for a total of 12 towers. Each tower complex will operate independently and be dedicated to one unit. Each tower at SONGS consists of plume-abated cells arranged in a multicell, inline configuration.

3.3.1 SIZE

Each tower is constructed over a concrete collection basin 4 feet deep. The basin is larger than the footprint of the tower structure, extending an additional 2 feet in each direction. The concrete used for construction is suitable for saltwater applications. The principal tower material is fiberglass reinforced plastic (FRP) with stainless steel fittings. These materials are more resistant to the higher corrosive effects of saltwater. The dry coil sections that form the plume abatement portion of the towers are constructed of titanium rather than stainless steel to limit performance losses that might result from corrosion.

The size of the tower is primarily based on the thermal load rejected to the tower by the surface condenser and a 12° F approach to the ambient wet bulb temperature. Flow rates through the condenser, as well as the design cooling range and terminal temperature difference, remain unchanged.

General characteristics of the wet cooling tower selected for SONGS are summarized in Table N–7.

Table N–7. Wet Cooling Tower Design

	Tower Complex 1 (Unit 2)	Tower Complex 2 (Unit 3)
Thermal load (MMBTU/hr)	7950	7950
Circulating flow (gpm)	795,600	795,600
Number of cells	48	48
Plume-free design point	50°F dry bulb 90% relative humidity	50°F dry bulb 90% relative humidity
Tower type	Mechanical draft	Mechanical draft
Flow orientation	Counterflow	Counterflow
Fill type	Modular splash	Modular splash
Arrangement	Inline	Inline
Primary tower material	FRP	FRP
Tower dimensions (l x w x h) (ft) [a]	480 x 66 x 62	480 x 66 x 62
Tower footprint with basin (l x w) (ft) [a]	484 x 70	484 x 70

[a] Six individual towers of these dimensions form each cooling tower complex.

3.3.2 LOCATION

The initial site selection for each tower was based on the desire to locate each tower as close as possible to its respective generating unit to minimize the supply and return pipe distances and any increases in total pump head and brake horsepower. The available options at SONGS do not allow for close placement. Figure N–5 identifies the approximate location of Tower Complex 1 (Unit 2) and supply and return piping. Figure N–6 identifies the approximate location of Tower Complex 2 (Unit 3) and supply and return piping.

Figure N–5. Location of Tower Complex 1

Figure N-6. Location of Tower Complex 2

3.3.3 PIPING

The routing of the main supply and return pipelines to and from the condensers is based on the 1990 PLG report, which assumed placement of long sections at the foot of the bluff overlooking the beach. All supply and return pipes are made of prestressed concrete cylinder pipe (PCCP) suitable for saltwater applications. Pipes extending from the towers to the edge of the bluff will be located underground. These pipes range in size from 120 to 140 inches in diameter.

Pipes extending from the bluff to the condenser are also PCCP, but placed above ground. The location of the condensers at SONGS (23 feet below grade level) makes a direct connection to the supply and return lines difficult. This study assumes supply and return lines would be connected to the existing intake and discharge pipes at some point beyond the seawall that serves as the western boundary of the main facility.

All riser piping (extending from the foot of the tower to the level of water distribution) is constructed of FRP.

Appendix B details the total quantity of each pipe size and type for SONGS.

3.3.4 FANS AND PUMPS

Each tower cell uses an independent single-speed fan. The fan size and motor power are the same for each cell in all 12 towers.

This analysis includes new pumps to circulate water between the condensers and cooling tower. Pumps are sized according to the flow rate for the tower, the relative distance between the tower and condenser, and the total head required to deliver water to the top of the cooling tower riser. A separate, multilevel pump house is constructed for each cooling tower complex and is sized to accommodate the motor control centers (MCCs) and appropriate electrical switchgear. The electrical installation includes all necessary transformers, cabling, cable trays, lighting, and lightning protection. A 50-ton overhead crane is also included to allow for pump servicing.

Fan and pump characteristics associated with a wet cooling tower at SONGS are summarized in Table N–8. The net electrical demand of the fans and new pumps are discussed further as part of the energy penalty analysis in Section 4.6.

Table N–8. Cooling Tower Fans and Pumps

		Tower Complex 1 (Unit 2)	Tower Complex 1 (Unit 3)
Fans	Number	48	48
	Type	Single speed	Single speed
	Efficiency	0.95	0.95
	Motor power (hp)	259	259
Pumps	Number	5	5
	Type	50% recirculating Mixed flow Suspended bowl Vertical	50% recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88
	Motor power (hp)	7,000	7,000

3.4 ENVIRONMENTAL EFFECTS

Converting the existing once-through cooling system at SONGS to wet cooling towers will significantly reduce the intake of seawater from the Pacific Ocean and will presumably reduce impingement and entrainment by a similar proportion. Because closed-cycle systems will almost always result in condenser cooling water temperatures higher than those found in a comparable once-through system, wet towers will increase the operating heat rates at Unit 2 and Unit 3, thereby decreasing the facility's overall efficiency. Additional power will also be consumed by the tower fans and circulating pumps.

As a PWR facility, SONGS is generally limited in how it can respond to these changes. While fossil fuel facilities may be able to increase the amount of fuel consumed to compensate for any shortfall, the complexities of a nuclear-fueled steam-generating unit and the inherent safety precautions that govern its operation generally preclude SONGS from increasing the thermal input to the system. Thus, any compensation for the reduced output must be obtained from other facilities on the grid.

Depending on the fuel source and efficiency of the facility providing the additional electricity, emissions for pollutants such as PM10, SOx, and NOx may increase and may require additional control measures or the purchase of emission credits to meet air quality regulations. The towers themselves will constitute a new source of PM10 emissions; the annual mass increase will largely depend on the utilization capacity of the generating units the tower serves.

If SONGS retains its NPDES permit to discharge wastewater to the Pacific Ocean with a wet cooling tower system, it may have to address revised effluent limitations resulting from the substantial change in the quantity and characteristics of the discharge. Impacts from the discharge of elevated-temperature wastes associated with the current once-through system, if any, will be minimized by using a wet cooling system.

3.4.1 AIR EMISSIONS

Drift volumes from wet cooling towers are expected to be within the range of 0.5 gallons for every 100,000 gallons of circulating water in the towers. At SONGS, this corresponds to a rate of approximately 8.2 gpm based on the maximum combined flow in the two tower complexes. The relative distances of the wet cooling towers from most facility structures (Figure N–5 and Figure N–6) do not appear to create any immediate concern over the effects of salt deposition on the switchyard or other sensitive equipment. Depending on the relocation of parking areas and other structures, drift is likely to be considered more of a nuisance rather than a threat to public health or safety, and will manifest itself as a whitish coating on exposed surfaces.

Total PM_{10} emissions from the SONGS cooling towers are a function of the number of hours in operation, overall water quality in the tower, and the evaporation rate of drift droplets prior to deposition on the ground. Makeup water at SONGS will be obtained from the same source currently used for once-through cooling water (Pacific Ocean). At 1.5 cycles of concentration and assuming an initial Total Dissolved Solids (TDS) value of 35 parts per thousand (ppt), the water within the cooling towers will reach a maximum TDS level of roughly 53 ppt. Any drift droplets exiting the tower will have the same TDS concentration.

As a nuclear facility, SONGS does not emit significant quantities of PM_{10}, SO_x, CO_2, or NO_x from its current operations. The emission of PM_{10} in substantial quantity from the wet cooling towers is likely to trigger enforcement of air quality regulations and may require SCE to obtain necessary operating permits from the San Diego County Air Pollution Control District (APCD). Table N–9 summarizes the estimated drift and PM_{10} emissions from the SONGS wet cooling towers.

Table N–9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower Complex 1	105	458	4.1	1,991
Tower Complex 2	105	458	4.1	1,991
Total SONGS PM_{10} and drift emissions	**210**	**916**	**8.2**	**3,982**

3.4.2 MAKEUP WATER

The volume of makeup water required by the cooling tower at SONGS is the sum of evaporative loss and the blowdown volume required to maintain the circulating water in the tower at the design TDS concentration. Drift expelled from the tower represents an insignificant volume by comparison and is accounted for by rounding up estimates of evaporative losses. Makeup water volumes are based on design conditions, and may fluctuate seasonally depending on climate conditions and facility operations. Use of wet cooling towers will reduce once-through cooling water withdrawals from the Pacific Ocean by approximately 95 percent over the current design intake capacity. (See Table N–10.)

Table N–10. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower Complex 1	795,600	12,800	25,600	38,400
Tower Complex 2	795,600	12,800	25,600	38,400
Total SONGS makeup water demand	**1,591,200**	**25,600**	**51,200**	**76,800**

The existing circulating water pumps are rated at 207,000 gpm while makeup water demand is only 38,400 per unit. In this case, the difference between these two values makes it unlikely that the existing pumps can be repurposed for use with the new system. The design developed for DCPP includes four new circulating water new circulating water pumps (two per unit) rated at 30,000 gpm each.

The existing once-through cooling system at SONGS does not treat water withdrawn from the Pacific Ocean, with the exception of screening for debris and larger organisms and periodic chlorination to control biofouling in the condenser tubes. Biofouling is controlled by periodic heat treatments that raise the temperature of the circulating water to 100º F.

Makeup water will continue to be withdrawn from the Pacific Ocean.

The wet cooling tower system proposed for SONGS includes water treatment for standard operational measures, i.e., fouling and corrosion control. Chemical treatment allowances are included in annual O&M costs. It is assumed that the current once-through cooling water quality will be acceptable for use in a seawater cooling tower (with continued screening and chlorination) and will not require any pretreatment to enable its use.

3.4.3 NPDES PERMIT COMPLIANCE

At maximum operation, wet cooling towers at SONGS will discharge approximately 73 mgd of blowdown in addition to other in-plant waste streams, such as regeneration wastes, boiler blowdown, and treated sanitary wastes. These low-volume wastes may add an additional 20 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, SONGS will be required to modify its existing individual wastewater discharge (NPDES) permit.

Current effluent limitations for conventional and priority pollutants, as well as thermal discharge limitations, are contained in NPDES permits CA0108073 (Unit 2) and CA0108181 (Unit 3), as implemented by SDRWQCB orders R9-2005-0005 (Unit 2) and R9-2005-0006 (Unit 3). All wastewaters are discharged to the Pacific Ocean through discharge conduits extending 8,350 feet and 5,900 feet offshore, terminating at a depth of 49 feet. The existing order contains effluent limitations based on the 2001 California Ocean Plan.

SONGS will be required to meet technology-based effluent limitations for cooling tower blowdown established under the Effluent Limitation Guidelines (ELGs) for Steam Electric Facilities (40 CFR 423.13(d)(1)). These ELGs set numeric limitations for chromium and zinc (0.2 mg/L and 1.0 mg/L, respectively) while establishing narrative criteria for priority pollutants (no detectable quantity). Because ELGs are technology-based limitations, mixing zones or dilution factors are not applicable when determining compliance; limits must be met at the point of discharge from the cooling tower prior to commingling with any other waste stream. ELGs for cooling tower blowdown target priority pollutants that are contributed by maintenance chemicals and do not apply when limits may be exceeded as a result of background concentrations or other sources. Further discussion can be found in Chapter 4, Section 3.6.

Conversion to wet cooling towers will alter the volume and composition of a facility's wastewater discharge because wet towers concentrate certain pollutants in the effluent waste stream. The cooling towers designed for SONGS operate at 1.5 cycles of concentration, i.e., the blowdown discharge will contain a dissolved solids concentration 50 percent higher than the makeup water.

Changes to discharge composition may affect compliance with water quality objectives included in the Ocean Plan. If compliance with these objectives becomes problematic, alternative treatment or discharge methods may be necessary. Compliance may be achieved by altering the discharge configuration in such a way as to increase dilution (e.g., diffuser ports), or by seeking a mixing zone and dilution credits as permissible under the Ocean Plan. Alternately, some low volume waste streams (e.g., boiler blowdown, laboratory drains) may be diverted, with necessary permits, for treatment at a POTW.

If more pollutant-specific treatment methods, such as filtration or precipitation technologies, become necessary to meet WQBELs, the initial capital cost may range from $2 to $5.50 per 1,000 gallons of treatment capacity, with annual costs of approximately $0.5 per gallon of capacity, depending on the method of treatment (FRTR 2002). Hazardous material disposal fees and permits would further increase costs.

This evaluation did not include alternative discharge or effluent treatment measures in the conceptual design because the variables used to determine final WQBELs, which would be used to determine the type and scope of the desired compliance method, cannot be quantified here. Likewise, the final cost evaluation (Section 4.0) does not include any allowance for these possibilities.

Thermal discharge standards are based on narrative criteria established for discharges to coastal waters under the Thermal Plan, which requires that existing discharges of elevated-temperature wastes comply with effluent limitations necessary to assure the protection of designated beneficial uses. The SDRWQCB has implemented this provision by establishing a maximum discharge temperature of no more than 25º F in excess of the temperature of the receiving water during normal operations (SDRWQCB 2005a, 2005b).

Information available for review indicates SONGS has consistently been able to comply with this requirement. Because cooling tower blowdown will be taken from the "cold" side of the tower, conversion to a wet cooling system will significantly reduce the discharge temperature (to less than 82º F) and the size of any related thermal plume in the receiving water.

3.4.4 RECLAIMED WATER

The use of reclaimed or alternative water sources could potentially eliminate all surface water withdrawals at SONGS. Doing so would completely eliminate impingement and entrainment concerns, and might enable the facility to avoid possible effluent quality and permit compliance issues, depending on the quality of reclaimed water available for use. In addition, wet cooling towers using reclaimed water would be expected to have lower PM_{10} emissions due to the lower TDS levels.

The California State Water Resources Control Board (SWRCB), in 1975, issued a policy statement requiring the consideration of alternative cooling methods in new power plants, including the use of reclaimed water, over the use of freshwater (SWRCB 1975). There is no similar policy regarding the use of marine waters, but the clear preference of state agencies is to encourage alternative cooling methods, including the use of reclaimed water, wherever possible.

The present volume of available reclaimed water within a 15-mile radius of SONGS (46 mgd) does not meet the current once-through cooling demand; thus, the use of reclaimed water is only applicable as a source of makeup water for a wet cooling tower system. This study did not pursue a detailed investigation of the use of reclaimed water because the conversion of the SONGS once-through cooling systems to saltwater cooling towers enables the facility to meet the performance targets for impingement and entrainment impact reductions outlined in the 2006 California Ocean Protection Council (OPC) Resolution on Once-Through Cooling Water (see Chapter 1).

To be acceptable for use as makeup water in cooling towers, reclaimed water must meet tertiary treatment and disinfection standards under California Code of Regulations (CCR) Title 22. If the reclaimed water is not treated to the required levels, SONGS would be required to provide sufficient treatment prior to use in the cooling towers.

Two combined outfalls to the Pacific Ocean were identified within a 15-mile radius of SONGS. These outfalls are managed by municipal agencies or authorities and combine the treated effluent from several publicly owned treatment works (POTWs) in the region. The combined discharge from these outfalls is 46 mgd. Figure N–8 shows the relative locations of these facilities to SONGS.

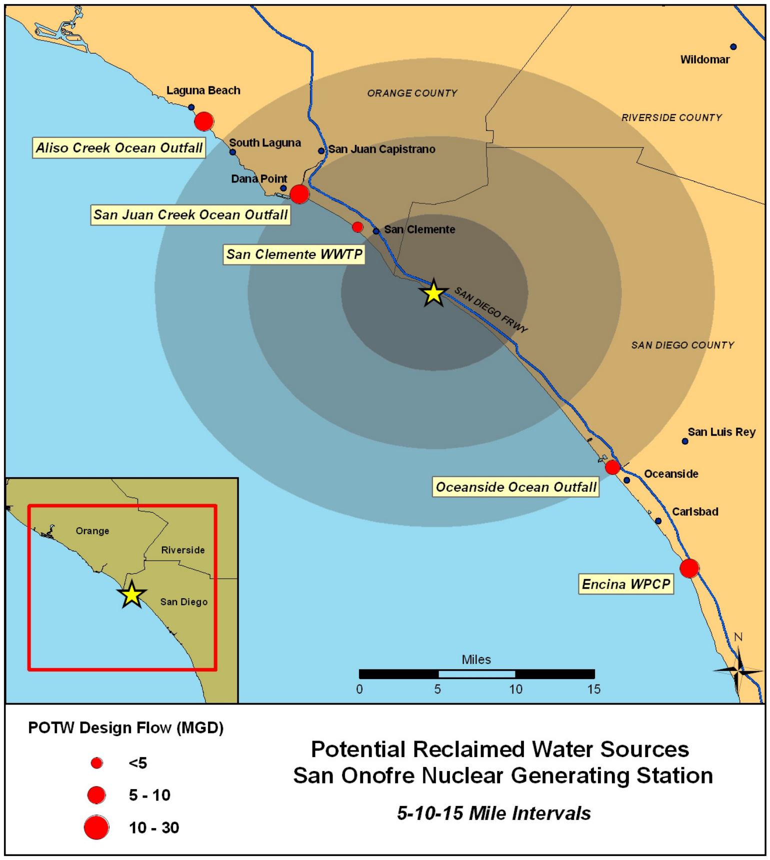

Figure N–7. Reclaimed Water Sources

- *Oceanside Ocean Outfall—City of Oceanside*
  Discharge volume: 27 mgd
  Distance: 15 miles SE
  Treatment level: Secondary

  The Oceanside Ocean Outfall (OOO) discharges treated effluent received from the San Luis Rey Wastewater Treatment Plant and La Salina Wastewater Treatment Plant operated by the city of Oceanside, the Fallbrook Public Utility District, and the U.S. Marine Corps Base at Camp Pendleton. The OOO extends approximately 8,000 feet offshore into the Pacific Ocean, terminating at a depth of 103 feet. No information is available regarding the volume of water currently reclaimed for other uses.

- *San Juan Creek Ocean Outfall—South Orange County Water Authority (SOCWA)*
  Discharge volume: 19 mgd
  Distance: 9.5 miles NW
  Treatment level: Secondary

  The San Juan Creek Ocean Outfall (SJCOO) discharges treated effluent received from the city of San Juan Capistrano, in addition to the South Coast, Santa Margarita, Trabuco Canyon, and Moulton Niguel water districts. The SJCOO extends approximately 10,500 feet offshore, southwest of Doheny State Beach. A portion of the wastewater generated in the SOCWA region is reclaimed for other purposes at the South Coast Water District's Advanced Water Treatment Plant. The volume of water discharged through the SJCOO represents the available volume of water that could be used to supply a portion of the makeup water demand at SONGS (45 to 50 mgd as freshwater towers).

- *San Clemente Wastewater Treatment Plant—San Clemente*
  Discharge volume: 4.7 mgd
  Distance: 6 miles NW
  Treatment level: Tertiary

  A portion of the tertiary treated water is used for local irrigation projects. No additional information available.

The costs associated with installing transmission pipelines (excavation/drilling, material, labor), in addition to design and permitting costs, are difficult to quantify in the absence of a detailed analysis of various site-specific parameters that influence the final configuration. Based on data compiled for this study and others, the estimated installed cost of a 60-inch prestressed concrete cylinder pipe, sufficient to provide 50 mgd to SONGS, is $600 per linear foot, or approximately $3.2 million per mile. Additional considerations, such as pump capacity and any required treatment, would increase the total cost. This estimate is based on excavating and installing a pipeline on land. It may be feasible or more practical to establish a connection to the outfalls by pipelines installed in the ocean.

Regulatory concerns beyond the scope of this investigation, however, may make the use of reclaimed water comparable or preferable to the use of saltwater from marine sources as makeup water. Reclaimed water may enable SONGS to reduce PM_{10} emissions from the cooling tower, which is a concern, given the current nonattainment status of the San Diego air basin, or to eliminate potential conflicts with water discharge limitations. SONGS might also realize other benefits by using reclaimed water in the form of reduced O&M costs. At any facility where wet cooling towers are a feasible alternative, reclaimed water may be used as a makeup water source. The practicality of its use, however, depends on the overall cost, availability, and additional environmental benefits that may occur.

3.4.5 THERMAL EFFICIENCY

The use of wet cooling towers at SONGS will increase the temperature of the condenser inlet water by 6 to 13° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at SONGS are designed to operate at the conditions described in Table N–11. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures at SONGS is described in Figure N–8.

Table N–11. Design Thermal Conditions

	Unit 2	Unit 3
Design backpressure (in. HgA)	2.1	2.1
Design water temperature (°F)	64	64
Turbine inlet temp (°F)	521	521
Turbine inlet pressure (psia)	821	821
Full load heat rate (BTU/kWh)	9,940	9,940

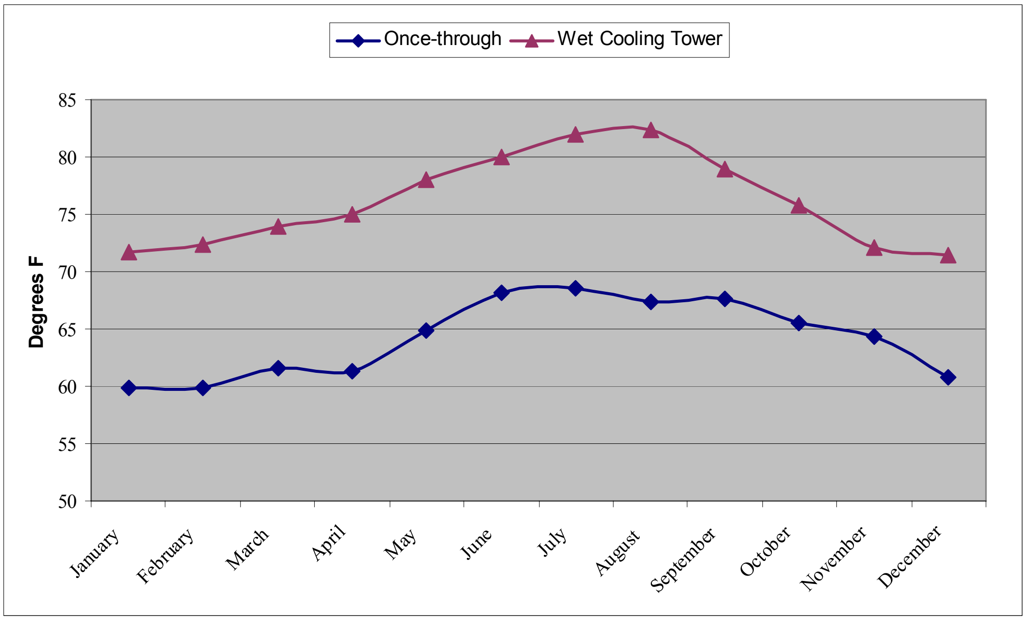

Figure N–8. Condenser Inlet Temperatures

Backpressures for the once-through and wet cooling tower configurations were calculated using the design criteria described in the sections above on a monthly basis using ambient climate data (Table N–6). In general, backpressures associated with the wet cooling tower were elevated by 0.5 to 0.85 inches HgA compared with the current once-through system (Figure N–9 and Figure N–11).

Heat rate adjustments were calculated by comparing the theoretical change in available energy that occurs at different turbine exhaust backpressures, assuming the thermal load and turbine inlet pressure remain constant, i.e., at the maximum load rating.4 The relative change at different backpressures was compared with the value calculated for the design conditions (i.e., at design turbine inlet and exhaust backpressures) and plotted as a percentage of the maximum operating heat rate to develop estimated correction curves (Figure N–10 and Figure N–12). A comparison was then made between the relative heat rates of the once-through and wet cooling systems for a given month. The difference between these two values represents the net increase in heat rate that would be expected in a converted system.

Table N–12 summarizes the annual average heat rate increase for each unit as well as the increase associated with the peak demand period of July-August-September. Monthly values were used to develop an estimate of the monetized value of these heat rate changes (Section 4.6). Month-by-month calculations are presented in Appendix A.

Table N–12. Summary of Estimated Heat Rate Increases

	Unit 2	Unit 3
Peak (July-August-September)	3.74%	3.74%
Annual average	2.88%	2.88%

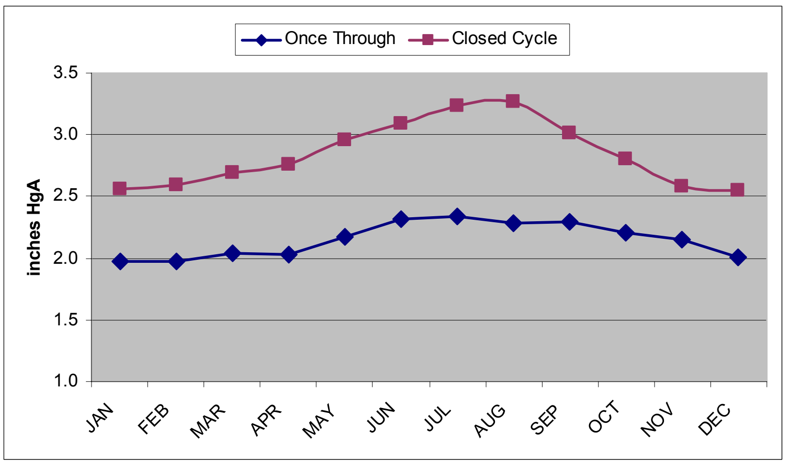

Figure N–9. Estimated Backpressures (Unit 2)

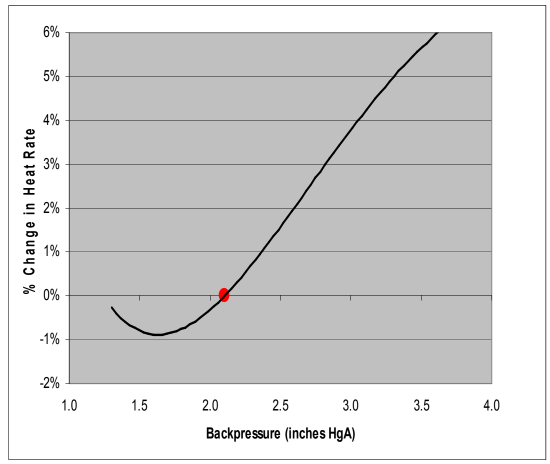

Figure N–10. Estimated Heat Rate Correction (Unit 2)

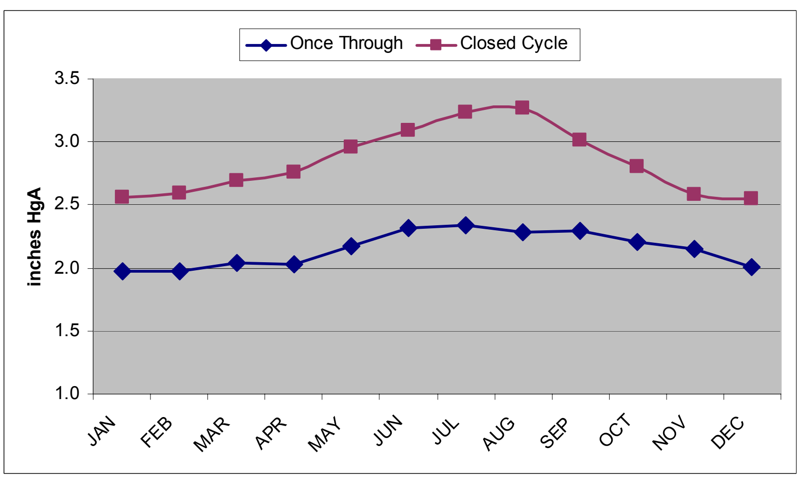

Figure N–11. Estimated Backpressures (Unit 3)

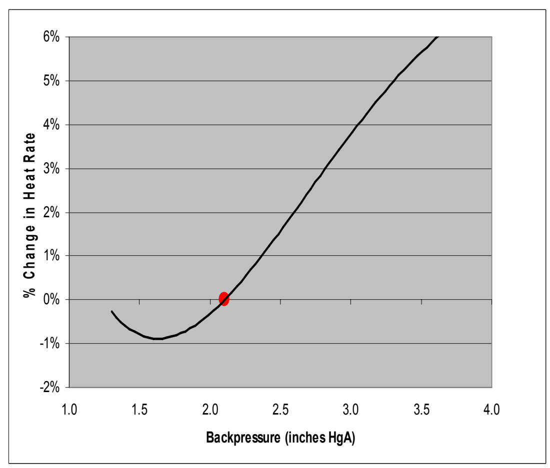

Figure N–12. Estimated Heat Rate Correction (Unit 3)

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for SONGS is based on incorporating plume-abated wet cooling towers as a replacement for the existing once-through systems for each unit. Standard cost elements for this project include the following:

- Direct (cooling tower installation, civil/structural, mechanical, piping, electrical, and demolition)
- Indirect (smaller project costs not itemized)
- Contingency (allowance for unknown project variables)
- Operations and maintenance (non–energy related cooling tower operations)
- Energy penalty (includes increased parasitic use from fans and pumps as well as decreased thermal efficiency)
- Revenue loss from shutdown (net loss in revenue during construction phase)

The cost analysis does not include allowances for elements that are not quantified in this study, such as land acquisition, effluent treatment, or air emission reduction credits. The methodology used to develop cost estimates is discussed in Chapter 5.

4.1 COOLING TOWER INSTALLATION

The requirement to use plume-abated towers at SONGS increases the per-cell cost by a factor of approximately 2.9 over the cost of conventional tower cells (compared with the cost estimates for other facilities in this study). Table N–13 summarizes the design-and-build cost estimate for each tower developed by vendors, inclusive of all labor and management required for its installation.

The dry components of the plume-abated cooling towers were designed with titanium tubing instead of stainless steel. Titanium is more resistant to corrosion and performance losses that would result from continued exposure to salt drift from the tower. Use of stainless steel tubing would decrease the cost of the towers by a total of $27 million, but with additional maintenance costs and potentially diminished performance.

Table N–13. Wet Cooling Tower Design-and-Build Cost Estimate

	Unit 2	Unit 3	SONGS total
Number of cells	48	48	**96**
Cost/cell ($)	1,770,833	1,770,833	**1,770,833**
Total SONGS D&B Cost ($)	**85,000,000**	**85,000,000**	**170,000,000**

4.2 OTHER DIRECT COSTS

A significant portion of the cost incurred for the wet cooling tower installation results from the various support structures and materials (pipes, pumps, etc.), as well the necessary equipment and labor required to prepare the cooling tower site and connect the towers to the cooling system. At SONGS, these costs comprise approximately 50 percent of the initial capital cost. Line item costs are detailed in Appendix B.

Deviations from or additions to the general cost elements discussed in Chapter 5 are discussed below. Other direct costs (non–cooling tower) are summarized in Table N–14.

- *Civil, Structural, and Piping*
  The significant distances at which the cooling tower complexes must be placed from their respective units (approximately 3,500 feet for each complex), and the large size of the necessary pipes (144 inches), represent substantial increases in cost over an average facility. In total, the cooling tower configurations developed for SONGS require more than 19,000 feet of supply and return piping. An additional allowance is included in this category to reflect the installation of pipelines on a steep grade from the top of the bluffs to the beach.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect incorporating new pumps (eight total) to circulate cooling water between the tower and condenser. No new pumps are required to provide makeup water from the Pacific Ocean. Electrical costs are based on the battery limit after the main feeder breakers.
- *Demolition*
  A small allowance is made for the demolition of the existing parking lot that will serve as the location for Tower Complex 1.

Table N–14. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	SONGS total ($)
Civil/structural/piping	13,900,000	68,500,000	40,700,000	**123,100,000**
Mechanical	25,100,000	0	1,900,000	**27,000,000**
Electrical	3,800,000	8,500,000	5,500,000	**17,800,000**
Demolition	0	0	100,000	**100,000**
Total SONGS other direct costs	**42,800,000**	**77,000,000**	**48,200,000**	**168,000,000**

4.3 INDIRECT AND CONTINGENCY

Indirect costs are calculated as 30 percent of all direct costs (civil/structural, mechanical, electrical, demolition, and cooling towers). An additional allowance is included for reinforcement of the condenser to withstand the increased pressures resulting from incorporating wet cooling towers. Each condenser may require reinforcement of the tube sheet bracing with 6-inch x 1-inch steel, and water box reinforcement/replacement with 5/8-inch carbon steel. Based on the data outlined in Chapter 5, a conservative estimate of 5 percent of all direct costs is included to account for possible condenser modifications. The location of the condensers (23 feet below grade) and the difficulty in accessing them for modifications may increase costs further, but cannot be evaluated within the scope of this study.

The contingency cost is calculated as 30 percent of the sum of all direct and indirect costs, including condenser reinforcement. At SONGS, potential costs in this category include relocation or demolition of small buildings and parking lots and the potential interference with underground structures, as well as the generally higher costs of construction projects at a secure nuclear facility. Disruption of coastal resources, if permitted, may require mitigation measures to allow the project to proceed. Soils were not characterized for this analysis. The instability of sandy soils may require additional pilings to support any large structures built at the site. Initial capital costs are summarized in Table N–15.

Table N–15. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	170,000,000
Civil/structural/piping	123,100,000
Mechanical	27,000,000
Electrical	17,800,000
Demolition	100,000
Indirect cost	101,400,000
Condenser modification	16,900,000
Contingency	136,900,000
Total SONGS capital cost	**593,200,000**

4.4 SHUTDOWN

A significant portion of the work relating to installing wet cooling towers can be completed without major disruption to operations. The principal disruption to the output of one or both units will result from the time and complexity of condenser reinforcements and the time needed to integrate the new cooling system and conduct acceptance testing.

For SONGS, a conservative estimate of 6 months per unit was developed. As a baseload facility, SONGS is typically operational 90 to 95 percent of the year; the difference between "low" and "high" output months is not significant; thus, the period selected for shutdown is based on the time of year when SONGS is "least" critical to the grid. The lost revenue estimate for SONGS is based on the average replacement cost for the month(s) of shutdown (November through April), less the estimated cost of generation for a nuclear facility ($/MWh). The estimated revenue loss for SONGS is $595 million and summarized in Table N-16.

Table N–16. Estimated Revenue Loss from Construction Shutdown

Estimated output (MWh)	Production savings ($/MWh)	Replacement cost ($/MWh)	Gross replacement cost ($)	Revenue loss ($)
8,261,443	12	84	693,961,212	**594,823,896**

This analysis did not consider shutdown with respect to the required availability of a particular generating unit, nor can it automatically be assumed that the generating profile for 2006 will be the same in each subsequent year. Net output data from 2006 may not reflect any contractual obligations that mandate a particular unit's availability during a given time period.

4.5 OPERATIONS AND MAINTENANCE

O&M costs for a wet cooling tower system at SONGS include routine maintenance activities, chemicals and treatment systems to control fouling and corrosion in the towers, management and labor, and an allowance for spare parts and replacement. Annual costs are calculated based on the circulating water flow capacity of the towers using a base cost of $4.00/gpm in Year 1 and $5.80/gpm in Year 12, with an annual escalator of 2 percent (USEPA 2001). Year 12 costs increase based on the assumption that maintenance needs, particularly for spare parts and replacements, will be greater for years 12–20. Annual O&M costs, based on the design circulating water flow for the 12 cooling towers at SONGS (1,591,200 gpm), are presented in Table N–17. These costs reflect maximum operation.

Table N–17. Annual O&M Costs (Full Load)

	Year 1 ($)	Year 12 ($)
Management/labor	1,591,200	2,307,240
Service/parts	2,545,920	3,691,584
Fouling	2,227,680	3,230,136
Total SONGS O&M cost	**6,364,800**	**9,228,960**

4.6 ENERGY PENALTY

The energy penalty is divided into two components: increased parasitic use resulting from the additional electrical demand of cooling tower fans and pumps; and the decrease in thermal efficiency resulting from elevated turbine backpressure values. As discussed above, it is unlikely that SONGS will be able to alter operations to compensate for the shortfall in electricity production resulting from the energy penalty; any changes to generation output will be absorbed as a direct loss of revenue. The energy penalty for SONGS is calculated by first estimating the increased parasitic demand from the cooling tower pumps and fans, expressed as a percentage of the rated capacity of the particular unit(s). Likewise, the change in the unit's heat rate is also expressed as a capacity percentage. The sum of these values represents the percentage reduction in revenue-generating electricity SONGS will be able to produce with a wet cooling tower system.

4.6.1 INCREASED PARASITIC USE (FANS AND PUMPS)

As a baseload facility with an annual capacity utilization average of 85 percent or greater, SONGS will likely require the maximum cooling capacity of the wet cooling towers when the generating units are operational. During cooler periods of the year, SONGS may be able to take one or more cooling tower cells offline and still obtain the required cooling level. This would also reduce the fans' cumulative electrical demand. For the purposes of this study, however, operations are evaluated at the design conditions, i.e., maximum load; no allowance is made for seasonal changes. The increased electrical demand associated with operation of the cooling tower fans is summarized in Table N–18.

Table N–18. Cooling Tower Fan Parasitic Use

	Tower Complex 1	Tower Complex 2	SONGS total
Units served	Unit 2	Unit 3	--
Generating capacity (MW)	1,127	1,127	**2,254**
Number of fans (one per cell)	48	48	**96**
Motor power per fan (hp)	259	259	--
Total motor power (hp)	12,429	12,429	**24,858**
MW total	9.27	9.27	**18.54**
Fan parasitic use (% of capacity)	**0.82%**	**0.82%**	**0.82%**

The addition of new circulating water pump capacity for the wet cooling towers will also increase the parasitic use of electricity at SONGS. Makeup water will continue to be withdrawn from the Pacific Ocean through the use of one of the existing circulating water pumps; the remaining pumps will be retired. The net increase in pump-related parasitic usage is the difference between the new wet cooling tower configuration (new plus retained pumps) and the existing once-through configuration. Because one of the main design assumptions maintains the existing flow rate through each condenser, the new circulating pumps are single speed and are assumed to operate at their full rated capacity. The increased electrical demand associated with operating the cooling tower pumps is summarized in Table N–19.

Table N–19. Cooling Tower Pump Parasitic Use

	Tower Complex 1	Tower Complex 2	SONGS total
Units served	Unit 2	Unit 3	--
Generating capacity (MW)	1127	1127	**2,254**
Existing pump configuration (hp)	11,400	11,400	**22,800**
New pump configuration (hp)	38,200	38,200	**76,400**
Difference (hp)	26,800	26,800	**53,600**
Difference (MW)	20.0	20.0	**40.0**
Net pump parasitic use (% of capacity)	**1.77%**	**1.77%**	**1.77%**

4.6.2 HEAT RATE CHANGE

Adjustments to the heat rate were calculated based on the ambient conditions for each month and reflect the estimated difference between operations with once-through and wet cooling tower systems. As noted above, the energy penalty analysis assumes SONGS will absorb the financial loss associated with the reduction in revenue-generating electricity. The monthly percentage changes in the heat rate for each unit at SONGS are presented in Figure N–13 and Figure N–14.

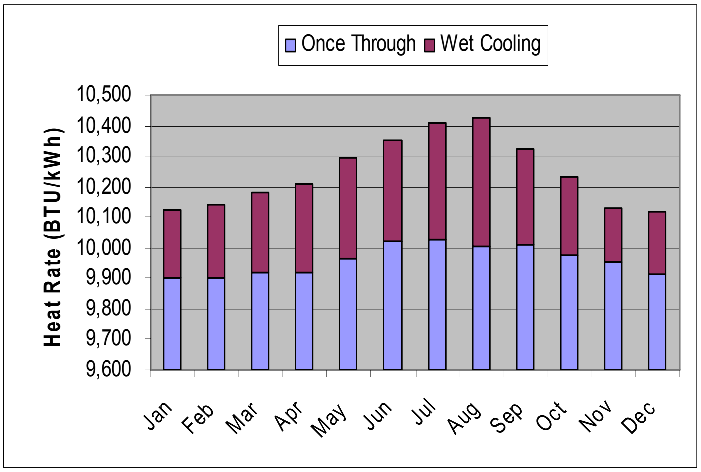

Figure N–13. Estimated Heat Rate Change (Unit 2)

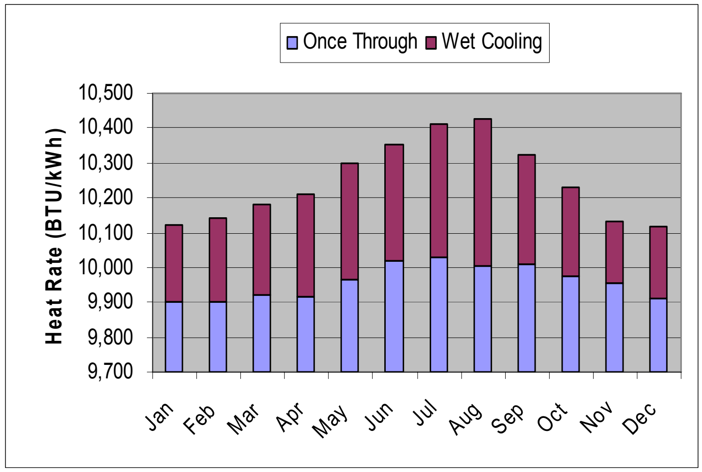

Figure N–14. Estimated Heat Rate Change (Unit 3)

4.6.3 CUMULATIVE ESTIMATE

The cost of the energy penalty for SONGS is calculated by first summing the three components of the penalty (efficiency + fan + pump), expressed as a percentage of the capacity, and multiplying this value by the net generation for each month. This yields the relative amount of revenue-generating electricity, expressed as MWh, that will be lost as a result of converting the once-through cooling system to wet cooling towers. The monthly cost is calculated using the average annual replacement cost ($84/MWh) obtained from the PG&E 2006 annual report. Based on 2006 net output, the monetary value of the annual energy penalty for SONGS will be approximately $80 million in Year 1. Table N–20 and Table N–21 summarize the Year 1 energy penalty estimates for each unit.

Table N-20. Unit 2 Energy Penalty—Year 1

Month	Replacement cost ($/MWh)	Net 2006 Generation (MWh)	Energy penalty				Generation shortfall (MWh)	Net Cost ($)
			Efficiency (%)	Fan (%)	Pump (%)	Total (%)		
January	84.00	712,715	2.22	0.82	1.77	4.82	34,336	2,884,246
February	84.00	545,288	2.39	0.82	1.77	4.99	27,206	2,285,276
March	84.00	0	2.63	0.82	1.77	5.23	0	0
April	84.00	730,296	2.95	0.82	1.77	5.54	40,470	3,399,445
May	84.00	820,213	3.35	0.82	1.77	5.95	48,808	4,099,842
June	84.00	804,330	3.37	0.82	1.77	5.97	47,981	4,030,439
July	84.00	826,713	3.83	0.82	1.77	6.43	53,154	4,464,948
August	84.00	832,706	4.21	0.82	1.77	6.81	56,670	4,760,316
September	84.00	806,706	3.16	0.82	1.77	5.76	46,457	3,902,347
October	84.00	835,284	2.59	0.82	1.77	5.19	43,336	3,640,233
November	84.00	809,927	1.78	0.82	1.77	4.38	35,470	2,979,444
December	84.00	842,201	2.06	0.82	1.77	4.66	39,250	3,297,001
							Unit 3 total	**39,743,537**

Table N-21. Unit 3 Energy Penalty—Year 1

Month	Replacement cost ($/MWh)	Net 2006 Generation (MWh)	Energy penalty				Generation shortfall (MWh)	Net Cost ($)
			Efficiency (%)	Fan (%)	Pump (%)	Total (%)		
January	84.00	837,731	2.22	0.82	1.77	4.82	40,359	3,390,168
February	84.00	754,393	2.39	0.82	1.77	4.99	37,638	3,161,627
March	84.00	755,515	2.63	0.82	1.77	5.23	39,512	3,319,008
April	84.00	730,296	2.95	0.82	1.77	5.54	40,470	3,399,445
May	84.00	763,024	3.35	0.82	1.77	5.95	45,405	3,813,983
June	84.00	807,492	3.37	0.82	1.77	5.97	48,170	4,046,283
July	84.00	828,197	3.83	0.82	1.77	6.43	53,250	4,472,963
August	84.00	835,310	4.21	0.82	1.77	6.81	56,848	4,775,202
September	84.00	807,408	3.16	0.82	1.77	5.76	46,497	3,905,743
October	84.00	737,869	2.59	0.82	1.77	5.19	38,282	3,215,692
November	84.00	0	1.78	0.82	1.77	4.38	0	0
December	84.00	712,715	2.06	0.82	1.77	4.66	33,215	2,790,096
							Unit 3 total	**40,290,210**

4.7 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at SONGS is the sum of all annual expenditures over the 20-year life span of the project, discounted according to the year in which the expense is incurred, and the selected discount rate. The NPC represents the total change in revenue streams, in 2007 dollars, that SONGS can expect over 20 years as a direct result of converting to wet cooling towers. The following values were used to calculate the NPC at a 7 percent discount rate:

- *Capital and Start-up.* Includes all capital, indirect, contingency, and shutdown costs. All costs in this category are incurred in Year 0. (See Table N–15 and Table N–16.)
- *Annual O&M*. Base cost values for Year 1 and Year 12 are adjusted for subsequent years using a 2 percent year-over-year escalator. Because SONGS is a baseload facility and operates at a relatively high capacity utilization factor, O&M costs for the NPC calculation were estimated at 100 percent of their maximum value. (See Table N–17.)
- *Annual Energy Penalty.* As a baseload facility, SONGS can be expected to operate at a high capacity utilization rate over its remaining life span. This study uses the 5-year average MWh output (2001–2006) as the basis for calculating the energy penalty in Years 1 through 20, including a year-over-year wholesale price escalation of 5.8 percent (based on the Producer Price Index). (See Table N–20 and Table N–21.)

Using these values, the NPC20 for SONGS is $2,621 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by SONGS for the retrofit of the once-through cooling system is the sum of the annual amortized capital cost plus the annual average of O&M and energy penalty expenditures. Capital costs are amortized at a 7 percent discount rate over 20 years. O&M and energy penalty costs are calculated in the same manner as for the NPC_{20} (Section Table N–22).

Table N–22. Annual Cost

Discount rate (%)	Capital ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00	56,000,000	8,400,000	144,500,000	**208,900,000**

4.9 COST-TO-GROSS REVENUE COMPARISON

Financial data available to conduct a detailed analysis of the economic impact that a wet cooling system retrofit will have on annual revenues for SGS are limited. As an investor-owned utility, SCE's gross revenues will include costs for transmission and distribution. An approximation of gross annual revenues was calculated using public data sources (US EIA 2005) that showed SCE's average annual retail rate was $125/MWh. This rate was applied to the monthly net generating outputs for each unit in 2006 (CEC 2006) to arrive at a facility-wide revenue estimate.

This estimate does not reflect seasonal adjustments that may translate to higher or lower per-MWh retail rates through the year, nor does it include other liabilities such as taxes or other operational costs.

The estimated gross revenue for SONGS is summarized in Table N–23. A comparison of annual costs to annual gross revenue is summarized in Table N–24.

Table N–23. Estimated Gross Revenue

	Retail rate ($/MWh)	Net generation (MWh)		Estimated gross revenue ($)		
		Unit 2	Unit 3	Unit 2	Unit 3	SONGS total
January	125	712,715	837,731	89,089,350	104,716,375	**193,805,725**
February	125	545,288	754,393	68,160,960	94,299,125	**162,460,085**
March	125	0	755,515	0	94,439,375	**94,439,375**
April	125	730,296	730,296	91,287,000	91,287,000	**182,574,000**
May	125	820,213	763,024	102,526,625	95,378,010	**197,904,635**
June	125	804,330	807,492	100,541,250	100,936,500	**201,477,750**
July	125	826,713	828,197	103,339,125	103,524,625	**206,863,750**
August	125	832,706	835,310	104,088,250	104,413,750	**208,502,000**
September	125	806,706	807,408	100,838,250	100,926,000	**201,764,250**
October	125	835,284	737,869	104,410,500	92,233,680	**196,644,180**
November	125	809,927	0	101,240,875	0	**101,240,875**
December	125	842,201	712,715	105,275,125	89,089,350	**194,364,475**
	SONGS total	**8,566,379**	**8,569,950**	**1,070,797,310**	**1,071,243,790**	**2,142,041,100**

Table N–24. Cost-Revenue Comparison

Estimated gross annual revenue ($)	Initial capital		O&M		Energy penalty		Total annual cost	
	Cost ($)	% of gross	Cost ($)	% of gross	Cost ($)	% of gross	Cost ($)	% of gross
2,142,000,000	56,000,000	2.6	8,400,000	0.4	144,500,000	6.7	**208,900,000**	**9.8**

5.0 OTHER TECHNOLOGIES

Within the scope of this study, and using the OPC resolution's stated goal of reducing impingement and entrainment by 90–95 percent as a benchmark, the effectiveness of other technologies commonly used to address such impacts could not be conclusively determined for use at SONGS. As with many existing facilities, the location and configuration of the site complicates the use of some technologies that might be used successfully elsewhere. A more detailed analysis that also comprises a biological evaluation may determine the applicability of one or more of these technologies to SONGS. A brief summary of the applicability of these technologies follows.

5.1 MODIFIED RISTROPH SCREENS—FINE MESH

The principal concern with this technology is the successful return of viable organisms captured on the screens to the source water body. SONGS currently withdraws its cooling water through a submerged conduit extending approximately 3,100 feet offshore at a depth of 35 feet. Returning any collected organisms to a similar location would be impractical. It is unclear whether organisms could be returned to a near-shore location closer to the facility and remain viable.

5.2 BARRIER NETS

Barrier nets are unproven in an open ocean environment.

5.3 AQUATIC FILTRATION BARRIERS

Aquatic filtration barriers (AFBs) are unproven in an open ocean environment.

5.4 VARIABLE SPEED DRIVES

Variable speed drives (VSDs) were not considered for analysis at SONGS because the technology alone cannot be expected to achieve the desired level of reductions in impingement and entrainment, nor could it be combined with another technology to yield the desired reductions.

Pumps that have been retrofitted with VSDs can reduce overall flow intake volumes by 10–35 percent over the current once-through configuration (USEPA 2001). The actual reduction, however, will vary based on the cooling water demand at different times of the year. At peak demand, the pumps will essentially function as standard circulating water pumps and withdraw water at the maximum rated capacity, negating any potential benefit. Use of VSDs may be an economically desirable option when pumps are retrofitted or replaced for other reasons, but were not considered further for this study.

5.5 CYLINDRICAL FINE-MESH WEDGEWIRE

Fine-mesh cylindrical wedgewire screens have not been deployed or evaluated at open coastal facilities for applications as large as required at SONGS (approximately 2,300 mgd). To function as intended, cylindrical wedgewire screens must be submerged in a water body with a consistent ambient current of 0.5 fps. Ideally, this current would be unidirectional so that screens may be oriented properly and any debris impinged on the screens will be carried downstream when the airburst cleaning system is activated.

Fine-mesh wedgewire screens for SONGS would be located offshore in the Pacific Ocean, west of the facility. Information regarding the subsurface currents in the near-shore environment close to SONGS is limited. Data suggest that these currents are multidirectional, depending on the tide and season, and fluctuate in terms of velocity, with prolonged periods below 0.5 fps (SCCOOS 2006).

To attain sufficient depth (approximately 20 feet) and an ambient current that might allow deployment, screens would need to be located 2,000 feet or more offshore. Discussions with vendors who design these systems indicated that distances more than 1,000 to 1,500 feet become problematic due to the inability of the airburst system to maintain adequate pressure for sufficient cleaning (Someah 2007). Together, these considerations preclude further evaluation of fine-mesh cylindrical wedgewire screens at SONGS.

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Appendix A. Once-Through and Closed-Cycle Thermal Performance

		Unit 2			Unit 3		
		Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase
JAN	Backpressure (in. HgA)	1.97	2.56	**0.58**	1.97	2.56	**0.58**
	Heat rate Δ (%)	*-0.39*	*1.83*	***2.22***	*-0.39*	*1.83*	***2.22***
FEB	Backpressure (in. HgA)	1.98	2.60	**0.62**	1.98	2.60	**0.62**
	Heat rate Δ (%)	*-0.38*	*2.01*	***2.39***	*-0.38*	*2.01*	***2.39***
MAR	Backpressure (in. HgA)	2.04	2.69	**0.65**	2.04	2.69	**0.65**
	Heat rate Δ (%)	*-0.21*	*2.42*	***2.63***	*-0.21*	*2.42*	***2.63***
APR	Backpressure (in. HgA)	2.03	2.75	**0.72**	2.03	2.75	**0.72**
	Heat rate Δ (%)	*-0.24*	*2.71*	***2.95***	*-0.24*	*2.71*	***2.95***
MAY	Backpressure (in. HgA)	2.17	2.95	**0.78**	2.17	2.95	**0.78**
	Heat rate Δ (%)	*0.23*	*3.59*	***3.35***	*0.23*	*3.59*	***3.35***
JUN	Backpressure (in. HgA)	2.32	3.09	**0.77**	2.32	3.09	**0.77**
	Heat rate Δ (%)	*0.79*	*4.16*	***3.37***	*0.79*	*4.16*	***3.37***
JUL	Backpressure (in. HgA)	2.34	3.23	**0.89**	2.34	3.23	**0.89**
	Heat rate Δ (%)	*0.90*	*4.73*	***3.83***	*0.90*	*4.73*	***3.83***
AUG	Backpressure (in. HgA)	2.28	3.27	**0.99**	2.28	3.27	**0.99**
	Heat rate Δ (%)	*0.66*	*4.87*	***4.21***	*0.66*	*4.87*	***4.21***
SEP	Backpressure (in. HgA)	2.29	3.02	**0.72**	2.29	3.02	**0.72**
	Heat rate Δ (%)	*0.70*	*3.86*	***3.16***	*0.70*	*3.86*	***3.16***
OCT	Backpressure (in. HgA)	2.20	2.80	**0.60**	2.20	2.80	**0.60**
	Heat rate Δ (%)	*0.34*	*2.94*	***2.59***	*0.34*	*2.94*	***2.59***
NOV	Backpressure (in. HgA)	2.15	2.58	**0.43**	2.15	2.58	**0.43**
	Heat rate Δ (%)	*0.15*	*1.94*	***1.78***	*0.15*	*1.94*	***1.78***
DEC	Backpressure (in. HgA)	2.01	2.55	**0.54**	2.01	2.55	**0.54**
	Heat rate Δ (%)	*-0.29*	*1.77*	***2.06***	*-0.29*	*1.77*	***2.06***

Note: Heat rate delta represents change from design value calculated according to estimated ambient conditions for each month.

Appendix B. Itemized Capital Costs

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
CIVIL / STRUCTURAL / PIPING	--	--	--	--	--	--	--	--	--	--
Allocation for additional costs for installing pipes in steep hill	lot	1	--	--	1,000,000	1,000,000	10,000.00	100	1,000,000	**2,000,000**
Allocation for other accessories (bends, water hammers…)	lot	1	--	--	500,000	500,000	4,000.00	85	340,000	**840,000**
Allocation for pipe racks (approx 1200 ft) and cable racks	t	120	--	--	2,500	300,000	17.00	105	214,200	**514,200**
Allocation for sheet piling and dewatering	lot	1	--	--	2,500,000	2,500,000	25,000.00	100	2,500,000	**5,000,000**
Allocation for testing pipes	lot	2	--	--	--	--	2,000.00	95	380,000	**380,000**
Allocation for Tie-Ins to existing condenser's piping	lot	1	--	--	250,000	250,000	2,000.00	85	170,000	**420,000**
Allocation for trust blocks	lot	1	--	--	50,000	50,000	500.00	95	47,500	**97,500**
Backfill for PCCP pipe (reusing excavated material)	m3	88,365	--	--	--	--	0.04	200	706,920	**706,920**
Bedding for PCCP pipe	m3	63,365	--	--	25	1,584,125	0.04	200	506,920	**2,091,045**
Bend for PCCP pipe 120" diam (allocation)	ea	10	--	--	35,000	350,000	100.00	95	95,000	**445,000**
Bend for PCCP pipe 144" diam. (allocation)	ea	35	--	--	75,000	2,625,000	180.00	95	598,500	**3,223,500**
Bend for PCCP pipe 42" & 48" diam (allocation)	ea	34	--	--	5,000	170,000	25.00	95	80,750	**250,750**
Building architectural (siding, roofing, doors, painting…etc)	ea	4	--	--	250,000	1,000,000	3,000.00	95	1,140,000	**2,140,000**
Butterfly valves 120" c/w allocation for actuator & air lines	ea	4	252,000	1,008,000	--	--	80.00	85	27,200	**1,035,200**
Butterfly valves 144" c/w allocation for actuator & air lines	ea	12	429,000	5,148,000	--	--	100.00	85	102,000	**5,250,000**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	96	30,800	2,956,800	--	--	50.00	85	408,000	**3,364,800**
Butterfly valves 48" c/w allocation for actuator & air lines	ea	10	46,200	462,000	--	--	50.00	85	42,500	**504,500**
Butterfly valves 96" c/w allocation for actuator & air lines	ea	16	151,200	2,419,200	--	--	75.00	85	102,000	**2,521,200**
Check valves 48"	ea	2	66,000	132,000	--	--	24.00	85	4,080	**136,080**
Check valves 96"	ea	8	216,000	1,728,000	--	--	40.00	85	27,200	**1,755,200**
Concrete basin walls (all in)	m3	1,869	--	--	225	420,525	8.00	75	1,121,400	**1,541,925**
Concrete elevated slabs (all in)	m3	1,702	--	--	250	425,500	10.00	75	1,276,500	**1,702,000**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Concrete for transformers and oil catch basin (allocation)	m3	200	--	--	250	50,000	10.00	75	150,000	**200,000**
Concrete slabs on grade (all in)	m3	16,075	--	--	200	3,215,000	4.00	75	4,822,500	**8,037,500**
Ductile iron cement pipe 12" diam. for fire water line	ft	6,000	--	--	100	600,000	0.60	95	342,000	**942,000**
Excavation and backfill for fire line, blowdown & make-up (using excavated material for backfill except for bedding)	m3	21,785	--	--	--	--	0.08	200	348,560	**348,560**
Excavation for PCCP pipe	m3	####	--	--	--	--	0.04	200	1,794,080	**1,794,080**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	**5,250**
Flange for PCCP joints 120"	ea	12	--	--	39,795	477,540	40.00	95	45,600	**523,140**
Flange for PCCP joints 144"	ea	24	--	--	68,000	1,632,000	75.00	95	171,000	**1,803,000**
Flange for PCCP joints 30"	ea	96	--	--	2,260	216,960	16.00	95	145,920	**362,880**
Flange for PCCP joints 42"	ea	2	--	--	3,270	6,540	18.00	95	3,420	**9,960**
Foundations for pipe racks and cable racks	m3	280	--	--	250	70,000	8.00	75	168,000	**238,000**
FRP flange 30"	ea	288	--	--	1,679	483,595	50.00	85	1,224,000	**1,707,595**
FRP flange 48"	ea	26	--	--	3,000	78,000	75.00	85	165,750	**243,750**
FRP flange 96"	ea	56	--	--	40,000	2,240,000	500.00	85	2,380,000	**4,620,000**
FRP pipe 96" diam.	ft	400	--	--	2,838	1,135,200	1.75	85	59,500	**1,194,700**
Harness clamp 120" c/w internal testable joint for PCCP pipe	ea	250	--	--	4,310	1,077,500	25.00	95	593,750	**1,671,250**
Harness clamp 144" c/w internal testable joint	ea	1,300	--	--	5,275	6,857,500	30.00	95	3,705,000	**10,562,500**
Harness clamp 42" & 48" c/w internal testable joint	ea	340	--	--	2,000	680,000	16.00	95	516,800	**1,196,800**
Joint for FRP pipe 96" diam.	ea	20	--	--	17,974	359,480	600.00	85	1,020,000	**1,379,480**
PCCP pipe 120" diam.	ft	4,000	--	--	1,285	5,140,000	3.50	95	1,330,000	**6,470,000**
PCCP pipe 144" diam.	ft	15,200	--	--	1,820	27,664,000	5.00	95	7,220,000	**34,884,000**
PCCP pipe 42" dia.for blowdown	ft	400	--	--	195	78,000	0.90	95	34,200	**112,200**
PCCP pipe 48" dia. for make-up water line	ft	6,400	--	--	260	1,664,000	1.00	95	608,000	**2,272,000**
Riser (FRP pipe 30" diam X55 ft)	ea	96	--	--	15,350	1,473,580	150.00	85	1,224,000	**2,697,580**
Structural steel for building	t	840	--	--	2,500	2,100,000	20.00	105	1,764,000	**3,864,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**13,854,000**	**--**	**68,475,546**	**--**	**--**	**40,730,500**	**123,060,046**
DEMOLITION	--	--	--	--	--	--	--	--	--	--
Demolition of parking lot	ea	1	--	--	--	--	1,000.00	100	100,000	**100,000**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
DEMOLITION TOTAL	--	--	--	**0**	--	**0**	--	--	**100,000**	**100,000**
ELECTRICAL	--	--	--	--	--	--	--	--	--	--
4.16 kv cabling feeding MCC's	m	4,000	--	--	75	300,000	0.40	85	136,000	**436,000**
4.16kV switchgear - 8 breakers	ea	1	350,000	350,000	--	--	250.00	85	21,250	**371,250**
480 volt cabling feeding MCC's	m	2,000	--	--	70	140,000	0.40	85	68,000	**208,000**
480V Switchgear - 1 breaker 3000A	ea	16	30,000	480,000	--	--	80.00	85	108,800	**588,800**
Allocation for automation and control	lot	1	--	--	2,000,000	2,000,000	20,000.00	85	1,700,000	**3,700,000**
Allocation for cable trays and duct banks	m	7,000	--	--	75	525,000	1.00	85	595,000	**1,120,000**
Allocation for lighting and lightning protection	lot	1	--	--	200,000	200,000	2,000.00	85	170,000	**370,000**
Dry Transformer 2MVA xxkV-480V	ea	16	100,000	1,600,000	--	--	100.00	85	136,000	**1,736,000**
Lighting & electrical services for pump house building	ea	4	--	--	90,000	360,000	1,000.00	85	340,000	**700,000**
Local feeder for 250 HP motor 460 V (up to MCC)	ea	96	--	--	18,000	1,728,000	150.00	85	1,224,000	**2,952,000**
Local feeder for 7000 HP motor 4160 V (up to MCC)	ea	8	--	--	60,000	480,000	250.00	85	170,000	**650,000**
Oil Transformer 20MVA xx-4.16kV	ea	4	250,000	1,000,000	--	--	200.00	85	68,000	**1,068,000**
Primary breaker(xxkV)	ea	8	45,000	360,000	--	--	60.00	85	40,800	**400,800**
Primary feed cabling (assumed 13.8 kv)	m	16,000	--	--	175	2,800,000	0.50	85	680,000	**3,480,000**
ELECTRICAL TOTAL	--	--	--	**3,790,000**	--	**8,533,000**	--	--	**5,457,850**	**17,780,850**
MECHANICAL	--	--	--	--	--	--	--	--	--	--
Allocation for ventilation of buildings	ea	4	100,000	400,000	--	--	1,000.00	85	340,000	**740,000**
Cooling tower for unit 2	lot	1	85,000,000	85,000,000	--	--	--	--	--	**85,000,000**
Cooling tower for unit 3	lot	1	85,000,000	85,000,000	--	--	--	--	--	**85,000,000**
Overhead crane 50 ton in (in pump house) Including additional structure to reduce the span	ea	4	500,000	2,000,000	--	--	1,000.00	85	340,000	**2,340,000**
Pump 4160 V 2000 HP	ea	4	1,000,000	4,000,000	--	--	500.00	85	170,000	**4,170,000**
Pump 4160 V 7000 HP	ea	10	1,870,000	18,700,000	--	--	1,200.00	85	1,020,000	**19,720,000**
MECHANICAL TOTAL	--	--	--	**195,100,000**	--	**0**	--	--	**1,870,000**	**196,970,000**

Appendix C. Net Present Cost Calculation

Project year	Capital/start-up ($)	O & M ($)	Energy penalty ($)		Total ($)	Annual discount factor	Present value ($)
			Unit 1	Unit 2			
0	1,187,823,896	--	--	--	1,187,823,896	1	**1,187,823,896**
1	--	6,364,800	39,743,538	40,290,210	86,398,548	0.9346	**80,748,083**
2	--	6,492,096	42,060,586	42,639,130	91,191,812	0.8734	**79,646,929**
3	--	6,621,938	44,512,718	45,124,991	96,259,647	0.8163	**78,576,750**
4	--	6,754,377	47,107,810	47,755,778	101,617,964	0.7629	**77,524,345**
5	--	6,889,464	49,854,195	50,539,940	107,283,599	0.713	**76,493,206**
6	--	7,027,253	52,760,695	53,486,418	113,274,367	0.6663	**75,474,710**
7	--	7,167,799	55,836,643	56,604,677	119,609,118	0.6227	**74,480,598**
8	--	7,311,155	59,091,920	59,904,729	126,307,803	0.582	**73,511,141**
9	--	7,457,378	62,536,978	63,397,175	133,391,531	0.5439	**72,551,654**
10	--	7,606,525	66,182,884	67,093,230	140,882,640	0.5083	**71,610,646**
11	--	7,758,656	70,041,346	71,004,765	148,804,768	0.4751	**70,697,145**
12	--	9,413,539	74,124,757	75,144,343	158,682,639	0.444	**70,455,092**
13	--	9,601,810	78,446,230	79,525,259	167,573,299	0.415	**69,542,919**
14	--	9,793,846	83,019,645	84,161,581	176,975,073	0.3878	**68,630,933**
15	--	9,989,723	87,859,691	89,068,201	186,917,615	0.3624	**67,738,944**
16	--	10,189,518	92,981,911	94,260,877	197,432,306	0.3387	**66,870,322**
17	--	10,393,308	98,402,756	99,756,287	208,552,351	0.3166	**66,027,674**
18	--	10,601,174	104,139,637	105,572,078	220,312,889	0.2959	**65,190,584**
19	--	10,813,198	110,210,978	111,726,930	232,751,105	0.2765	**64,355,681**
20	--	11,029,462	116,636,278	118,240,610	245,906,349	0.2584	**63,542,201**
Total							**2,621,493,453**