K. Ormond Beach Generating Station

Reliant Energy, Inc—Oxnard, CA

Contents

Tables

Figures

Appendices

1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at Ormond Beach Generating Station (OBGS) with closed-cycle wet cooling towers poses several significant challenges with respect to potential siting locations and conflicts with local use restrictions. The facility's compact dimensions, the layout of existing structures and the site's proximity to state beaches limit the different wet cooling tower configurations that could be evaluated. In addition, the location of OBGS approximately 2.5 miles west of Pt. Mugu Naval Air Station makes it likely that plume abatement would be necessary to prevent interference with flight operations. Plume-abated cooling towers, therefore, are the preferred option for OBGS.

Despite the probability that plume-abated towers would be required at OBGS, a workable configuration could not be developed. In recent years, Reliant Energy, Inc. and the previous owner—Southern California Edison (SCE)—have transferred portions of the original property to state and local conservation agencies as part of ongoing efforts to restore the Ormond Beach wetlands. This has reduced the site's total size by more than half. The facility's compact dimensions, the layout of existing structures and the site's proximity to state beaches limit the different wet cooling tower configurations that could be evaluated. The current size of the OBGS property and the layout of essential structures, however, do not allow for the placement of plume-abated cooling towers in any reasonable configuration at OBGS.

Based on these factors, the preferred option for OBGS is considered logistically infeasible.

If plume-abatement cooling towers were not required, a conventional tower design could be configured at the existing location. The discussion in this chapter, and all cost estimates, evaluates the alternative design based on conventional cooling towers.

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

1.1 COST

Initial capital and net present costs associated with installing and operating wet cooling towers at OBGS are summarized in Table K–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table K–2.

Table K–1. Cumulative Cost Summary

Cost category	Cost ($)	Cost per MWh (rated capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Total capital and start-up [a]	132,500,000	10.08	280
NPC_{20} [b]	149,800,000	11.40	317

[a] Includes all costs associated with the cooling tower construction and installation and shutdown loss, if any.
[b] NPC_{20} includes all capital costs, operation and maintenance costs, and energy penalty costs over 20 years discounted at 7 percent.

Table K–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up	12,500,000	0.95	26.43
Operations and maintenance	700,000	0.05	1.48
Energy penalty	1,100,000	0.08	2.33
Total OBGS annual cost	**14,300,000**	**1.08**	**30.24**

1.2 ENVIRONMENTAL

Environmental changes associated with a cooling tower retrofit for OBGS are summarized in Table K–3 and discussed further in Section 3.4.

Table K–3. Environmental Summary

		Unit 1	Unit 2
Water use	Design intake volume (gpm)	227,000	227,000
	Cooling tower makeup water (gpm)	16,200	16,200
	Reduction from capacity (%)	93	93
Energy efficiency [a]	Summer heat rate increase (%)	1.90	1.90
	Summer energy penalty (%)	2.77	2.77
	Annual heat rate increase (%)	1.69	1.69
	Annual energy penalty (%)	2.57	2.57
Direct air emissions [b]	PM_{10} emissions (tons/yr) (maximum capacity)	131	131
	PM_{10} emissions (tons/yr) (2006 capacity utilization)	0.32	9.1

[a] Reflects the comparative increase between once-through and wet cooling systems, but does not account for any operational changes to address the change in efficiency, such as increased fuel consumption (see Section 4.6).
[b] Reflects emissions from the cooling tower only; does not include any increase in stack emissions.

1.3 OTHER POTENTIAL FACTORS

As noted above, the preferred option is considered infeasible at this location.

The alternative option (conventional cooling towers) can only be sited by constructing 4 inline towers on the north side of the property close to the switchyard and transmission lines. This location would be immediately upwind and potentially subject these structures to the adverse effects of salt drift deposition.

Siting constraints are discussed further in Section 3.2.3.

2.0 BACKGROUND

OBGS is a natural gas–fired steam electric generating facility located in the city of Oxnard, Ventura County, owned and operated by Reliant Energy, Inc. OBGS currently operates two conventional steam turbine units (Unit 1 and Unit 2) with a combined generating capacity of 1,500 MW. The facility occupies approximately 37 acres of a 693-acre industrial site adjacent to Ormond Beach along the Pacific Ocean, approximately 2.5 miles southeast of Port Hueneme. (See Table K–4 and Figure K–1.)

Table K–4. General Information

Unit	In-service year	Rated capacity (MW)	2006 capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 1	1959	215	7.80%	83,700
Unit 2	1959	215	8.60%	83,700
OBGS total		430	3.6%	167,400

[a] *Quarterly Fuel and Energy Report*—**2006 (CEC 2006).**

Figure K–1. General Vicinity of Ormond Beach Generating Station

2.1 COOLING WATER SYSTEM

OBGS operates one cooling water intake structure (CWIS) to provide condenser cooling water to the two generating units (Figure K–2). Once-through cooling water is combined with low-volume wastes generated by OBGS and discharged through a single submerged outfall to the Pacific Ocean, located approximately 1,790 feet offshore at a depth of 20 feet. Surface water withdrawals and discharges are regulated by National Pollutant Discharge Eliminations System (NPDES) Permit CA0001198, as implemented by Los Angeles Regional Water Quality Control Board (LARWQCB) Order 01-092.[1]

Cooling water is obtained from the Pacific Ocean through a submerged intake conduit terminating 1,950 feet offshore at a depth of approximately 35 feet. The conduit's submerged end 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 the CWIS comprises four screen bays, each approximately 11 feet wide. Each bay is fitted with a vertical traveling screen with 5/8-inch mesh panels. Screens rotate periodically for cleaning based on a pressure differential between the screens' upstream and downstream faces. 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 in a landfill. Downstream of each screen is a circulating water pump rated at 119,000 gallons per minute (gpm), for a total facility capacity of 476,000 gpm, or 685 million gallons per day (mgd) (Reliant Energy 2005).

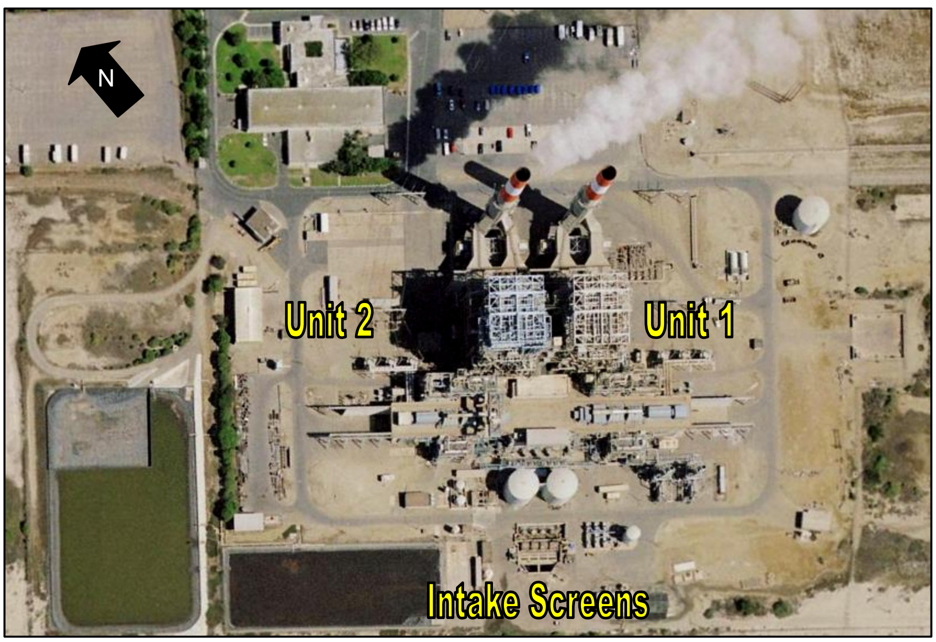

Figure K–2. Site View

[1] LARWQCB Order 01-092 expired on May 10, 2006, but has been administratively extended pending adoption of a renewed order.

At maximum capacity, OBGS maintains a total pumping capacity rated at 685 mgd, with a condenser flow rating of 654 mgd. On an annual basis, OBGS withdraws substantially less than its design capacity due to its low generating capacity utilization (3.6 percent for 2006). When in operation and generating the maximum load, OBGS can be expected to withdraw water from the Pacific Ocean at a rate approaching its maximum capacity.

2.2 SECTION 316(B) PERMIT COMPLIANCE

The CWIS currently in operation at OBGS uses a velocity cap to reduce the entrainment of motile fish through the system, although it is commonly thought of as an impingement-reduction technology because it targets 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. This study did not evaluate the effectiveness of either measure.

LARWQCB Order 01-092, adopted in 2001, states that "the design, construction and operation of the intake structure [at OBGS] represents Best Available Technology (BAT) [*sic*] as required by Section 316(b) of the Clean Water Act" (LARWQCB 2001, Finding 13). The order does not contain any numeric or narrative limitations regarding impingement or entrainment resulting from CWIS operation, but does require semiannual monitoring of impingement at each intake structure (coinciding with scheduled heat treatments). Based on the record available for review, OBGS has been compliant with this permit requirement.

The LARWQCB has notified OBGS of its intent to revisit requirements under CWA Section 316(b), including a determination of best technology available (BTA) for minimization of adverse environmental impact, during the current permit reissuance process. A final decision regarding any Section 316(b)–related requirements has not been made as of this study's publication.

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

This study evaluates saltwater cooling towers as a retrofit option at OBGS, with the current source water (Pacific Ocean) continuing to provide makeup water to the facility. Converting the existing once-through cooling system to wet cooling towers will reduce the facility's current intake capacity by approximately 93 percent; rates of impingement and entrainment will decline by a similar proportion. Use of reclaimed water was considered for OBGS but not analyzed in detail because the available volume cannot serve as a replacement for once-through cooling water. The proximity of available sources, however, may make reclaimed water an attractive alternative as makeup water for a wet cooling tower system when considering additional benefits its use may provide, such as avoidance of conflicts with effluent limitations or air emission standards.

The wet cooling towers' configuration—their size, arrangement, 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. Information not available to this study that offers a more complete facility characterization may lead to different conclusions regarding the cooling towers' physical configuration.

This study developed a conceptual design of wet cooling towers sufficient to meet each active generating unit's cooling demand 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 OBGS.

The overall practicality of retrofitting both units at OBGS will require an evaluation of factors outside the scope of this study, such as each unit's age and efficiency and its role in the overall reliability of electricity production and transmission in California, particularly the Los Angeles Region.

3.2 DESIGN BASIS

3.2.1 CONDENSER SPECIFICATIONS

For this study, the wet cooling tower conceptual design selected for OBGS is based on the assumption that the condenser flow rate and thermal load to each 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 cooling tower riser elevation. [2]

[2] In this context, re-optimization refers to a comprehensive condenser overhaul that reduces thermal efficiency losses associated with a wet cooling tower's higher circulating water temperatures. Modifications discussed in this study are generally limited to reinforcement measures that enable the condenser to withstand increased water pressures.

The practicality and difficulty of these modifications are dependent each unit's age and configuration but are assumed to be feasible at OBGS. Condenser water boxes for both units are located at grade level and appear to be readily accessible. Additional costs for condenser modifications are included in the discussion of capital expenditures (Section 4.3).

Information provided by OBGS 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.

Parameters used in the development of the cooling tower design are summarized in Table K–5.

Table K–5. Condenser Design Specifications

	Unit 1	Unit 2
Thermal load (MMBTU/hr)	3371.67	3371.67
Surface area (ft^2)	210,000	210,000
Condenser flow rate (gpm)	227,000	227,000
Tube material	Cu-Ni (90-10)	Cu-Ni (90-10)
Heat transfer coefficient (BTU/hr•ft^2•°F)	521	521
Cleanliness factor	0.85	0.85
Inlet temperature (°F)	62	62
Temperature rise (°F)	29.72	29.72
Steam condensate temperature (°F)	110.9	110.9
Turbine exhaust pressure (in. HgA)	2.67	2.67

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

OBGS is located in Ventura County adjacent to Ormond Beach and the Pacific Ocean approximately 2.5 miles southeast of Port Hueneme. Cooling water is from the Pacific Ocean via a submerged conduit extending offshore. Inlet temperature data were not available from OBGS. Instead, surface water temperatures used in this analysis were based on monthly average coastal water temperatures as reported in the NOAA *Coastal Water Temperature Guide, Ventura and Port Hueneme* (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 coastal Ventura County indicate a 1 percent ambient wet bulb temperature of 66° 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 78° F.

Monthly maximum wet bulb temperatures used in the development of energy penalty estimates in Section 4.6 were calculated using data obtained from California Irrigation Management Information System (CIMIS) Monitoring Station 156 in Oxnard (CIMIS 2006). Climate data used in this analysis are summarized in Table K–6.

Table K–6. Surface Water and Ambient Wet Bulb Temperatures

	Surface (°F)	Ambient wet bulb (°F)
January	57.2	57.9
February	58.3	58.3
March	59.5	59.7
April	61.1	60.7
May	61.4	62.5
June	62.6	65.3
July	64.1	66.1
August	63.9	66.3
September	62.0	64.7
October	60.9	62.4
November	59.3	61.3
December	58.7	58.9

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Industrial development in the vicinity of OBGS is covered by the City of Oxnard General Plan and the City of Oxnard Land Use Plan (LUP). General Plan Section 10 (Noise Element) outlines the broad policy related to noise impacts within the city's different development zones. The plan outlines narrative criteria to be used as a guide for future development, but does not identify numeric noise limits for new construction (Oxnard 2006). Land use within the general vicinity of OBGS is primarily agricultural, although recent residential developments have encroached upon the area. Noise associated with the cooling towers is not expected to have any discernible impact upon these areas. The proximity to state beaches, however, may conflict with recreational standards set forth in the Ventura County Local Coastal Plan, but again, no numeric limits are specified.

In lieu of specific noise criteria, this study used an ambient noise limit of 65 dBA at a distance of 1,200 feet in selecting the design elements of the wet tower installation. Accordingly, the final design selected for OBGS does not require any measures that specifically address noise, such as low-noise fans or barrier walls.

3.2.3.2 BUILDING HEIGHT

OBGS is located within the coastal energy facilities subzone (EC) of the City of Oxnard LUP, which encourages the expansion of energy-related activities within the existing site consistent with other plan provisions. The LUP does not establish specific criteria for building height and instead relies on conditional use permitting that evaluates each project independently. Given the height of existing structures at OBGS, this study selected a height restriction of 50 feet above grade level. The height of the wet cooling towers designed for OBGS, from grade level to the top of the fan deck, is 49 feet.

3.2.3.3 PLUME ABATEMENT

Local zoning ordinances do not contain any specific criteria for addressing any impact associated with a wet cooling tower plume. The proximity of OBGS to the Point Mugu Naval Air Station, however, may necessitate incorporating plume abatement measures into the final design. As shown in Figure K–1, OBGS is located approximately 2.5 miles northwest of the air station. With prevailing winds from the west, a persistent plume has the potential to interfere with flight operations at the air station, but specific requirements or limits could not be identified.

Likewise, community standards for assessing the visual impact associated with a cooling tower plume cannot be determined within the scope of this study. Agricultural uses predominate in the general vicinity of OBGS, with few residential areas located in the area. The proximity of OBGS to coastal recreational areas and sensitive wetlands, and the potential visual impact on those resources, may require plume abatement measures. 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.

Plume abatement towers were initially selected for evaluation at OBGS due to the likelihood they would be required to eliminate potential impact on operations at the Point Mugu Naval Air Station. Further investigation and consultation with cooling tower vendors, however, indicated that plume-abated towers could not be located at the site given the constraints on available space and building height that would preclude their construction. Accordingly, all towers evaluated for OBGS are of a conventional design.

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 OBGS, with an accepted efficiency of 0.0005 percent. Because cooling tower PM_{10} emissions are a function of the drift rate, 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 Cooling Tower Institute's Isokinetic Drift Test Code is required at initial start-up on only one representative cell of each tower for an approximate cost of $60,000 per test, or approximately $240,000 for both cooling towers at OBGS (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 existing site's configuration and the total available area present significant challenges to identifying sufficient space on which to place wet cooling towers. Because the maximum combined condenser thermal load from the generating units (6,742 MMBTU/hr) is relatively large, the cooling towers will have to incorporate a large number of cells to achieve the desired level of cooling. Prior to the acquisition of OBGS by Reliant Energy, Inc., the original site included a large area owned by SCE, which contained several large fuel oil tanks (since removed). In June 2002 following negotiations with SCE, the State Coastal Conservancy acquired 256 acres of the former tank farm site in support of efforts to protect wetlands and related habitats in the vicinity of Ormond Beach (SCC 2003). Figure K–3 outlines the current and former property boundaries, with the fuel tank footprints still clearly visible.

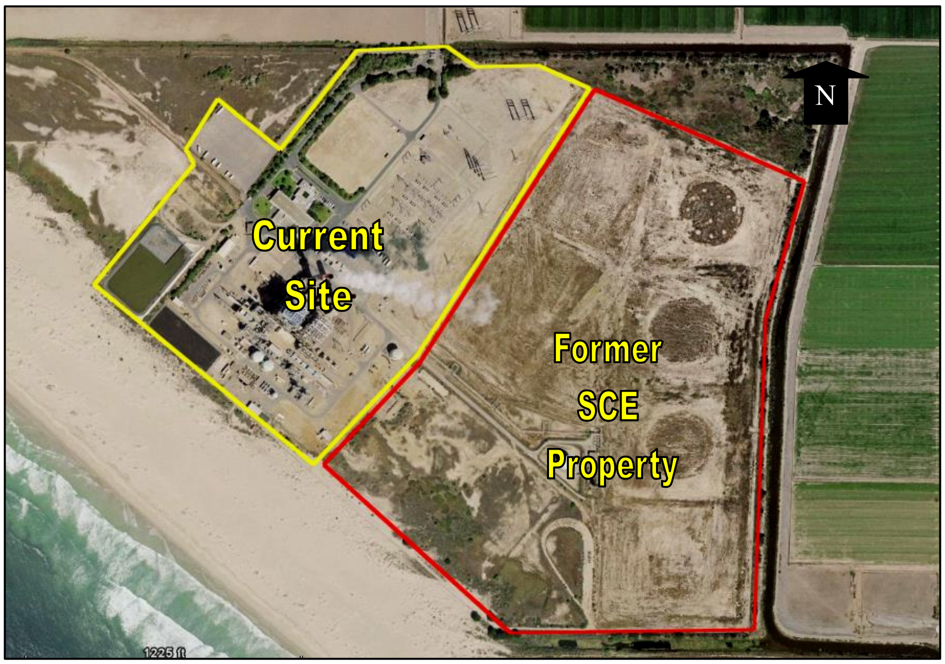

Figure K–3. Current and Former Site Boundaries

The remaining areas at OBGS that can accommodate wet cooling towers are shown in Figure K–4. Placement of towers in Area 1 is impractical due to the proximity to the generating units and the prevailing wind direction, which places the towers immediately upwind of the power block at a distance of less than 150 feet. Drift from wet cooling towers in this location would likely settle on sensitive equipment and pose significant maintenance challenges from salt corrosion.

Use of Area 2, located north of the units, would minimize this effect on the power block but create similar impacts on the switchyard and transmission lines that extend northward. Ultimately, while neither area is ideal, Area 2 was selected as the most practical location for wet cooling tower. Drift deposition and salt corrosion on switchyard equipment and transmission lines would likely be a significant issue and, if wet cooling towers were constructed here, the equipment and lines might require relocation or replacement with gas insulated switchgear (GIS). Use of reclaimed water might mitigate these effects (see Section 3.4.4).

The space limitations at OBGS are more restrictive when attempting to design plume-abated towers for the site. If configured in an inline arrangement, these towers would be nearly twice the length of a conventional tower design. Consultations with cooling tower vendors indicated a round plume-abated tower might be feasible, but would have to be very tall (70 to 80 feet). This would likely conflict with building height restrictions in the coastal zone for Ventura County and might present design challenges to comply with Zone 4 seismic construction requirements.

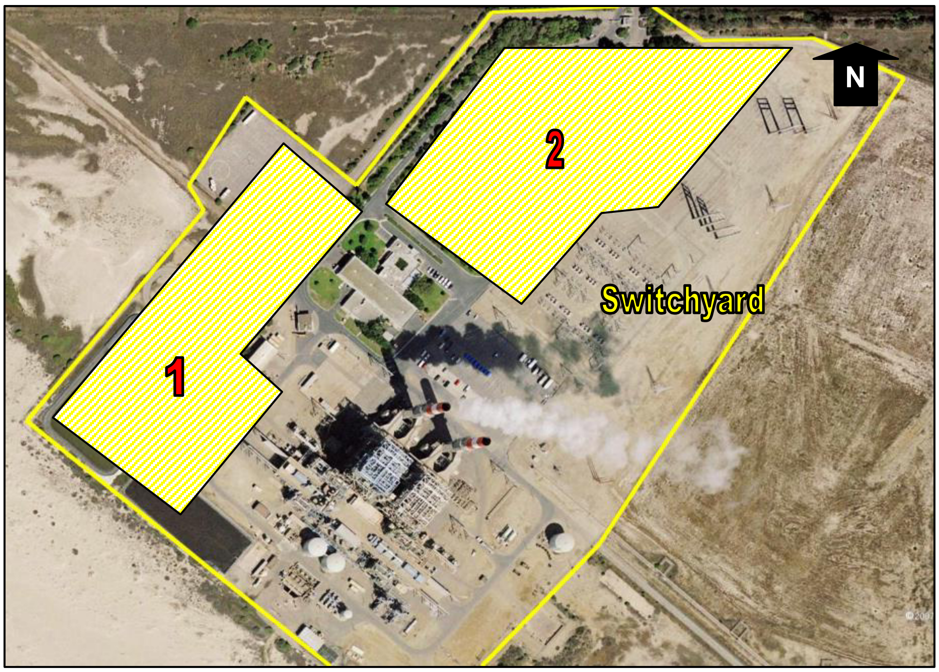

Figure K–4. Cooling Tower Siting Areas

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above two wet cooling tower complexes, each consisting of two towers, were selected to replace the current once-through cooling system at OBGS, for a total of four towers. Each tower complex will operate independently and be dedicated to one unit. Each tower is configured in a multicell, inline arrangement.

3.3.1 SIZE

Each tower is constructed over a concrete collection basin 4 feet deep. The basin is larger than the tower structure's footprint, 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 size of each 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 each condenser remain unchanged.

General characteristics of the wet cooling towers selected for OBGS are summarized in Table K–7.

Table K–7. Wet Cooling Tower Design

	Tower Complex 1 (Unit 1)	Tower Complex 2 (Unit 2)
Thermal load (MMBTU/hr)	3371.67	3371.67
Circulating flow (gpm)	227,000	227,000
Number of cells	18	18
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]	486 x 54 x 49	486 x 54 x 49
Tower footprint with basin (l x w) (ft) [a]	490 x 58	490 x 58

[a] Two individual towers with 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. Tower Complex 1, serving Unit 1, is located at an approximate distance of 550 feet. Tower Complex 2, serving Unit 2, is located at approximate distance of 800 feet. (Figure K–5).

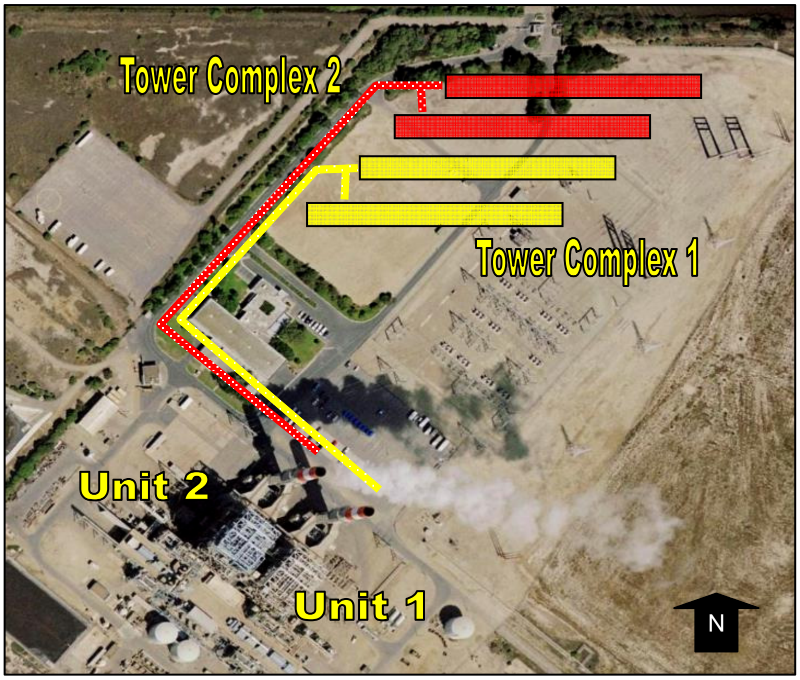

Figure K–5. Cooling Tower Locations

3.3.3 PIPING

The main supply and return pipelines to and from both towers will be located underground and made of prestressed concrete cylinder pipe (PCCP) suitable for saltwater applications. These pipes range in size from 72 to 96 inches in diameter. Pipes connecting the condensers to the supply and return lines are made of FRP and placed above ground on pipe racks. Above-ground placement avoids the potential disruption that may be caused by excavation in and around the power block. The condensers at OBGS are located at grade level, enabling a relatively straightforward connection.

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

Potential interference with underground obstacles and infrastructure is a concern, particularly at existing sites that are several decades old and have been substantially modified or rebuilt in the interim. Avoidance of these obstacles is considered to the degree practical in this study. Associated costs are included in the contingency estimate and are generally higher than similar estimates for new facilities (Section 4.3).

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

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 each tower.

This analysis includes new pumps to circulate water between the condensers and cooling towers. Pumps are sized according to the flow rate for each tower, the relative distance between the towers and condensers, and the total head required to deliver water to the top of each cooling tower riser. A separate, multilevel pump house is constructed for each tower and 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 wet cooling towers at OBGS are summarized in Table K–8. The net electrical demand of fans and new pumps is discussed further as part of the energy penalty analysis in Section 4.6.

Table K–8. Cooling Tower Fans and Pumps

		Tower Complex 1 (Unit 1)	Tower Complex 2 (Unit 2)
Fans	Number	18	18
	Type	Single speed	Single speed
	Efficiency	0.95	0.95
	Motor power (hp)	263	263
Pumps	Number	4	4
	Type	50% recirculating Mixed flow Suspended bowl Vertical	50% recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88
	Motor power (hp)	1,386	1,386

3.4 ENVIRONMENTAL EFFECTS

Converting the existing once-through cooling system at OBGS to wet cooling towers will significantly reduce the intake of seawater 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 both of OBGS's steam units, thereby decreasing the facility's overall efficiency. Additional power will also be consumed by the tower fans and circulating pumps.

Depending on how OBGS chooses to address this change in efficiency, total stack emissions may increase for pollutants such as PM_{10}, SO_x, and NO_x, and may require additional control measures (e.g., electrostatic precipitation, flue gas desulfurization, and selective catalytic reduction) or the purchase of emission credits to meet air quality regulations. The availability of emission reduction credits (ERCs) and their associated cost was not evaluated as part of this study. Both factors, however, may limit the air emission compliance options available to OBGS.

No control measures are currently available for CO_2 emissions, which will increase, on a per-kWh basis, by the same proportion as any change in the heat rate. The towers themselves will constitute an additional source of PM_{10} emissions, the annual mass of which will largely depend on the capacity utilization rate for the generating units served by each tower.

If OBGS 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 discharge quantity and characteristics. Thermal impacts from the current once-through system, if any, will be minimized with a wet cooling system.

3.4.1 AIR EMISSIONS

OBGS is located in the South Central Coast air basin. Air emissions are permitted by the Ventura County Air Pollution Control District (VCAPCD) (Facility ID 65).

Drift volumes are expected to be within the range of 0.5 gallons for every 100,000 gallons of circulating water in the towers. At OBGS, this corresponds to a rate of approximately 2.25 gpm based on the maximum combined flow both two towers. Agricultural operations lie within 0.25 mile to the north and 0.75 mile to the east. Given the direction of prevailing winds (from the west) some drift may carry to these areas, but the impact is not likely to be significant.

Total PM_{10} emissions from the OBGS cooling towers are a function of the number of hours in operation, the overall water quality in the tower, and the evaporation rate of drift droplets prior to deposition on the ground. Makeup water at OBGS 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.

The cumulative mass emission of PM_{10} from OBGS will increase as a result of the direct emissions from the cooling towers themselves. Stack emissions of PM_{10}, as well as SO_x, NO_x, and other pollutants, will increase due to the drop in fuel efficiency, although the cumulative increase will depend on actual operations and emission control technologies currently in use. Maximum drift and PM_{10} emissions from the cooling towers are summarized in Table K–9.[3]

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table K–10 (CARB 2005). In 2005, OBGS operated at an annual capacity utilization rate of 4 percent.

[3] This is a conservative estimate that assumes all dissolved solids present in drift droplets will be converted to PM_{10}. Studies suggest this may overestimate actual emission profiles for saltwater cooling towers (Chapter 4).

Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 10.5 tons/year, or 110 percent.[4]

Table K–9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower Complex 1	30	131	1.14	568
Tower Complex 2	30	131	1.14	568
Total OBGS PM_{10} and drift emissions	**60**	**262**	**2.28**	**1,136**

Table K–10. 2005 Emissions of SO_x, NO_x, PM_{10}

Pollutant	Tons/year
NO_x	20.1
SO_x	1.7
PM_{10}	9.6

3.4.2 MAKEUP WATER

The volume of makeup water required by both cooling towers at OBGS is the sum of evaporative loss and the blowdown volume required to maintain the circulating water in each tower at the design TDS concentration. Drift expelled from the towers represents an insignificant volume by comparison and is accounted for by rounding up evaporative loss estimates. Makeup water volumes are based on design conditions, and may fluctuate seasonally depending on climate conditions and facility operations. Wet cooling towers will reduce once-through cooling water withdrawals from the Pacific Ocean by approximately 93 over the current design intake capacity.

Table K–11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower Complex 1	227,000	5,400	10,800	**16,200**
Tower Complex 2	227,000	5,400	10,800	**16,200**
Total OBGS makeup water demand	**454,000**	**10,800**	**21,600**	**32,400**

One circulating water pump, rated at 119,000 gpm, which is currently used to provide once-through cooling water to the facility, will be retained in a wet cooling system to provide makeup water to each cooling tower. The retained pump's capacity exceeds the makeup demand by approximately 86,000 gpm. Any excess capacity will be routed through a bypass conduit and returned to the wet well at a point located behind the intake screens. Recirculating the excess capacity in this manner reduces additional cost that would be incurred if new pumps were required while maintaining the desired flow reduction. The intake of new water, measured at the intake screens, will be equal to the cooling towers' makeup water demand. Figure K–6 presents a schematic of this configuration.

[4] 2006 emission data are not currently available from the Air Resources Board website. For consistency, the comparative increase in PM10 emissions estimated here is based on the 2005 OBGS capacity utilization rate instead of the 2006 rate presented in Table K-4. All other calculations in this chapter use the 2006 value.

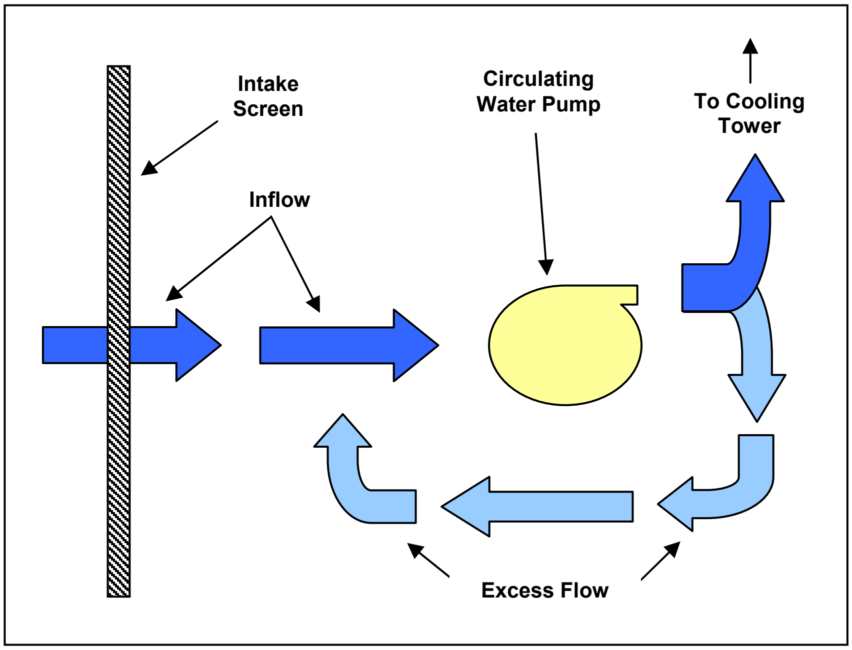

Figure K–5. Schematic of Intake Pump Configuration

The existing once-through cooling system at OBGS 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. Heat treatments are also periodically used to control mussel growth on pipes and condenser tubes by raising the circulating water temperature to 125º F. Conversion to a wet cooling tower system will not interfere with chlorination or heat treatment operations.

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

The wet cooling tower system proposed for OBGS includes water treatment for standard operational measures, i.e., corrosion inhibitors, biocides, and anti-scaling agents. An allowance for these additional chemical treatments is 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 OBGS will result in an effluent discharge of 31 mgd of blowdown in addition to other in-plant waste streams—such as boiler blowdown, regeneration wastes, and cleaning wastes. These low volume wastes may add an additional

0.75 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, OBGS 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 Permit CA0001198, as implemented by LARWQCB Order 01-092. All wastewaters are discharged to the Pacific Ocean through a submerged conduit extending approximately 1,790 feet offshore. The existing order contains effluent limitations based on the 1997 Ocean Plan and 1972 Thermal Plan.

OBGS 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 OBGS 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.

Use of reclaimed water as the cooling tower makeup source has the potential to reduce or eliminate conflicts with effluent limitations (see Section 3.4.4).

Thermal discharge standards are based on narrative criteria established for coastal discharges 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 LARWQCB has implemented this provision by establishing a maximum discharge temperature of 105º F during normal operations in Order 01-092 (LARWQCB 2001). Information available for review indicates OBGS 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 80º F) and the size of any related thermal plume in the receiving water.

3.4.4 RECLAIMED WATER

Reclaimed or alternative water sources used in conjunction with wet cooling towers could eliminate all surface water withdrawals at OBGS. 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 reclaimed water, over the use of freshwater (SWRCB 1975). There is no similar policy regarding marine waters, but the clear preference of state agencies is to encourage alternative cooling methods, including reclaimed water, wherever possible.

The present volume of available reclaimed water within a 15-mile radius of OBGS (53 mgd) does not meet the current once-through cooling demand; thus, 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 reclaimed water's use because the conversion of OBGS's once-through cooling system to saltwater cooling towers meets the performance benchmarks for impingement and entrainment impact reductions discussed 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, OBGS would be required to arrange for sufficient treatment, either onsite or at the source facility, prior to its use in the cooling towers.

An additional consideration for reclaimed water is the presence of any ammonia or ammonia-forming compounds in the reclaimed water. All the condenser tubes at OBGS contain copper alloys (copper nickel [90-10]) and can experience stress-corrosion cracking as a result of the interaction between copper and ammonia. Treatment for ammonia may include adding ferrous sulfate as a corrosion inhibitor or require ammonia-stripping towers to pretreat reclaimed water prior to use in the cooling towers (EPA 2001).

Five publicly owned treatment works (POTWs) were identified within a 15-mile radius of OBGS, with a combined discharge capacity of 53 mgd. Figure K–7 shows the relative locations of these facilities to OBGS.

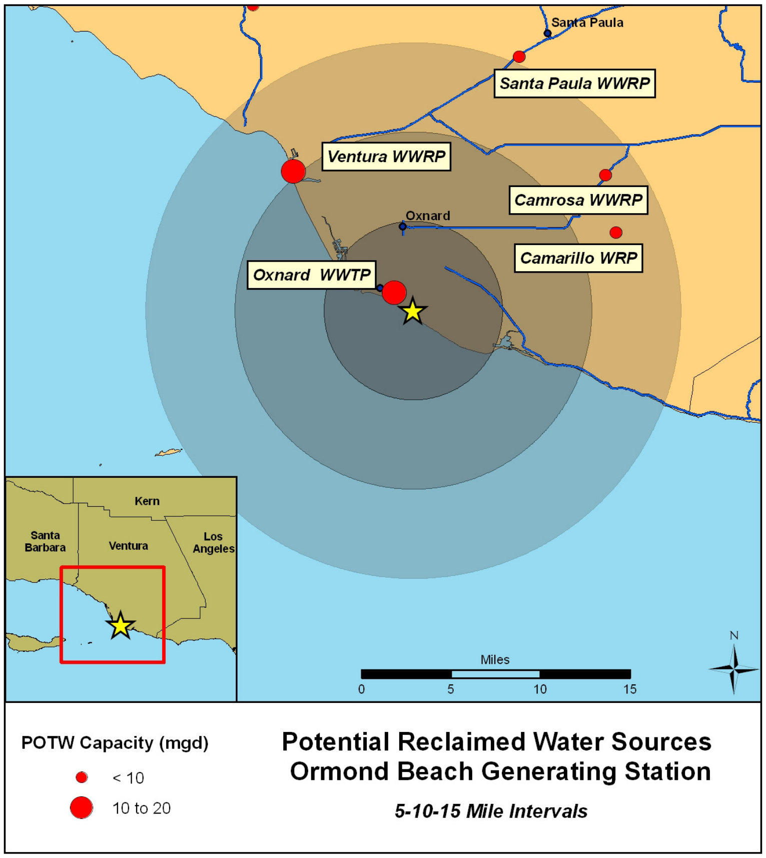

Figure K–6. Reclaimed Water Sources

- *City of Ventura Water Reclamation Facility (VWRF)—Ventura*
  Discharge volume: 14 mgd
  Distance: 10 miles NW
  Treatment level: Tertiary

  All wastewater at VWRF is treated to tertiary standards. Approximately 1.0 mgd is currently used for irrigation purposes in the vicinity. Facility staff indicated that demand is increasing as the area is developed and future uses may limit any capacity available to OBGS as a makeup water source. Based on the current available capacity, however, VWRF could provide most of the makeup water (13–15 mgd) for freshwater cooling towers at OBGS.

- *City of Oxnard Wastewater Treatment Plant—Oxnard*
  Discharge volume: 31 mgd
  Distance: 1.5 miles SE
  Treatment level: Secondary

  No information available. The existing capacity is sufficient to supply enough makeup water (13–15 mgd) for freshwater cooling towers at OBGS, although arrangements for tertiary treatment would have to be made prior to its use.

Three other wastewater treatment plants—Camarillo, Camrosa, and Santa Paula—lie within 10–5 miles of OBGS. The combined capacity of these facilities (approximately 8 mgd) is less than the makeup demand required in freshwater towers at OBGS. If reclaimed water sources are pursued, the most practical options are the Oxnard and Ventura facilities.

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 will influence the final configuration. The nearest facility with sufficient capacity to satisfy OBGS's freshwater tower makeup demand (5–8 mgd) is located approximately 2.5 miles from the site (Ventura WRF). The area between the two facilities is not heavily developed. Installing a transmission pipeline would not face any significant obstacles in terms of infrastructure or right of way.

Based on data compiled for this study and others, the estimated installed cost of a 36-inch prestressed concrete cylinder pipe, sufficient to provide 15 mgd to OBGS, is $320 per linear foot, or approximately $1.7 million per mile. Additional considerations, such as pump capacity and any required treatment, would increase the total cost.

Regulatory concerns beyond the scope of this investigation, however, may make reclaimed water (as a makeup water source) comparable or preferable to saltwater from the Pacific Ocean. Reclaimed water may enable OBGS to eliminate potential conflicts with water discharge limitations or reduce PM10 emissions from the cooling tower, which is a concern given the South Coast air basin's current nonattainment status.

Salt deposition, and the adverse impacts it can have on sensitive equipment, can be mitigated by using freshwater (reclaimed water) in the towers instead of saltwater from the Pacific Ocean. Although reclaimed water salinity levels would be substantially lower and are unlikely to cause the same, the switchyard and transmission lines would still require some measure of upgrade or protection because of their proximity immediately downwind of the towers' plume. Plume-abated towers could lessen this effect but cannot be configured within the site's current boundaries (Section 3.2.3).

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 benefit that may occur.

3.4.5 THERMAL EFFICIENCY

Wet cooling towers at OBGS will increase the condenser inlet water temperature by a range of 14 to 16° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at OBGS are designed to operate at the conditions described in Table K–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures is described in Figure K–8.

Table K–12. Design Thermal Conditions

	Unit 1	Unit 2
Design backpressure (in. HgA) (high pressure zone)	2.67	2.67
Design water temperature (°F)	62	62
Turbine inlet temp (°F)	1,000	1,000
Turbine inlet pressure (psia)	3,500	3,500
Full load heat rate (BTU/kWh) [a]	9,409	9,200

[a] CEC 2002.

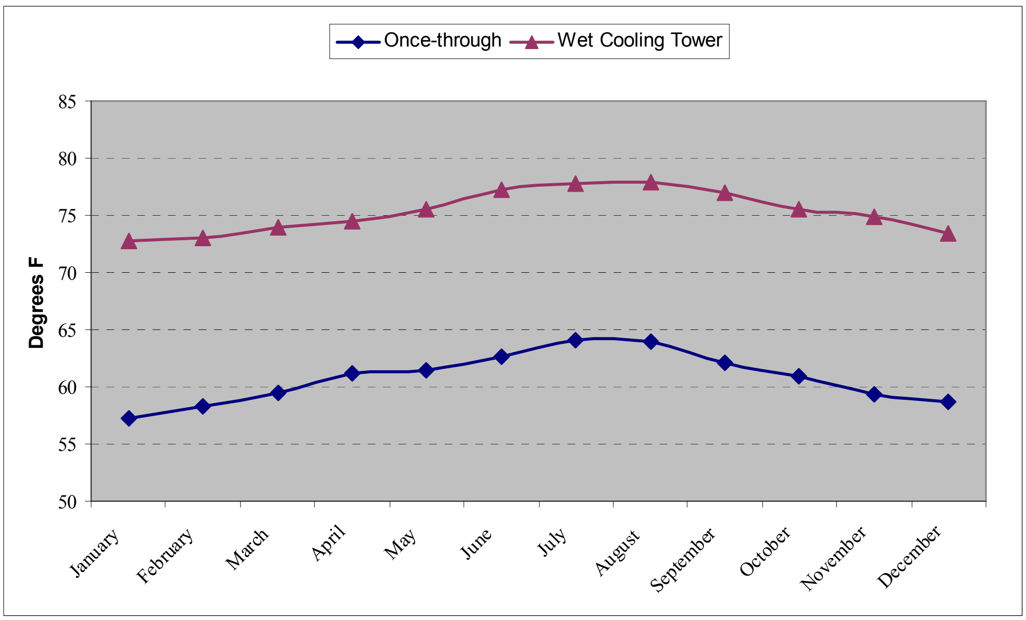

Figure K–7. Condenser Inlet Temperatures

Backpressures for the once-through and wet cooling tower configurations were calculated for each month using the design criteria described in the sections above and ambient climate data. In general, backpressures associated with the wet cooling tower were elevated by 1.0 to 1.15 inches HgA compared with the current once-through system (Figure K–9 and Figure K–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 full load rating. 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 full load operating heat rate to develop estimated correction curves (Figure K–10 and Figure K–10).

The difference between the estimated once-through and closed-cycle heat rates for each month represents the approximate heat rate increase that would be expected when converting to wet cooling towers.

Table K–13 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 calculate the monetized value of these heat rate changes (Section 4.6). Month-by-month calculations are presented in Appendix A.

Table K–13. Summary of Estimated Heat Rate Increases

	Unit 1	Unit 2
Peak (July-August-September)	1.90%	1.90%
Annual average	1.69%	1.69%

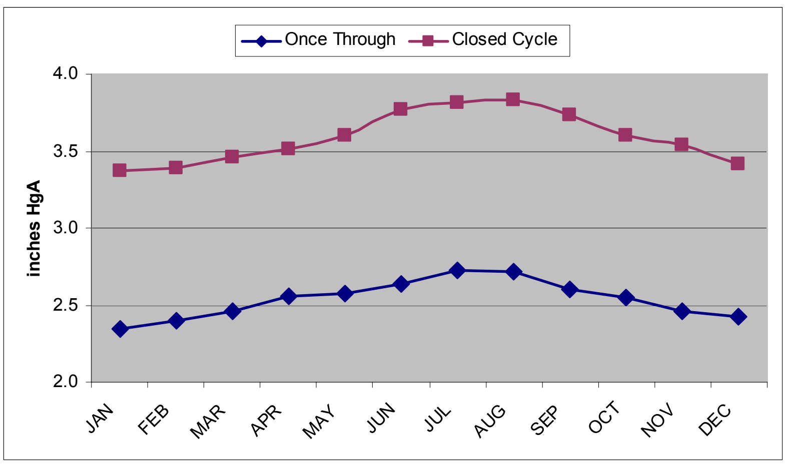

Figure K–8. Estimated Backpressures (Unit 1)

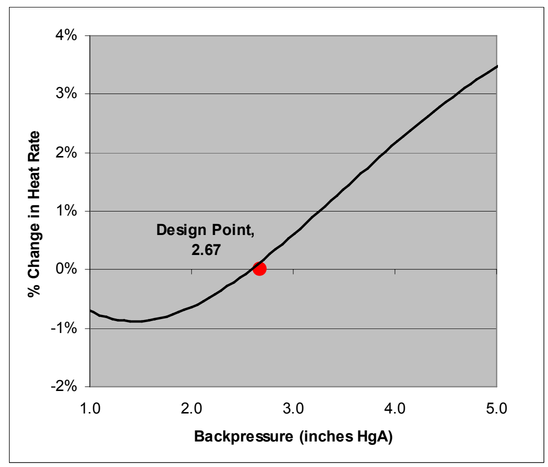

Figure K–9. Estimated Heat Rate Correction (Unit 1)

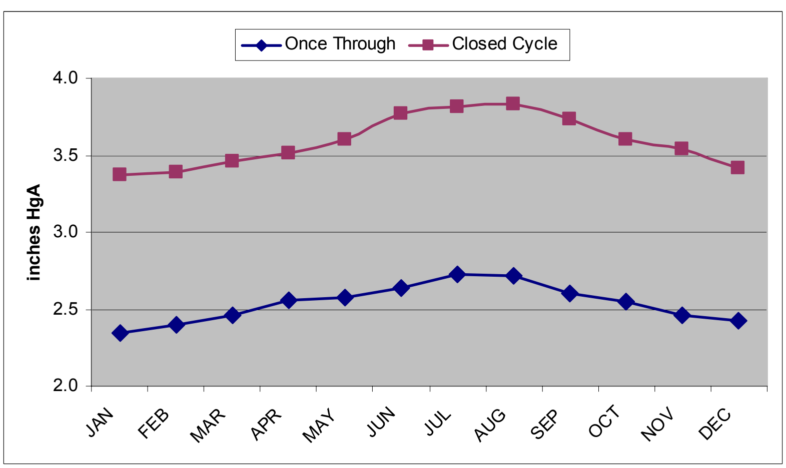

Figure K–10. Estimated Backpressures (Unit 2)

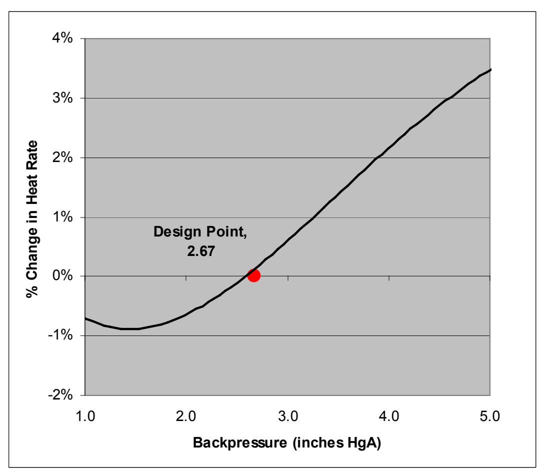

Figure K–11. Estimated Heat Rate Correction (Unit 2)

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for OBGS is based on incorporating conventional wet cooling towers as a replacement for the existing once-through system 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)
- Revenue loss from shutdown (net loss in revenue during construction phase)
- 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)

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 preferred design for OBGS—plume-abated towers—could not be configured at the site. Conventional cooling towers were evaluated instead.

In general, the evaluated cooling tower configuration conforms to a typical design; no significant variations from a conventional arrangement were required. The principal difference is the need to construct two cooling towers for each unit, which marginally increases costs.

Table K–14 summarizes the design-and-build cost estimate for each tower developed by vendors, inclusive of all labor and management required for their installation.

Table K–14. Wet Cooling Tower Design-and-Build Cost Estimate

	Unit 1	Unit 2	OBGS total
Number of cells	18	18	**36**
Cost/cell ($)	594,444	594,444	**594,444**
Total OBGS D&B cost ($)	**10,700,000**	**10,700,000**	**21,400,000**

4.2 OTHER DIRECT COSTS

A significant portion of wet cooling tower installation costs result from the various support structures, materials, equipment and labor necessary to prepare the cooling tower site and connect the towers to the condenser. At OBGS, these costs comprise approximately 55 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 K–15.

- *Civil, Structural, and Piping*
  The OBGS site configuration allows each tower complex to be located within relative proximity to the generating unit it services. Increased costs are incurred for additional materials and labor that result from dividing the cooling tower for each unit into two separate towers.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect the new pumps (four total) to circulate cooling water between the towers and condensers. Overall pump capacity is larger than an average arrangement as a result of dividing the cooling tower for each unit into two separate towers. 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*
  No demolition costs are required. Any demolition costs for minor projects are covered by the indirect cost estimate.

Table K–15. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	OBGS total ($)
Civil/structural/piping	6,300,000	20,900,000	15,100,000	**42,300,000**
Mechanical	10,100,000	0	800,000	**10,900,000**
Electrical	1,600,000	3,100,000	2,200,000	**6,900,000**
Demolition	0	0	0	**0**
Total OBGS other direct costs	**18,000,000**	**24,000,000**	**18,100,000**	**60,100,000**

4.3 INDIRECT AND CONTINGENCY

Indirect costs are calculated as 25 percent of all direct costs (civil/structural, mechanical, electrical, demolition, and cooling towers).

An additional allowance is included for condenser water box and tube sheet reinforcement to withstand the increased pressures associated with a recirculating system. 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 estimates outlined in Chapter 5, a conservative estimate of 5 percent of all direct costs is included to account for possible condenser modifications.

The contingency cost is calculated as 25 percent of the sum of all direct and indirect costs, including condenser reinforcement. At OBGS, potential costs in this category include relocating or demolishing small buildings and structures and potential interferences from underground structures. Significant modifications or upgrades to sensitive equipment may be necessary to mitigate or avoid salt drift impacts.

Soils were not characterized for this analysis. OBGS is situated at sea level adjacent to the Pacific Ocean. Seawater intrusion or 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 K–16.

Table K–16. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	21,400,000
Civil/structural/piping	42,300,000
Mechanical	10,900,000
Electrical	6,900,000
Demolition	0
Indirect cost	20,400,000
Condenser modification	4,100,000
Contingency	26,500,000
Total OBGS capital cost	**132,500,000**

4.4 SHUTDOWN

A portion of the work relating to installing wet cooling towers can be completed without significant disruption to the operations of OBGS. Units will be offline depending on the length of time it takes to integrate the new cooling system and conduct acceptance testing. For OBGS, a conservative estimate of 4 weeks per unit was developed. Based on 2006 generating output, however, no shutdown is forecast for either unit. Therefore, the cost analysis for OBGS does not include any loss of revenue associated with shutdown at OBGS.

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

Operations and maintenance (O&M) costs for a wet cooling tower system at OBGS 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 combined tower flow rate 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 two cooling towers at OBGS (454,000 gpm), are presented in Table K–17. These costs reflect maximum operation.

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

	Year 1 cost ($)	Year 12 cost ($)
Management/labor	454,000	658,300
Service/parts	726,400	1,053,280
Fouling	635,600	921,620
Total OBGS O&M cost	**1,816,000**	**2,633,200**

4.6 ENERGY PENALTY

The energy penalty is divided into two components: increased parasitic use from the added electrical demand from tower fans and pumps; and the decrease in thermal efficiency from elevated turbine backpressures. Monetizing the energy penalty at OBGS requires some assumption as to how the facility will choose to alter its operations to compensate for these changes, if at all. One option would be to accept the reduced amount of revenue-generating electricity available for sale and absorb the economic loss ("production loss option"). A second option would be to increase the firing rate to the turbine (i.e., consume more fuel) and produce the same amount of revenue-generating electricity as had been obtained with the once-through cooling system ("increased fuel option"). The degree to which a facility is able, or prefers, to operate at a higher firing rate, however, produces the more likely scenario—some combination of the two.

Ultimately, the manner in which OBGS would alter operations to address efficiency changes is driven by considerations unknown to this study (e.g., corporate strategy, contractual obligations, operating protocols and turbine pressure tolerances). In all summary cost estimates, this study calculates the energy penalty's monetized value by assuming the facility will use the increased fuel option to compensate for reduced efficiency and generate the amount of electricity equivalent to the estimated shortfall. With this option, the energy penalty is equivalent to the financial cost of additional fuel and is nominally less costly than the production loss option. This option, however, may not reflect long-term costs such as increased maintenance or system degradation that may result from continued operation at a higher-than-designed turbine firing rate.[5]

The energy penalty for OBGS is calculated by first estimating the increased parasitic demand from the cooling tower pumps and fans, expressed as a percentage of each unit's rated capacity. Likewise, the change in the unit's heat rate is also expressed as a capacity percentage.

4.6.1 INCREASED PARASITIC USE (FANS AND PUMPS)

Depending on ambient conditions or the operating load at a given time, OBGS may be able to take one or more cooling tower cells offline and still obtain the required level of cooling. This would also reduce the cumulative electrical demand from the fans. For the purposes of this study, however, operations are evaluated at the design conditions, i.e., full load; no allowance is made for seasonal changes. The increased electrical demand from cooling tower fan operation is summarized in Table K–18.

Table K–18. Cooling Tower Fan Parasitic Use

	Tower Complex 1	Tower Complex 2	OBGS total
Units served	Unit 1	Unit 2	--
Generating capacity (MW)	750	750	**1,500**
Number of fans (one per cell)	18	18	**36**
Motor power per fan (hp)	263	263	--
Total motor power (hp)	4,737	4,737	**9,474**
MW total	3.53	3.53	**7.06**
Fan parasitic use (% of capacity)	**0.47%**	**0.47%**	**0.47%**

Additional circulating water pump capacity for the wet cooling towers will also increase the parasitic electricity usage at OBGS. Makeup water will continue to be withdrawn from the Pacific Ocean with 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. For calculation purposes, this study assumes full-load operation to estimate the cost of increased parasitic use. Final estimates, therefore, allocate the retained pump's electrical demand to each tower based on the proportion of the facility's generating capacity it services. Operating fewer

[5] Increasing the thermal load to the turbine will raise the circulating water temperature exiting the condenser. The cooling towers selected for this study are designed with a maximum water return temperature of approximately 120º F. Depending on each unit's operating conditions (i.e., condenser outlet temperature), the degree to which the thermal input to the turbine can be increased may be limited.

towers or tower cells will alter the allocation of the retained pump's electrical demand, but not the total demand.

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 when in use. The increased electrical demand associated with cooling tower pump operation is summarized in Table K–19.

Table K–19. Cooling Tower Pump Parasitic Use

	Tower Complex 1	Tower Complex 2	OBGS total
Units served	Unit 1	Unit 2	**--**
Generating capacity (MW)	750	750	**1,500**
Existing pump configuration (hp)	2,000	2,000	**4,000**
New pump configuration (hp)	6,045	6,045	**12,091**
Difference (hp)	4,045	4,045	**8,091**
Difference (MW)	3.0	3.0	**6.0**
Net pump parasitic use (% of capacity)	**0.40%**	**0.40%**	**0.40%**

4.6.2 HEAT RATE CHANGE

Heat rate adjustments were calculated based on each month's ambient climate conditions and reflect the estimated difference between operations with once-through and wet cooling tower systems. As noted above, the energy penalty analysis assumes OBGS will increase its fuel consumption to compensate for lost efficiency and the increased parasitic load from fans and pumps. The higher turbine firing rate will increase the thermal load rejected to the condenser, which, in turn, results in a higher backpressure value and corresponding increase in the heat rate. No data are available describing the changes in turbine backpressures above the design thermal loads. For the purposes of monetizing the energy penalty only, this study conservatively assumed an additional increase in the heat rate of 0.5 percent at the higher firing rate; the actual effect at OBGS may be greater or less. Changes in the heat rate for each unit at OBGS are presented in Figure K–13 and Figure K–14.

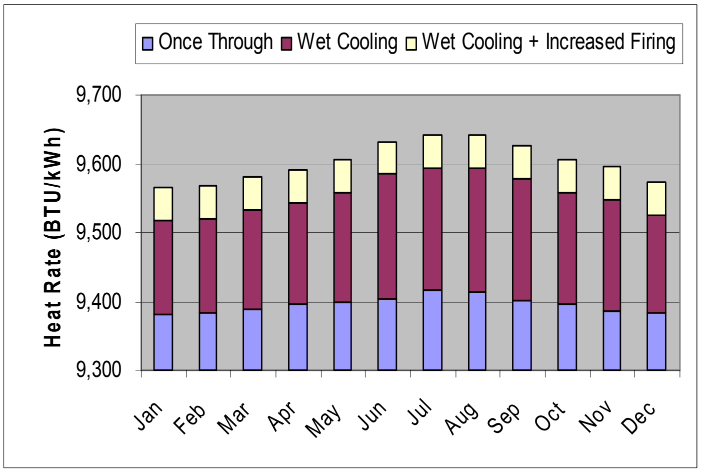

Figure K–12. Estimated Heat Rate Change (Unit 1)

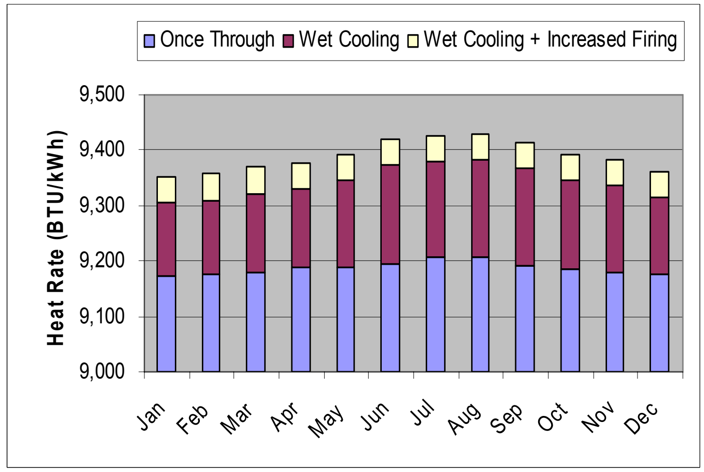

Figure K–13. Estimated Heat Rate Change (Unit 2)

4.6.3 CUMULATIVE ESTIMATE

Using the increased fuel option, the energy penalty's cumulative value is obtained by first calculating the relative costs of generation ($/MWh) for the once-through system and the wet cooling system adjusted for a higher turbine firing rate. The cost of generation for OBGS is based on the relative heat rates developed in Section 4.6 and the average monthly wholesale natural gas cost ($/MMBTU) (ICE 2006a). The difference between these two values represents the monthly increased cost, per MWh, that results from converting to wet cooling towers. This value is then applied to the net MWh generated for the each month and summed to calculate the annual cost.

Based on 2006 output data, the Year 1 energy penalty for OBGS will be approximately $600,000 million. In contrast, the energy penalty's value calculated with the production loss option would be approximately $1.1 million. Together, these values represent the range of potential energy penalty costs for OBGS. Table K–20 and Table K–21 summarize the energy penalty estimates for each unit using the increased fuel option.

Table K-20. Unit 1 Energy Penalty—Year 1

Month	Fuel cost ($/MMBTU)	Once-through system		Wet towers w/ increased firing		Difference ($/MWh)	2006 output (MWh)	Net cost ($)
		Heat rate (BTU/kWh)	Cost ($/MWh)	Heat rate (BTU/kWh)	Cost ($/MWh)			
January	6.00	9,380	56.28	9,566	57.39	1.11	0	0
February	5.50	9,383	51.61	9,569	52.63	1.02	0	0
March	4.75	9,388	44.59	9,582	45.51	0.92	0	0
April	4.75	9,396	44.63	9,591	45.56	0.93	0	0
May	4.75	9,398	44.64	9,606	45.63	0.99	0	0
June	5.00	9,405	47.02	9,633	48.16	1.14	0	0
July	6.50	9,416	61.20	9,641	62.66	1.46	14,356	21,002
August	6.50	9,415	61.20	9,643	62.68	1.48	0	0
September	4.75	9,401	44.65	9,627	45.73	1.07	1,583	1,700
October	5.00	9,395	46.98	9,606	48.03	1.05	0	0
November	6.00	9,387	56.32	9,596	57.57	1.25	0	0
December	6.50	9,385	61.00	9,574	62.23	1.23	0	0
							Unit 1 total	**22,702**

Table K-21. Unit 2 Energy Penalty—Year 1

Month	Fuel cost ($/MMBTU)	Once-through system		Wet towers w/ increased firing		Difference ($/MWh)	2006 output (MWh)	Net cost ($)
		Heat rate (BTU/kWh)	Cost ($/MWh)	Heat rate (BTU/kWh)	Cost ($/MWh)			
January	6.00	9,172	55.03	9,353	56.12	1.09	0	0
February	5.50	9,175	50.46	9,357	51.46	1.00	0	0
March	4.75	9,179	43.60	9,369	44.50	0.90	0	0
April	4.75	9,187	43.64	9,378	44.54	0.91	12,214	11,058
May	4.75	9,189	43.65	9,393	44.62	0.97	29,138	28,241
June	5.00	9,196	45.98	9,419	47.10	1.12	62,789	70,080
July	6.50	9,207	59.84	9,427	61.27	1.43	214,361	306,968
August	6.50	9,206	59.84	9,429	61.29	1.45	49,386	71,669
September	4.75	9,192	43.66	9,413	44.71	1.05	89,109	93,660
October	5.00	9,186	45.93	9,392	46.96	1.03	0	0
November	6.00	9,179	55.07	9,383	56.30	1.22	0	0
December	6.50	9,176	59.65	9,361	60.85	1.20	0	0
							Unit 2 total	**581,676**

4.7 NET PRESENT COST

The net present cost (NPC) of a wet cooling system retrofit at OBGS is the sum of all annual expenditures over the project's 20-year life span 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 OBGS 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 K–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 OBGS has a relatively low capacity utilization factor, O&M costs for the NPC calculation were estimated at 35 percent of their maximum value. (See Table K–17.)
- *Annual Energy Penalty.* Insufficient information is available to this study to forecast future generating output at OBGS. In lieu of annual estimates, this study uses the net MWh output from 2006 as the calculation basis for Years 1 through 20. Wholesale prices include a year-over-year price escalator of 5.8 percent (based on the Producer Price Index). The energy penalty values are based on the increased fuel option discussed in Section 4.6. (See Table K–20 and Table K– 21.)

Using these values, the NPC_{20} for OBGS is $150 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by OBGS for a wet cooling tower retrofit is the sum of annual amortized capital costs 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 4.7). Revenue losses from a construction-related shutdown, if any, are incurred in Year 0 only and not included in the annual cost summarized in Table K–22.

Table K–22. Annual Cost

Discount rate (%)	Capital Cost ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00%	12,500,000	700,000	1,100,000	**14,300,000**

4.9 COST-TO-GROSS REVENUE COMPARISON

Limited financial data are available to conduct a detailed analysis of the economic impact that a wet cooling system retrofit will have on OBGS's annual revenues. The facility's gross annual revenue can be approximated using 2006 net generating data (CEC 2006) and average wholesale prices for electricity as recorded at the SP 15 trading hub (ICE 2006b). This estimate, therefore, does not reflect any changes that may result from different wholesale prices or contract agreements that may increase or decrease the gross revenue summarized below, nor does it account for annual fixed revenue requirements or other variable costs.

The estimate of gross annual revenue from electricity sales at OBGS is a straightforward calculation that multiplies the monthly wholesale cost of electricity by the amount generated for the particular month. The estimated gross revenue for OBGS is summarized in Table K–23. A comparison of annual costs to annual gross revenue is summarized in Table K–24.

Table K–23. Estimated Gross Revenue

	Wholesale price ($/MWh)	2006 net output (MWh)		Estimated gross revenue ($)		
		Unit 1	Unit 2	Unit 1	Unit 2	OBGS total
January	66	0	0	0	0	**0**
February	61	0	0	0	0	**0**
March	51	0	0	0	0	**0**
April	51	0	12,214	0	622,914	**622,914**
May	51	0	29,138	0	1,486,038	**1,486,038**
June	55	0	62,789	0	3,453,395	**3,453,395**
July	91	14,356	214,361	1,306,396	19,506,851	**20,813,247**
August	73	0	49,386	0	3,605,178	**3,605,178**
September	53	1,583	89,109	83,899	4,722,777	**4,806,676**
October	57	0	0	0	0	**0**
November	66	0	0	0	0	**0**
December	67	0	0	0	0	**0**
OBGS total		**15,939**	**456,997**	**1,390,295**	**33,397,153**	**34,787,448**

Table K–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
34,800,000	12,500,000	36.0	700,000	2.0	1,100,000	3.2	**14,300,000**	**41.0**

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 OBGS. As with many existing facilities, the site's location and configuration complicate 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 OBGS. A brief summary of these technologies' applicability 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. OBGS currently withdraws its cooling water through a submerged conduit extending approximately 2,000 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 are unproven in an open ocean environment.

5.4 VARIABLE SPEED DRIVES

Variable speed drives (VSDs) were not considered for analysis at OBGS 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 to 50 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, thus negating any potential benefit. Use of VSDs may be an economically desirable option when pumps are retrofitted or replaced for other reasons, but they 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 would be required at OBGS (approximately 250 mgd). To function as intended, cylindrical wedgewire screens must be submerged in a water body with a consistent ambient current of 0.5 feet per second (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 OBGS would be located offshore in the Pacific Ocean, south of the facility. Limited information regarding the subsurface currents in the near-shore environment near OBGS is available. 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 over 1,000 to 1,500 feet become problematic due to the airburst system's inability to maintain adequate pressure for sufficient cleaning (Someah 2007). Together, these considerations preclude further evaluation of fine-mesh cylindrical wedgewire screens at OBGS.

6.0 REFERENCES

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). 2006. *AHSRAE Handbook—Fundamentals (Design Conditions for Ventura, CA).* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

CARB (California Air Resources Board). 2005. *Facility Emissions Data: Ormond Beach Generating Station.* <http://arb.ca.gov/app/emsinv/facinfo/facinfo.php>. Accessed August 10, 2007.

CEC (California Energy Commission). 2002. Resource, Reliability and Environmental Concerns of Aging Power Plant Operations and Retirements. California Energy Commission, Sacramento, CA.

— 2006. *Quarterly Fuel and Energy Report (QFER).* California Energy Commission, Sacramento, CA.

CIMIS (California Irrigation Management Information System). 2006. Daily Monitoring Data for Station 156—Oxnard (2000–2006). <http://www.cimis.water.ca.gov/cimis/data.jsp>. Accessed February 6, 2007.

CTI (Cooling Tower Institute). 1994. *Isokinetic Drift Test Code.* Cooling Tower Institute, Houston, TX.

FRTR (Federal Remediation Technologies Roundtable). 2002. *Remediation Technologies Screening Matrix and Reference Guide, 4th Edition.* Federal Remediation Technologies Roundtable, Washington, DC.

ICE (Intercontinental Exchange). 2006a. *Wholesale Natural Gas Prices—Citygate Trading Hub.* <https://www.theice.com/marketdata/naNaturalGas/naNatGasHistory.jsp>. Accessed June 3, 2007.

— 2006b. Wholesale Electricity Prices—SP 15 Trading Hub. <https://www.theice.com/marketdata/naPower/naPowerHistory.jsp>. Accessed July 14, 2007.

LARWQCB (Los Angeles Regional Water Quality Control Board). 2001. Order 01-092. Los Angeles Regional Water Quality Control Board, Los Angeles, CA.

NOAA (National Oceanographic and Atmospheric Administration). 2007. *National Oceanographic Data Center—Coastal Water Temperature Guide, Ventura and Port Hueneme.* <http://www.nodc.noaa.gov/dsdt/cwtg/index.html>. Accessed March 1, 2007.

Oxnard, City of. 2006. *General Plan, Section X—Noise Element.*

— 2007. *Coastal Land Use Plan.*

Reliant Energy, Inc. 2004. Report of Waste Discharge and Application for Renewal of NPDES Permit for Ormond Beach Generating Station. Reliant Energy, Inc, Oxnard, CA.

— 2005. Clean Water Act Section 316(b) Proposal for Information Collection for Ormond Beach Generating Station. Reliant Energy, Inc, Oxnard, CA.

SCC (California State Coastal Conservancy). October 23, 2003. *Project Summary: Ormond Beach Acquisitions.* File 90-048. California State Coastal Conservancy, Oakland, CA.

SCCOOS (Southern California Coastal Ocean Observing System). 2006. *Surface Currents—Ventura County.* <http://www.sccoos.org/data/hfrnet/?r=8>. Accessed July 1, 2007.

Someah, K., 2007. Personal communication from Kaveah Someah, Groupe Laperrière & Verreault Inc., to Tim Havey, Tetra Tech, Inc.

SWRCB (California State Water Resources Control Board). 1972. Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California. California State Water Resources Control Board, Sacramento, CA.

— 1975. Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling. Resolution 75-58. California State Water Resources Control Board, Sacramento, CA.

USEPA (U.S. Environmental Protection Agency). 2000. *Wastewater Technology Fact Sheet: Ammonia Stripping.* EPA-832-F-00-019. U.S. Environmental Protection Agency, Washington, DC.

— 2001. Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities. U.S. Environmental Protection Agency, Washington, DC.

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

		Unit 1			Unit 2		
		Once through	**Closed cycle**	**Net increase**	**Once through**	**Closed cycle**	**Net increase**
JAN	Backpressure (in. HgA)	2.34	3.37	**1.03**	2.34	3.37	**1.03**
	Heat rate Δ (%)	*-0.31*	*1.16*	***1.46***	*-0.31*	*1.16*	***1.47***
FEB	Backpressure (in. HgA)	2.40	3.39	**0.99**	2.40	3.39	**0.99**
	Heat rate Δ (%)	*-0.27*	*1.19*	***1.47***	*-0.27*	*1.20*	***1.47***
MAR	Backpressure (in. HgA)	2.46	3.46	**1.00**	2.46	3.46	**1.00**
	Heat rate Δ (%)	*-0.23*	*1.33*	***1.56***	*-0.23*	*1.33*	***1.56***
APR	Backpressure (in. HgA)	2.55	3.51	**0.96**	2.55	3.51	**0.96**
	Heat rate Δ (%)	*-0.14*	*1.42*	***1.56***	*-0.14*	*1.42*	***1.56***
MAY	Backpressure (in. HgA)	2.57	3.61	**1.03**	2.57	3.61	**1.03**
	Heat rate Δ (%)	*-0.12*	*1.59*	***1.71***	*-0.12*	*1.59*	***1.71***
JUN	Backpressure (in. HgA)	2.64	3.77	**1.13**	2.64	3.77	**1.13**
	Heat rate Δ (%)	*-0.05*	*1.87*	***1.91***	*-0.05*	*1.87*	***1.92***
JUL	Backpressure (in. HgA)	2.73	3.82	**1.09**	2.73	3.82	**1.09**
	Heat rate Δ (%)	*0.07*	*1.95*	***1.88***	*0.07*	*1.96*	***1.88***
AUG	Backpressure (in. HgA)	2.72	3.83	**1.11**	2.72	3.83	**1.11**
	Heat rate Δ (%)	*0.06*	*1.98*	***1.91***	*0.06*	*1.98*	***1.92***
SEP	Backpressure (in. HgA)	2.60	3.73	**1.13**	2.60	3.73	**1.13**
	Heat rate Δ (%)	*-0.09*	*1.81*	***1.89***	*-0.09*	*1.81*	***1.90***
OCT	Backpressure (in. HgA)	2.55	3.60	**1.05**	2.55	3.60	**1.05**
	Heat rate Δ (%)	*-0.15*	*1.58*	***1.73***	*-0.15*	*1.58*	***1.73***
NOV	Backpressure (in. HgA)	2.46	3.54	**1.09**	2.46	3.54	**1.09**
	Heat rate Δ (%)	*-0.23*	*1.47*	***1.71***	*-0.23*	*1.48*	***1.71***
DEC	Backpressure (in. HgA)	2.42	3.42	**1.00**	2.42	3.42	**1.00**
	Heat rate Δ (%)	*-0.26*	*1.25*	***1.51***	*-0.26*	*1.25*	***1.51***

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 other accessories (bends, water hammers…)	lot	1	--	--	500,000	500,000	4,000.00	85	340,000	**840,000**
Allocation for pipe racks (approx 800 ft) and cable racks	t	80	--	--	2,500	200,000	17.00	105	142,800	**342,800**
Allocation for sheet piling and dewatering	lot	1	--	--	500,000	500,000	5,000.00	100	500,000	**1,000,000**
Allocation for testing pipes	lot	1	--	--	--	--	2,000.00	95	190,000	**190,000**
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	22,042	--	--	--	--	0.04	200	176,336	**176,336**
Bedding for PCCP pipe	m3	3,321	--	--	25	83,025	0.04	200	26,568	**109,593**
Bend for PCCP pipe 42" & 48" diam (allocation)	ea	15	--	--	5,000	75,000	25.00	95	35,625	**110,625**
Bend for PCCP pipe 72" diam (allocation)	ea	30	--	--	18,000	540,000	40.00	95	114,000	**654,000**
Bend for PCCP pipe 96" diam (allocation)	ea	40	--	--	30,000	1,200,000	75.00	95	285,000	**1,485,000**
Building architectural (siding, roofing, doors, painting…etc)	ea	4	--	--	57,500	230,000	690.00	75	207,000	**437,000**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	40	30,800	1,232,000	--	--	50.00	85	170,000	**1,402,000**
Butterfly valves 36" c/w allocation for actuator & air lines	ea	4	33,600	134,400	--	--	50.00	85	17,000	**151,400**
Butterfly valves 54" c/w allocation for actuator & air lines	ea	8	60,900	487,200	--	--	55.00	85	37,400	**524,600**
Butterfly valves 72" c/w allocation for actuator & air lines	ea	8	96,600	772,800	--	--	75.00	85	51,000	**823,800**
Butterfly valves 84" c/w allocation for actuator & air lines	ea	8	124,600	996,800	--	--	75.00	85	51,000	**1,047,800**
Butterfly valves 96" c/w allocation for actuator & air lines	ea	12	151,200	1,814,400	--	--	75.00	85	76,500	**1,890,900**
Check valves 36"	ea	4	48,000	192,000	--	--	24.00	85	8,160	**200,160**
Check valves 54"	ea	8	87,000	696,000	--	--	26.00	85	17,680	**713,680**
Concrete basin walls (all in)	m3	724	--	--	225	162,900	8.00	75	434,400	**597,300**
Concrete elevated slabs (all in)	m3	644	--	--	250	161,000	10.00	75	483,000	**644,000**

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	4,652	--	--	200	930,400	4.00	75	1,395,600	**2,326,000**
Ductile iron cement pipe 12" diam. for fire water line	ft	1,500	--	--	100	150,000	0.60	95	85,500	**235,500**
Excavation and backfill for fire line & make-up (using excavated material for backfill except for bedding)	m3	8,663	--	--	--	--	0.08	200	138,608	**138,608**
Excavation for PCCP pipe	m3	35,585	--	--	--	--	0.04	200	284,680	**284,680**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	**5,250**
Flange for PCCP joints 30"	ea	36	--	--	2,260	81,360	16.00	95	54,720	**136,080**
Flange for PCCP joints 72"	ea	16	--	--	9,860	157,760	25.00	95	38,000	**195,760**
Flange for PCCP joints 96"	ea	16	--	--	15,080	241,280	35.00	95	53,200	**294,480**
Foundations for pipe racks and cable racks	m3	190	--	--	250	47,500	8.00	75	114,000	**161,500**
FRP flange 30"	ea	116	--	--	1,679	194,781	50.00	85	493,000	**687,781**
FRP flange 36"	ea	16	--	--	2,500	40,000	70.00	85	95,200	**135,200**
FRP flange 54"	ea	32	--	--	5,835	186,718	80.00	85	217,600	**404,318**
FRP flange 72"	ea	8	--	--	20,888	167,101	200.00	85	136,000	**303,101**
FRP flange 84"	ea	24	--	--	33,381	801,145	300.00	85	612,000	**1,413,145**
FRP flange 96"	ea	8	--	--	40,000	320,000	500.00	85	340,000	**660,000**
FRP pipe 30" diam.	ft	600	--	--	121	72,766	0.40	85	20,400	**93,166**
FRP pipe 54" diam.	ft	320	--	--	426	136,224	0.80	85	21,760	**157,984**
FRP pipe 72" diam.	ft	400	--	--	851	340,560	1.20	85	40,800	**381,360**
FRP pipe 84" diam.	ft	200	--	--	946	189,200	1.50	85	25,500	**214,700**
FRP pipe 96" diam.	ft	1,200	--	--	2,838	3,405,600	1.75	85	178,500	**3,584,100**
Harness clamp 42" & 48" c/w internal testable joint	ea	85	--	--	2,000	170,000	16.00	95	129,200	**299,200**
Harness clamp 72" c/w internal testable joint	ea	150	--	--	2,440	366,000	18.00	95	256,500	**622,500**
Harness clamp 96" c/w internal testable joint	ea	240	--	--	3,300	792,000	22.00	95	501,600	**1,293,600**
Joint for FRP pipe 30" diam.	ea	30	--	--	1,126	33,769	50.00	85	127,500	**161,269**
Joint for FRP pipe 54" diam.	ea	16	--	--	1,324	21,190	85.00	85	115,600	**136,790**
Joint for FRP pipe 72" diam.	ea	20	--	--	3,122	62,436	200.00	85	340,000	**402,436**
Joint for FRP pipe 84" diam.	ea	10	--	--	5,014	50,138	300.00	85	255,000	**305,138**
Joint for FRP pipe 96" diam.	ea	60	--	--	17,974	1,078,440	600.00	85	3,060,000	**4,138,440**
PCCP pipe 42" dia.for make-up water line	ft	1,500	--	--	195	292,500	0.90	95	128,250	**420,750**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
PCCP pipe 72" diam.	ft	2,600	--	--	507	1,318,200	1.30	95	321,100	**1,639,300**
PCCP pipe 96" diam.	ft	4,400	--	--	890	3,916,000	2.00	95	836,000	**4,752,000**
Riser (FRP pipe 30" diam X40 ft)	ea	36	--	--	14,603	525,708	100.00	85	306,000	**831,708**
Structural steel for building	t	320	--	--	2,500	800,000	20.00	105	672,000	**1,472,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**6,325,600**	**--**	**20,892,202**	**--**	**--**	**15,128,537**	**42,346,339**
ELECTRICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
4.16 kv cabling feeding MCC's	m	2,000	--	--	75	150,000	0.40	85	68,000	**218,000**
4.16kV switchgear - 4 breakers	ea	1	250,000	250,000	--	--	150.00	85	12,750	**262,750**
480 volt cabling feeding MCC's	m	1,500	--	--	70	105,000	0.40	85	51,000	**156,000**
480V Switchgear - 1 breaker 3000A	ea	6	30,000	180,000	--	--	80.00	85	40,800	**220,800**
Allocation for automation and control	lot	1	--	--	1,000,000	1,000,000	10,000.00	85	850,000	**1,850,000**
Allocation for cable trays and duct banks	m	2,000	--	--	75	150,000	1.00	85	170,000	**320,000**
Allocation for lighting and lightning protection	lot	1	--	--	150,000	150,000	1,500.00	85	127,500	**277,500**
Dry Transformer 2MVA xxkV-480V	ea	6	100,000	600,000	--	--	100.00	85	51,000	**651,000**
Lighting & electrical services for pump house building	ea	4	--	--	20,000	80,000	250.00	85	85,000	**165,000**
Local feeder for 2000 HP motor 4160 V (up to MCC)	ea	8	--	--	40,000	320,000	160.00	85	108,800	**428,800**
Local feeder for 250 HP motor 460 V (up to MCC)	ea	36	--	--	18,000	648,000	150.00	85	459,000	**1,107,000**
Oil Transformer 10/13.33MVA xx-4.16kV	ea	2	190,000	380,000	--	--	150.00	85	25,500	**405,500**
Primary breaker(xxkV)	ea	4	45,000	180,000	--	--	60.00	85	20,400	**200,400**
Primary feed cabling (assumed 13.8 kv)	m	3,000	--	--	175	525,000	0.50	85	127,500	**652,500**
ELECTRICAL TOTAL	**--**	**--**	**--**	**1,590,000**	**--**	**3,128,000**	**--**	**--**	**2,197,250**	**6,915,250**
MECHANICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Allocation for ventilation of buildings	ea	4	25,000	100,000	--	--	250.00	85	85,000	**185,000**
Cooling tower for unit 1	lot	1	10,700,000	10,700,000	--	--	--	--	--	**10,700,000**
Cooling tower for unit 2	lot	1	10,700,000	10,700,000	--	--	--	--	--	**10,700,000**
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	8	1,000,000	8,000,000	--	--	500.00	85	340,000	**8,340,000**
MECHANICAL TOTAL	**--**	**--**	**--**	**31,500,000**	**--**	**0**	**--**	**--**	**765,000**	**32,265,000**

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	132,500,000	--	--	--	132,500,000	1	**132,500,000**
1	--	544,800	22,702	581,677	1,149,179	0.9346	**1,074,022**
2	--	555,696	24,025	615,589	1,195,310	0.8734	**1,043,984**
3	--	566,810	25,426	651,478	1,243,713	0.8163	**1,015,243**
4	--	578,146	26,908	689,459	1,294,513	0.7629	**987,584**
5	--	589,709	28,477	729,654	1,347,840	0.713	**961,010**
6	--	601,503	30,137	772,193	1,403,833	0.6663	**935,374**
7	--	613,533	31,894	817,212	1,462,639	0.6227	**910,785**
8	--	625,804	33,753	864,855	1,524,413	0.582	**887,208**
9	--	638,320	35,721	915,277	1,589,318	0.5439	**864,430**
10	--	651,086	37,804	968,637	1,657,527	0.5083	**842,521**
11	--	664,108	40,008	1,025,109	1,729,225	0.4751	**821,555**
12	--	805,759	42,340	1,084,873	1,932,972	0.444	**858,240**
13	--	821,874	44,809	1,148,121	2,014,804	0.415	**836,143**
14	--	838,312	47,421	1,215,056	2,100,789	0.3878	**814,686**
15	--	855,078	50,186	1,285,894	2,191,158	0.3624	**794,075**
16	--	872,180	53,111	1,360,861	2,286,153	0.3387	**774,320**
17	--	889,623	56,208	1,440,200	2,386,031	0.3166	**755,417**
18	--	907,416	59,485	1,524,163	2,491,064	0.2959	**737,106**
19	--	925,564	62,953	1,613,022	2,601,539	0.2765	**719,325**
20	--	944,075	66,623	1,707,061	2,717,759	0.2584	**702,269**
Total							**149,835,297**