A. ALAMITOS GENERATING STATION

AES ALAMITOS, LLC—LONG BEACH, CA

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1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at Alamitos Generating Station (AGS) 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 Los Cerritos Channel by approximately 95 percent. Impingement and entrainment impacts would be reduced by a similar proportion.

The preferred option selected for AGS includes 3 conventional wet cooling towers (without plume abatement), with individual cells arranged in a back-to-back configuration to accommodate limited space at the site. This option assumes the availability of adjoining property currently owned by Pacific Energy to site one of the cooling towers (for Units 1 and 2). Space limitations would appear to preclude plume-abated towers in the design if they were required to mitigate visual impacts. Initial capital costs for the towers would also increase by a factor of 2 or 3.

Construction-related shutdowns are estimated to take approximately 4 weeks per unit (concurrent), although AGS is not expected to incur any financial loss as a result based on 2006 capacity utilization rates for all units.

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 costs associated with the installation and operation of wet cooling towers at AGS are summarized in Table A–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table A–2.

Table A–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]	209,800,000	12.28	125
NPC_{20} [b]	263,100,000	15.40	157

[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 A–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up	19,800,000	1.16	11.81
Operations and maintenance	2,100,000	0.12	1.25
Energy penalty	3,500,000	0.20	2.09
Total AGS annual cost	**25,400,000**	**1.48**	**15.15**

1.2 ENVIRONMENTAL

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

Table A–3. Environmental Summary

		Units 1 & 2	Units 3 & 4	Units 5 & 6
Water use	Design intake volume (gpm)	137,000	259,000	404,200
	Cooling tower makeup water (gpm)	8,200	13,600	17,800
	Reduction from capacity (%)	94	95	96
Energy efficiency [a]	Summer heat rate increase (%)	1.69	1.73	1.67
	Summer energy penalty (%)	2.69	2.62	2.61
	Annual heat rate increase (%)	1.39	1.45	1.35
	Annual energy penalty (%)	2.38	2.35	2.29
Direct air emissions [b]	PM10 emissions (tons/yr) (maximum capacity)	79	149	233
	PM10 emissions (tons/yr) (2006 capacity utilization)	2.4	19	24

[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

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

Available space for wet cooling towers may be problematic if land currently owned by Pacific Energy cannot be secured for use. The analysis in this chapter assumes the land, currently unoccupied and zoned for industrial use, can be obtained, which enables the only reasonable tower configuration that accommodates all six operating units. If this land is not available, a revised analysis would likely be able to accommodate only four units, with Units 1 & 2, as the oldest and least efficient, the most likely to be left out of a retrofit project. The Unit 5 & 6 cooling tower would be relocated to the north and occupy a narrow strip of land alongside the San Gabriel River.

AGS may also face wastewater discharge permit conflicts upon converting to wet cooling towers. The current source water (Los Cerritos Channel) has shown elevated concentrations of some pollutants that would become concentrated in a wet cooling tower. If cooling tower makeup water is obtained from the same source, compliance with effluent limitations may become more difficult. In addition, the facility's receiving water has been reclassified from an ocean to an estuary, which may result in more stringent limitations than those currently applicable. These potential conflicts may be mitigated or eliminated through the use of reclaimed water as the makeup source.

2.0 BACKGROUND

AGS is a natural gas-fired steam electric generating facility located in the city of Long Beach, Los Angeles County, owned and operated by AES Alamitos, LLC. AGS currently operates six conventional steam turbine units (Units 1-6) with a combined generating capacity of 1,950 MW. The facility occupies approximately 120 acres of a 230-acre industrial site along the west bank of the San Gabriel River, two miles northeast of the entrance to Alamitos Bay and the Long Beach Marina. The property's western edge is bordered by the Los Cerritos Channel and North Studebaker Avenue. State Highway 22 borders the northern edge of the property and Westminster Avenue/East 2nd Street borders the south. The Los Angeles Department of Water and Power's (LADWP) Haynes Generating Station (HnGS) is located directly opposite AGS on the east bank of the San Gabriel River (Table A–4 and Figure A–1).

Table A–4. General Information

Unit	In-service year	Rated capacity (MW)	2006 capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 1	1956	175	3.3%	68,500
Unit 2	1957	175	2.7%	68,500
Unit 3	1961	320	17.1%	129,500
Unit 4	1962	320	7.9%	129,500
Unit 5	1969	480	9.3%	202,100
Unit 6	1966	480	11.3%	202,100
AGS total		**1,950**	**9.70%**	**800,200**

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

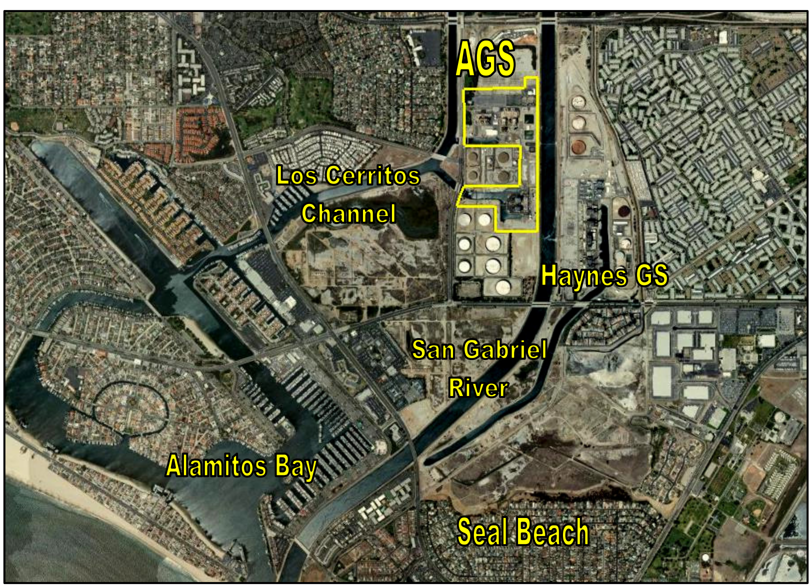

Figure A–1. General Vicinity of Alamitos Generating Station

2.1 COOLING WATER SYSTEM

AGS operates two separate cooling water intake structures (CWIS) to provide condenser cooling water to each of the six generating units (Figure A–2).[1] Two man-made canals draw water from Los Cerritos Channel to the generating units. Units 1 through 4 are served by the north canal, while Unit 5 and Unit 6 are served by the south canal. Once-through cooling water is combined with low-volume wastes generated by AGS and discharged through one of three outfalls to the San Gabriel River. Surface water withdrawals and discharges are regulated by NPDES Permit CA0001139 as implemented by Los Angeles Regional Water Quality Control Board (LARWQCB) Order 00-082.[2]

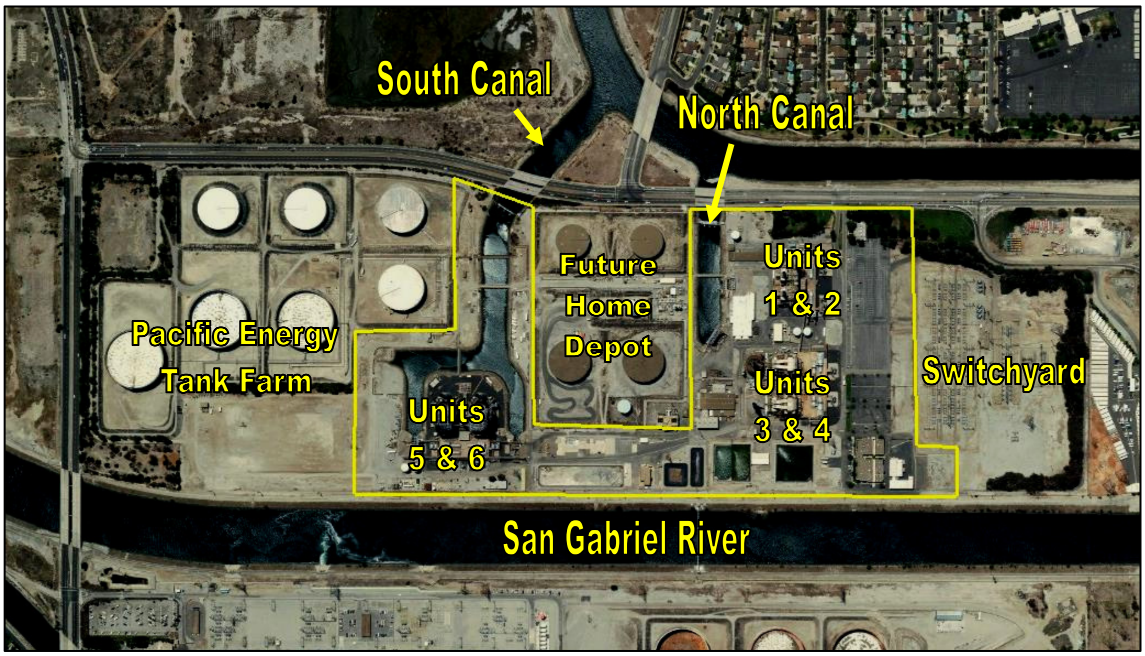

Figure A–2. Site View

The screen house for Units 1 and 2 contains four separate traveling screens (2 per unit) to remove large debris from the intake stream. The wire mesh panels have openings 0.5 by 0.75 inches, leading to a total through screen area of approximately 68 percent. Through-screen velocities for these screens are roughly 4.4 feet per second (fps). Screens are normally rotated and cleaned based on the pressure differential (8 inches) between the upstream and downstream faces of the screens. A high pressure spray removes any debris from the screens, including impinged fish, for disposal at a landfill. Downstream of each screen is a circulating water pump rated at 36,000

[1] The definition of a CWIS is taken from 40 CFR 125.93, which defines a CWIS as "the total physical structure and any associated constructed waterways used to withdraw cooling water from waters of the U.S. The cooling water intake structure extends from the point at which water is withdrawn from the surface water source up to, and including, the intake pumps." Past definitions of CWIS have often centered on the number of intake bays. The current NPDES permit for AGS alternately identifies three or four CWIS.

[2] LARWQCB Order #00-082 expired on May 10, 2005 but has been administratively extended pending adoption of a renewed order.

gallons per minute (gpm), for a total capacity of 144,000 gpm, or 207 million gallons per day (mgd) (AES 2005).

The configuration for Units 3 and 4 is essentially similar to Units 1 and 2, with the screen houses located approximately 200 feet to the east. Through-screen velocities are roughly 5.4 fps due to the larger capacity pumps that serve the units. Screens are normally rotated and cleaned based on the pressure differential (8 inches) between the upstream and downstream faces of the screens. A high pressure spray removes any debris from the screens, including impinged fish, for disposal at a landfill. Downstream of each screen is a circulating water pump rated at 68,000 gpm, for a total capacity of 272,000 gpm, or 392 mgd (AES 2005).

The intake structure for Units 5 and 6 (south canal) divides to two separate screen houses, one for Unit 5 and one for Unit 6. Each screen house contains two traveling screens to remove large debris from the intake stream. The wire mesh panels have openings 0.625 by 0.625 inches. Through-screen velocities for these screens are roughly 2.2 fps. Screens are normally rotated and cleaned based on the pressure differential (9 inches) between the upstream and downstream faces of the screens. A high pressure spray removes any debris from the screens, including impinged fish, for disposal at a landfill. Downstream of each screen is a circulating water pump rated at 117,000 gpm for a total capacity of 468,000 gpm, or 674 mgd. These pumps are mixed-flow, and can be operated as low as 65 percent of their rated maximum capacity (AES 2005).

At maximum capacity, AGS maintains a total pumping capacity rated at 1,273 mgd, with a total condenser flow rating of 1,152 mgd. On an annual basis, AGS withdraws substantially less than its design capacity due to its low generating capacity utilization (9.7 percent for 2006). On a daily basis during peak demand periods, however, intake flows may approach the design rate. When in operation and generating the maximum load, AGS can be expected to withdraw water from Los Cerritos Channel at a rate approaching its maximum capacity.

2.2 SECTION 316(B) PERMIT COMPLIANCE

None of the CWIS currently in operation at AGS use technologies generally considered to be effective at reducing impingement mortality and/or entrainment. LARWQCB Order 00-082, adopted in 2000, states that “the design, construction and operation of the intake structures [at AGS] represents Best Available Technology (BAT) [sic] as required by Section 316(b) of the Clean Water Act” (LARWQCB 2000. Finding 17). The order does not contain any numeric or narrative limitations regarding impingement or entrainment resulting from CWIS operation, but does require semi-annual monitoring of impingement at each intake structure (coinciding with scheduled heat treatments). Based on the record available for review, AGS has been compliant with this permit requirement.

The LARWQCB has notified AGS of its intent to revisit requirements under CWA section 316(b), including a determination of BTA for minimization of adverse environmental impact, during the current re-permitting 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 the use of saltwater wet cooling towers at AGS, with the current source water (Los Cerritos Channel) 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 95 percent; rates of impingement and entrainment will decline by a similar proportion. Use of reclaimed water was considered for AGS 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 the cooling demand for each active generating unit at AGS 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 AGS.

The overall practicality of retrofitting the six units at AGS 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 AGS 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.[3] The practicality and difficulty of these modifications are dependent on the age and configuration of

[3] 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.

each unit, but are assumed to be feasible at AGS. Condenser water boxes for all six units are located at grade level and appear to be readily accessible. Additional costs associated with condenser modifications are included in the discussion of capital expenditures (Section 4.3).

Information provided by AGS 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.

For example, the condenser specification sheet for Units 1 and 2 reports a design turbine exhaust pressure of 1.69 in. HgA, with a steam condensate temperature of 105.2 °F. At this pressure, the steam condensate would be approximately 95.5 °F. On the other hand, if the steam condensate temperature is correct, the corresponding turbine exhaust pressure would be approximately 2.26 in. HgA. A review of other information for the condenser (e.g., tube size and material, water flow, steam load) indicates that the steam condensate temperature is incorrectly reported.

Parameters used in the development of the cooling tower design are summarized in Table A–5. Units grouped together are mirror images of each other and generally share identical design specifications.

Table A–5. Condenser Design Specifications

	Units 1 & 2	Units 3 & 4	Units 5 & 6
Thermal load (MMBTU/hr)	843.9	1407	1835
Surface area (ft^2)	90,000	145,000	207,400
Condenser flow rate (gpm)	68,500	129,500	202,100
Tube material	Al Brass	Al Brass	Cu-Ni (90-10)
Heat transfer coefficient (U_d)	538	541	492
Cleanliness factor	0.85	0.85	0.85
Inlet temperature (°F)	63	63	63
Temperature rise (°F)	24.65	21.74	18.17
Steam condensate temperature (°F)	95.5	91.7	91.7
Turbine exhaust pressure (in. HgA)	1.69	1.5	1.5

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

AGS is located in Long Beach, Los Angeles County, approximately two miles inland from the entrance to Alamitos Bay. Cooling water is withdrawn at the surface from Los Cerritos Channel, which empties into the Long Beach Marina. Tidal influences and the operation of AGS's circulating water pumps draw ocean water through the marina to the CWIS. Inlet water temperatures are expected to be comparable with temperatures within the marina. Data provided by AGS detailing monthly inlet temperatures contained gaps for some months when units were not operational. Surface water temperatures used in this analysis were supplemented with monthly average coastal water temperatures as reported in the NOAA *Coastal Water Temperature Guide for Los Angeles* (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 the Long Beach area indicate a one percent ambient wet bulb temperature of 71° 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 83° 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 174 in Long Beach (CIMIS 2006). Climate data used in this analysis are summarized in Table A–6.

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

	Surface (°F)	Ambient wet bulb (°F)
January	58.2	54.0
February	59.8	56.0
March	62.0	58.0
April	64.5	63.0
May	67.8	66.0
June	70.2	68.0
July	69.1	70.0
August	68.3	71.0
September	67.3	69.0
October	65.4	64.0
November	61.6	58.0
December	58.0	54.0

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

AGS is located in Noise District 4 according to the City of Long Beach Health and Safety Code. This area is considered an “industrial sanctuary” within the city, although commercial and residential zoning areas are located in close proximity to the site, with some residences no more than 450 feet from the property line. The limit for continual noise in District 4 is 70 dBA. Limits for this district are generally applied at the nearest point of likely nuisance, such as a nearby residential or public recreation area. Residential areas to the west (across North Studebaker Avenue and Los Cerritos Channel) are the most likely to be adversely affected by any elevated noise levels. Discussions with the Noise Control Officer for the City of Long Beach indicated that despite the current noise district designation for AGS, new development in the area would likely be required to meet the daytime noise requirements for District 1 of the code (50 dBA compared with 70 dBA) (Long Beach 2006).

The wet cooling towers' overall design incorporates noise control measures to meet local zoning restrictions. Low noise fans and fan deck barrier walls are included to buffer noise associated with the towers' mechanical operation. In addition, concrete barrier walls will be constructed to minimize the noise associated with water falling through the tower. Barrier walls will be placed between the tower and the potentially affected areas and built to a height of 35 feet.

3.2.3.2 BUILDING HEIGHT

AGS is located within a planned industrial development zone (Southeast Development and Improvement Plan—SEADIP) within the City of Long Beach. Within this zone, structures are limited to a maximum above-grade height of 65 feet (Long Beach 2007). The height of the wet cooling towers designed for AGS, from grade level to the top of the fan deck barrier walls, is 62 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. Using the selection criteria for this study, plume abatement measures were not considered for AGS; all towers are a conventional design. The plume from wet cooling towers at AGS is not expected to adversely impact nearby infrastructure; the nearest area of immediate concern is the San Diego Freeway (I-405), located approximately 3/4 mile to the northeast.

Community standards for assessing the visual impact associated with a cooling tower plume cannot be determined within the scope of this study. The proximity of nearby residential and commercial areas, when viewed in the context of CEC siting guidelines, may contribute to the selection of an alternate design if a wet cooling tower retrofit is undertaken at AGS in the future. These guidelines assess the total size and persistence of a visual plume with respect to aesthetic standards for coastal resources.

Significant visual changes resulting from the plume may warrant incorporation of plume abatement measures. The selection of plume abated cooling towers, however, would increase the difficulty of identifying sufficient areas in which to locate such towers at AGS. Plume-abated towers require a larger overall area because they are not typically placed in a back-to-back configuration as are the conventional towers included in this study. Acquisition of adjoining land areas or major reconfiguration of facility structures may provide sufficient space. The additional height required for plume-abated towers (approximately 15–30 feet) would conflict with height restrictions under local zoning ordinances.

Section 3.2.3.5 discusses the available areas at AGS.

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 AGS, 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 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 $180,000 for all three cooling towers at AGS (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 site configuration and the relative locations of the six generating units creates several challenges in selecting a location for wet cooling towers at the facility. As shown in Figure A–3, much of the area at AGS not dedicated to the generating units or the intake canals is located along a narrow strip bordering the San Gabriel River. This study assumes the electrical switchyard located on the property's northern edge and the Pacific Energy tank farm to the southwest would both be unavailable for use as locations for cooling towers. Relocation of the switchyard, or replacement with gas insulated switchgear (GIS), coupled with the purchase or lease of the land, would free up a large portion of the area for wet cooling towers and enable alternate configurations.

Additional land area might allow a more favorable cooling tower configuration, which, in turn, would permit shorter individual cells and lower pump and fan capacities. Likewise, demolition of the tank farm and acquisition of the property would make sufficient space available for various arrangements of cooling towers, including plume-abated configurations. Due to the cost and uncertainty of both options, neither was selected for further analysis.

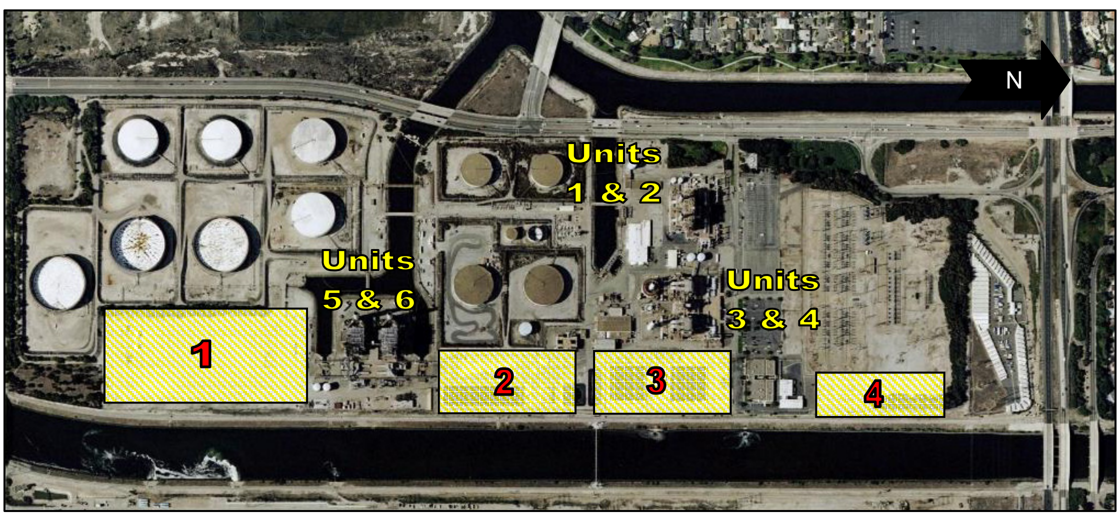

Figure A–3. Cooling Tower Siting Locations

The only sufficiently-sized area that is currently unoccupied is a 450' x 1,000' parcel (Area 1) located to the south of Units 5 & 6 between the tank farm and the San Gabriel River. A smaller parcel (300' x 400') lies immediately east of Units 3 & 4 (Area 3) and is currently occupied by two retention basins used to collect and treat the facility's low-volume wastes. Placement of cooling towers in this area will require the removal of the retention basins and, if necessary, relocation to another area at the site. Cleaning and decommissioning the retention basins may incur costs for hazardous material handling and disposal depending on the nature of wastes treated.

Two smaller areas were considered for cooling tower placement, but ultimately not selected. Area 2 is a narrow strip located north of Units 5 & 6 bordered by the San Gabriel River and the future location of a commercial development to the west. It was not selected due to its proximity to the development site. Area 4 is a narrow section located on the property's northern end bounded by the San Gabriel River and the switchyard. This area does not appear to be wide enough, with sufficient set-back from the river, for a back-to-back cooling tower configuration and concrete noise barrier wall.

Areas 1 and 3 were selected as the most practical locations given the constraints identified. Information not available to this study, such as the presence and configuration of underground infrastructure or future changes to the site or surrounding areas, may make other locations preferable for wet cooling towers.

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above, three separate wet cooling towers were selected to replace the current once-through cooling systems at AGS. Each tower will operate independently and be dedicated to each unit pair: Units 1 and 2; Units 3 and 4; and Units 5 and 6. The age, efficiency and design of each unit pair is essentially similar, with both often operating in tandem; thus, a single cooling tower to serve both units is a practical option that minimizes the required space and reduces some material costs. Each tower is configured in a multi-cell, back-to-back 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 AGS are summarized in Table A–7.

Table A–7. Wet Cooling Tower Design

	Tower 1 (Units 1 & 2)	Tower 2 (Units 3 & 4)	Tower 3 (Units 5 & 6)
Thermal load (MMBTU/hr)	1687.8	2814	3670
Circulating flow (gpm)	137,000	259,000	404,200
Number of cells	10	16	24
Tower type	Mechanical draft	Mechanical draft	Mechanical draft
Flow orientation	Counterflow	Counterflow	Counterflow
Fill type	Modular splash	Modular splash	Modular splash
Arrangement	Back-to-back	Back-to-back	Back-to-back
Primary tower material	FRP	FRP	FRP
Tower dimensions (l x w x h) (ft)	270 x 108 x 62	432 x 108 x 62	648 x 108 x 62
Tower footprint with basin (l x w) (ft)	274 x 112	436 x 112	652 x 112

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 the respective generating units to minimize the supply and return pipe distances and any increases in total pump head and brake horsepower. The limited space and configuration of AGS requires placement of Tower 1, serving Units 1 and 2, in the facility's southernmost area. This results in supply and return pipe distances of approximately 3,500 feet (each direction). Tower 2 serves Units 3 and 4 and is located immediately east of those units (Figure A–4). Tower 3 serves Units 5 and 6 and is located immediately south of the power block (Figure A–5).[4]

A 35-foot high concrete barrier wall (not shown) will be constructed on each tower's north and west sides to reduce the noise from falling water and enable compliance with local noise ordinances. Barrier walls will not be required on the tower's south or east sides because the potential for noise impacts in those directions is low.

[4] Figures A-4 and A-5 are not to the same scale.

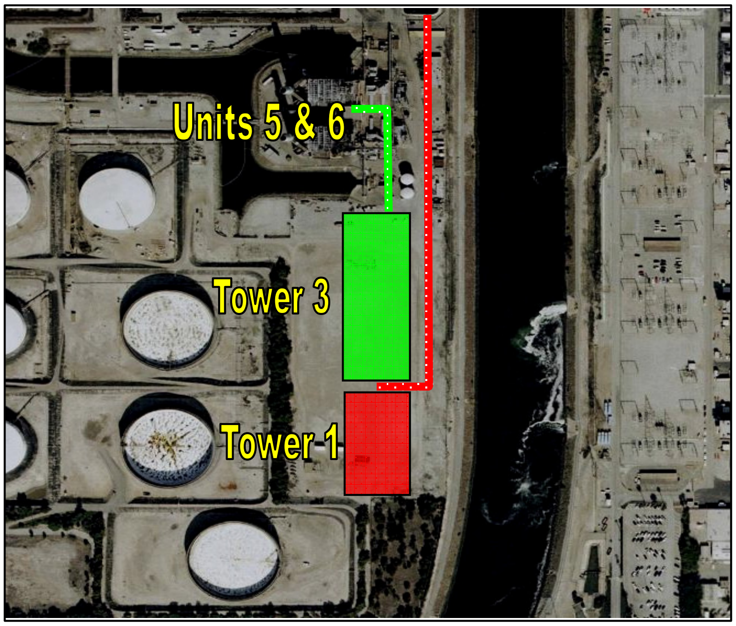

Figure A-4. Location of Tower 1 and Tower 3

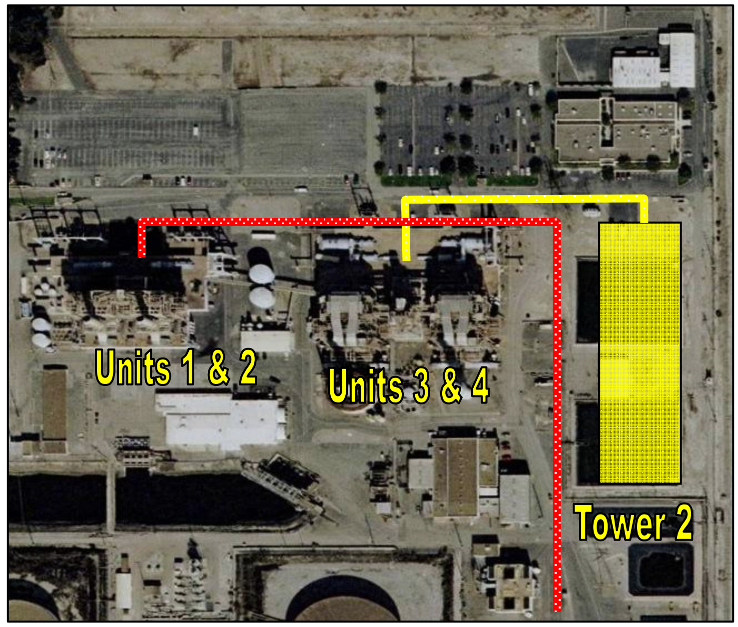

Figure A-5. Location of Tower 2

3.3.3 PIPING

The main supply and return pipelines for Tower 1 and Tower 2 will be located underground and made of prestressed concrete cylinder pipe (PCCP) suitable for salt water applications. These pipes range in size from 72 to 96 inches in diameter. The distance between Units 1 and 2 and Tower 1 requires roughly 7,500 feet of PCCP for the supply and return lines. An additional 1,100 feet are used for Tower 2. 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 AGS are all located at grade level, enabling a relatively straightforward connection.

The relative proximity of Tower 3 to Units 5 and 6 enables placement of nearly all piping above ground on pipe racks. Pipes are made of FRP except for the cooling water supply headers to the tower, which are PCCP and placed underground.

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 AGS.

3.3.4 FANS AND PUMPS

Each tower cell uses an independent single-speed fan. Low noise fan blades, gear box insulation and fan deck barrier walls are included to reduce operating noise and allow compliance with local noise ordinances. 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 cooling tower 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 wet cooling towers at AGS are summarized in Table A–8. The net electrical demand of fans and new pumps is discussed further as part of the energy penalty analysis in Section 4.6.1.

Table A–8. Cooling Tower Fans and Pumps

		Tower 1 (Units 1 & 2)	Tower 2 (Units 3 & 4)	Tower 3 (Units 5 & 6)
Fans	Number	10	16	24
	Type	Low noise Single speed	Low Noise Single speed	Low Noise Single speed
	Efficiency	0.95	0.95	0.95
	Motor power (hp)	263	263	263
Pumps	Number	2	2	2
	Type	50% recirculating Mixed flow Suspended bowl Vertical	50% recirculating Mixed flow Suspended bowl Vertical	50% recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88	0.88
	Motor power (hp)	2,023	3,375	5,216

3.4 ENVIRONMENTAL EFFECTS

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

Depending on how AGS 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 AGS.

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 AGS retains its NPDES permit to discharge wastewater to the San Gabriel River 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

AGS is located in the South Coast air basin. Air emissions are permitted by the South Coast Air Quality Management District (SCAQMD) (Facility ID 115394).

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 AGS, this corresponds to a rate of approximately 4 gpm based on the maximum combined flow in the three towers.

Optimal cooling tower placement considers the relative location of sensitive structures as well as the direction of prevailing winds to minimize any interference or impact from drift deposition. Given the spatial constraints at AGS, however, potential impacts cannot always be avoided. Areas potentially affected by drift deposition include residential neighborhoods located to the northwest, the switchyard located to the north, and the HnGS switchyard located on the opposite bank of the San Gabriel River. No agricultural areas are present in the vicinity of AGS that could potentially be impacted by drift.

Total PM_{10} emissions from the AGS 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 AGS will be obtained from the same source currently used for once-through cooling water (Los Cerritos Channel). This water is drawn through Alamitos Bay from the Pacific Ocean and mixes with a small volume of fresh water from upland locations. The water quality, however, is substantially similar to marine water with respect to the total dissolved solids (TDS) concentration. At 1.5 cycles of concentration and assuming an initial 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 AGS 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 A–9.

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table A–10 (CARB 2005). In 2005, AGS operated at an annual capacity utilization rate of 7.1 percent. Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 32 tons/year, or 79 percent. [5]

Table A–9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower 1	18	79	0.69	343
Tower 2	34	149	1.30	648
Tower 3	53	233	2.02	1,011
Total AGS PM_{10} and drift emissions	**105**	**461**	**4.01**	**2,002**

Table A–10. 2005 Emissions of SOx, NOx, PM10

Pollutant	Tons/year
NO_x	71.3
SO_x	7.2
PM_{10}	40.6

3.4.2

3.4.3 MAKEUP WATER

The volume of makeup water required by the three cooling tower at AGS is the sum of evaporative loss and the blowdown volume required to maintain the circulating water in each tower at the design TDS concentration (Table A-11). Drift expelled from the towers 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 Los Cerritos Channel by approximately 95 percent over the current design intake capacity.

Table A–11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower 1	137,000	2,700	5,400	**8,100**
Tower 2	259,000	4,500	9,000	**13,500**
Tower 3	404,200	5,900	11,700	**17,600**
Total AGS makeup water demand	**800,200**	**13,100**	**26,100**	**39,200**

[5] 2006 emission data are not currently available from the ARB website. For consistency, the comparative increase in PM_{10} emissions estimated here is based on the 2005 AGS capacity utilization rate instead of the 2006 rate presented in Table A–4. All other calculations in this chapter use the 2006 value.

One circulating water pump, rated at 68,000 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 29,000 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 A–6 presents a schematic of this configuration.

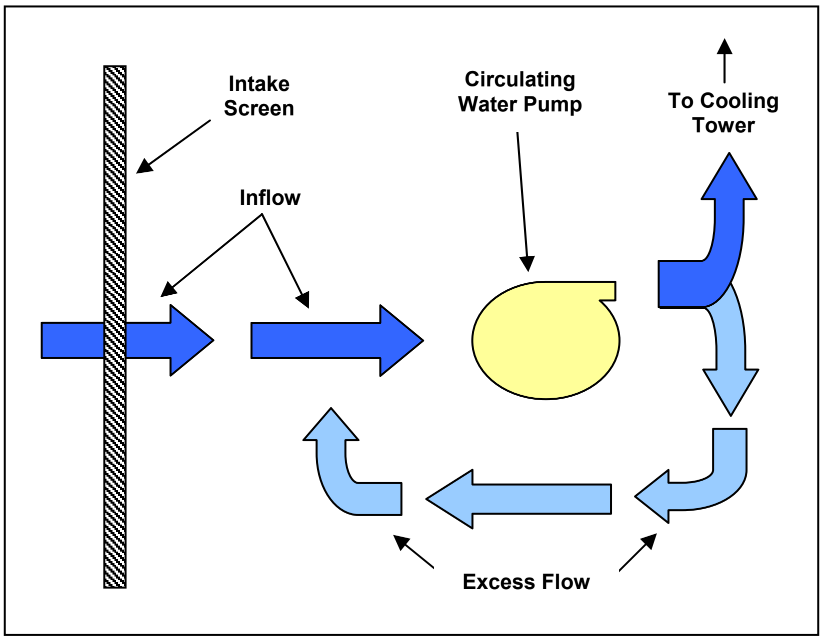

Figure A–6. Schematic of Intake Pump Configuration

The existing once-through cooling system at AGS does not treat water withdrawn from Los Cerritos Channel, 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 120º 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 Los Cerritos Channel.

The wet cooling tower system proposed for AGS includes water treatment for standard operational measures, i.e., fouling and corrosion control. Chemical treatment allowances are included in annual operations and maintenance (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 will not require any pretreatment to enable its use.

3.4.4 NPDES PERMIT COMPLIANCE

At maximum operation, wet cooling towers at AGS will result in an effluent discharge of approximately 38 mgd of blowdown in addition to other in-plant waste streams—such as boiler blowdown, treated sanitary waste, and cleaning wastes. These low volume wastes may add an additional 3.5 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, AGS 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 CA0001139, as implemented by LARWQCB Order 00-082. All wastewaters are discharged to the San Gabriel River through one of three separate outfalls.

The existing Order contains effluent limitations based on the 1997 Ocean Plan and 1972 Thermal Plan. By letter dated January 21, 2003, the LARWQCB notified AGS that the facility's receiving water, the San Gabriel River, had been reclassified from a marine water body to an estuarine water body for the purposes of wastewater discharge permitting (LARWQCB 2003). Thus, in subsequent permit renewals, any water quality-based effluent limitations (WQBELs) will be based on the California Toxics Rule (CTR) and the State Implementation Policy for Inland Waters (SIP).

AGS 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 AGS 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 criteria included in the SIP. If compliance with these objectives becomes problematic, alternative treatment or discharge methods may be necessary. Data submitted by AGS in support of its NPDES renewal application demonstrates a reasonable potential to exceed effluent limitations for copper, zinc, and cyanide (AES 2004). These assessments reflect the existing once-through cooling system and, for zinc and copper, are primarily driven by the elevated concentrations detected in the intake water at AGS. 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 SIP and Basin Plan. Alternately, some low volume waste streams (e.g., boiler blowdown, laboratory drains) may be diverted, with necessary permits, for treatment at a POTW.

The SIP does make an allowance for intake credits under some circumstances but none would be applicable to AGS due to the fact that a cooling tower effectively changes the intake water characteristics by concentrating pollutants (through evaporation) by as much as 50 percent above their initial levels. In addition, the current receiving water (San Gabriel River) may not meet the criteria establishing it as “hydrologically connected” to Los Cerritos Channel (SWRCB 2000).

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)

Existing thermal discharges to an estuary are limited to a maximum discharge temperature of 20º F above the receiving water’s natural temperature, may not exceed 86º F, and meet other criteria specified by the Thermal Plan (SWRCB 1972). It is unclear if AGS will be able to meet this thermal limitation based on the current once-through configuration, with discharge temperatures reaching as high as 100 ºF and ambient water temperatures in the mid to upper 60s. Compliance is also uncertain with wet cooling towers but is more likely given that blowdown discharge will be taken from the cold water side of the system, ensuring an effluent discharge temperature not in excess of 83º F for normal operations (not including heat treatments). This temperature is below the maximum permissible discharge temperature and within the required 20º F range of ambient temperatures in the San Gabriel River, although other criteria would also have to be met.

3.4.5 RECLAIMED WATER

The use of reclaimed or alternative water sources could potentially eliminate all surface water withdrawals at AGS. 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 AGS (635 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 reclaimed water's use of because the conversion of AGS's once-through cooling system to saltwater cooling towers enables the facility to meet the performance targets 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, AGS 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 the use of reclaimed water is the presence of any ammonia or ammonia-forming compounds in the reclaimed water. All the condenser tubes at AGS contain copper alloys (aluminum brass and copper-nickel) and can experience stress-corrosion cracking as a result of the interaction between copper and ammonia. Treatment for ammonia may include the addition of 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 AGS, with a combined discharge capacity of 635 mgd. Figure A–7 shows the relative locations of these facilities to AGS.

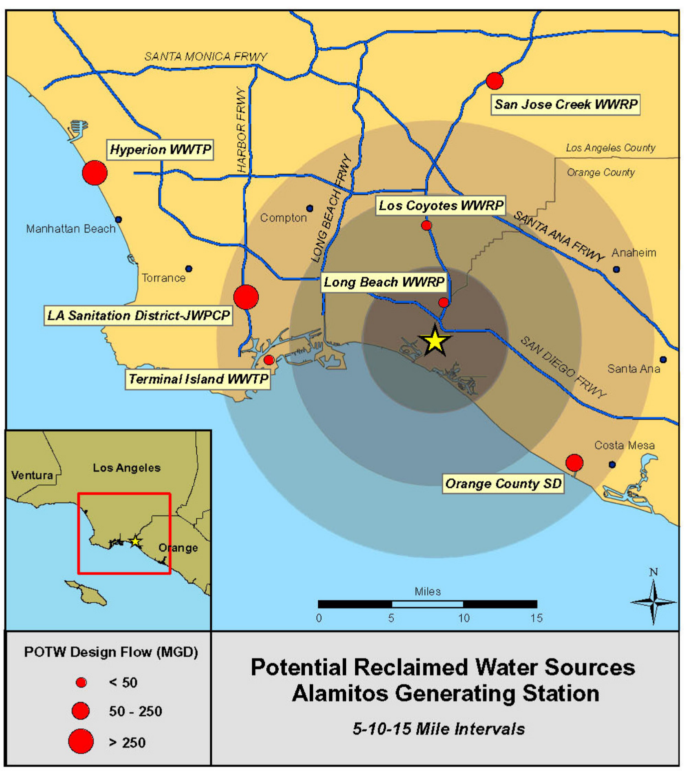

Figure A–7. Reclaimed Water Sources

- *Los Angeles Sanitation District, Joint Water Pollution Control Plant (JWPCP)—Carson*.
  Discharge Volume: 330 mgd
  Distance: 14 miles NW
  Treatment Level: Secondary

  The facility representative at JWPCP indicated that the effluent is not currently considered a potential source of reclaimed water for irrigation due to high TDS concentrations (brine from the Hyperion WWTP is treated at Carson), but the suitability for use as a makeup water source is not currently known. TDS levels may be less than normally found in seawater and thus be at least comparable with the current makeup water source at AGS. In the future, a portion of the effluent may be used for a new hydrogen plant under consideration by BP, but no formal agreement currently exists. Even with such an agreement, sufficient capacity would remain to satisfy the full makeup water demand for freshwater towers at AGS (23 to 26 mgd).

- *Los Coyotes Wastewater Reclamation Plant—Cerritos.*
  Discharge Volume: 33 mgd
  Distance: 9 miles N
  Treatment Level: 30 % tertiary; 70 % secondary

  Approximately 10 MGD are treated to tertiary standards and reused for irrigation at various locations in the area, leaving approximately 23 mgd available as a makeup water source. The remaining 23 mgd would require additional treatment prior to use at AGS.

- *Terminal Island Wastewater Treatment Plant—San Pedro.*
  Discharge Volume: 20 mgd
  Distance: 10 miles W
  Treatment Level: 10 % tertiary; 90 % secondary

  Tertiary treated water is used for local irrigation. A previous study to assess the feasibility of using Terminal Island's reclaimed water at Harbor Generating Station determined the water quality (pH) would have adverse effects on the condenser and cooling system, although treatment systems could be installed on site to condition the water to an acceptable pH level.[6]

- *Orange County Sanitation District Wastewater Treatment Plant—Huntington Beach.*
  Discharge Volume: 232 mgd
  Distance: 13 miles SE
  Treatment Level: Secondary

  Sufficient capacity exists to supply the full makeup water demand for freshwater towers at AGS (23 to 26 mgd), although any use would require additional on-site treatment.

- *Long Beach Wastewater Treatment Plant—Long Beach.*
  Discharge Volume: 20 mgd
  Distance: 3 miles N
  Treatment Level: Tertiary

[6] This study was referenced in documents provided by LADWP but not available for review.

Approximately 50 percent is currently used for irrigation in the vicinity the plant. The remaining capacity could supply 20 to 30 percent of the makeup water demand for freshwater cooling tower.

The costs associated with the 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 AGS's makeup demand (23 to 26 mgd as a freshwater tower) is located approximately 10 miles from the site (JWPCP). Transmission pipelines would have to traverse a heavily-urbanized area and navigate infrastructure obstacles such as freeways and flood control channels.

Based on data compiled for this study, the estimated installed cost of a 36-inch prestressed concrete cylinder pipe, sufficient to provide 26 mgd to AGS, is $514 per linear foot, or approximately $2.7 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 the use of reclaimed water as makeup water comparable or preferable to the use of saltwater from marine sources. Reclaimed water may enable AGS to reduce PM_{10} emissions from the cooling tower, which is a concern given the South Coast air basin's current nonattainment status, or eliminate potential conflicts with water discharge limitations. Use of reclaimed water might also mitigate impacts of high-salinity drift on sensitive equipment.

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.

3.4.6 THERMAL EFFICIENCY

The use of wet cooling towers at AGS will increase the condenser inlet water temperature by a range of 11 to 15° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at AGS are designed to operate at the conditions described in Table A–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures at AGS is described in Figure A–8.

Table A–12. Design Thermal Conditions

	Units 1 & 2	Units 3 & 4	Units 5 & 6
Design backpressure (in. HgA)	1.69	1.5	1.5
Design water temperature (°F)	63	63	63
Turbine inlet temp (°F)	1,000	1,000	1,000
Turbine inlet pressure (psia)	2,400	2,400	2,400
Full load heat rate (BTU/kWh) [a]	11,566	9,800	9,680

[a] CEC 2002.

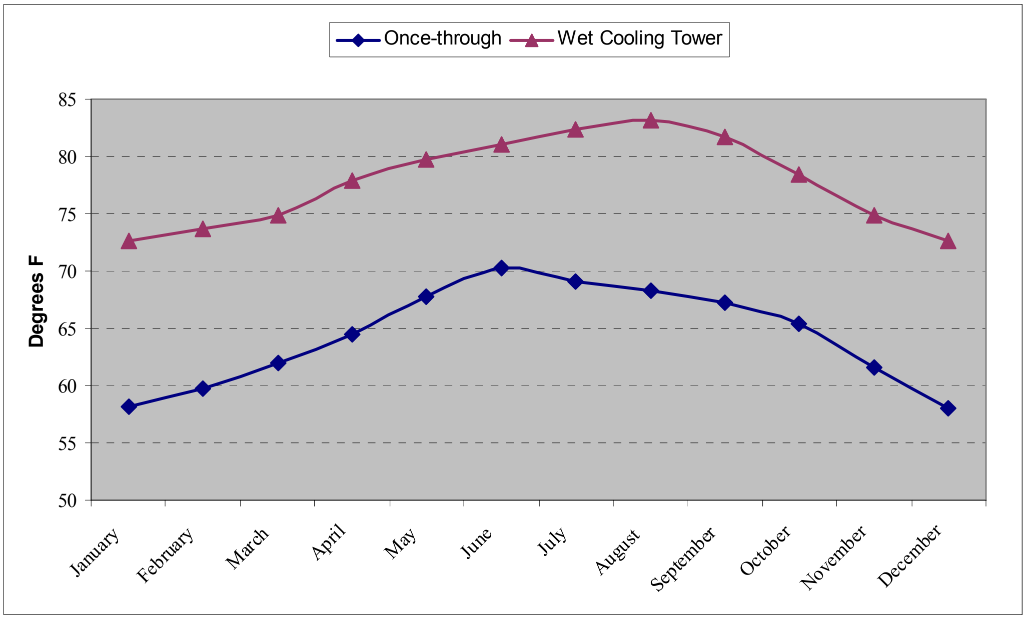

Figure A–8. Condenser Inlet Temperatures

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 (Table A–6). In general, backpressures associated with the wet cooling tower were elevated by 0.6 to 0.95 inches HgA compared with the current once-through system (Figure A–9, Figure A–11, and Figure A–13).

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.[7] 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 (Table A–12) to develop estimated correction curves (Figure A–10, Figure A–12, and Figure A–14).

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 A–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.

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[7] Changes in thermal efficiency estimated for AGS are based on the design specifications provided by the facility. This may not reflect system modifications that might influence actual performance. In addition, the age of the units and the operating protocols used by AGS might result in different calculations.

Table A-13. Summary of Estimated Heat Rate Increases

	Units 1 & 2	Units 3 & 4	Units 5 & 6
Peak (July-August-September)	1.69%	1.73%	1.67%
Annual average	1.39%	1.45%	1.35%

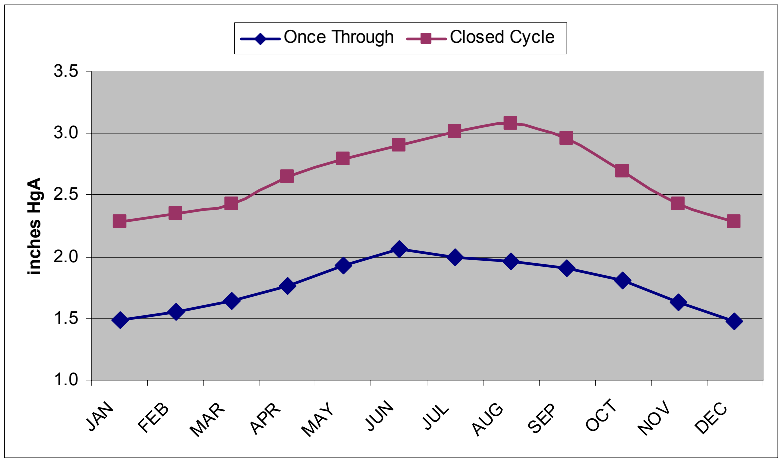

Figure A-9. Estimated Backpressures (Units 1 & 2)

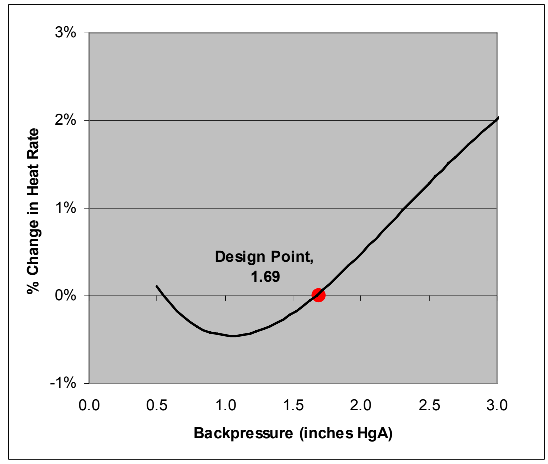

Figure A-10. Estimated Heat Rate Correction (Units 1 & 2)

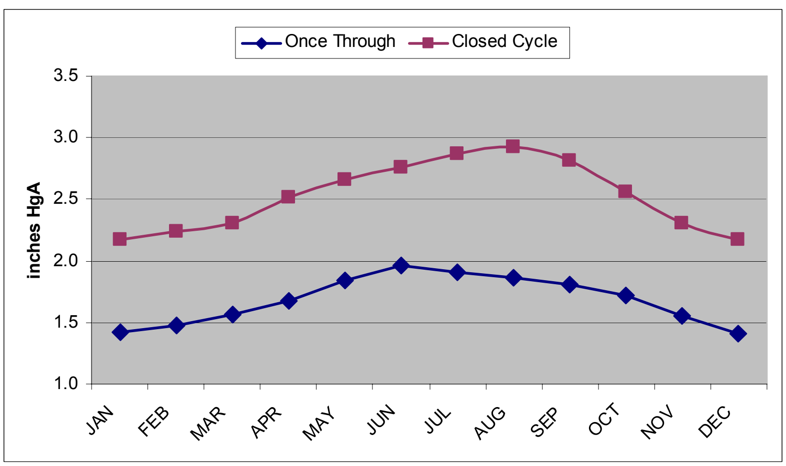

Figure A-11. Estimated Backpressures (Units 3 & 4)

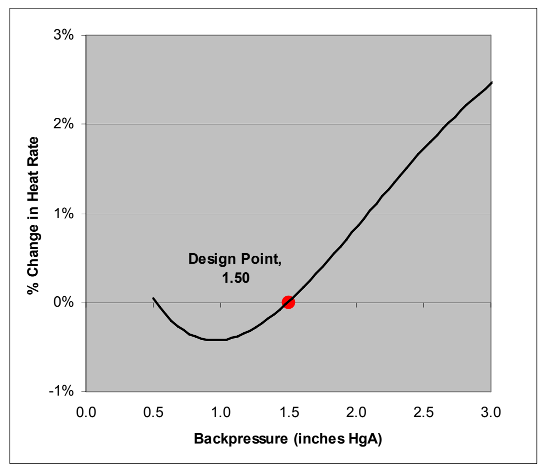

Figure A-12. Estimated Heat Rate Correction (Units 3 & 4)

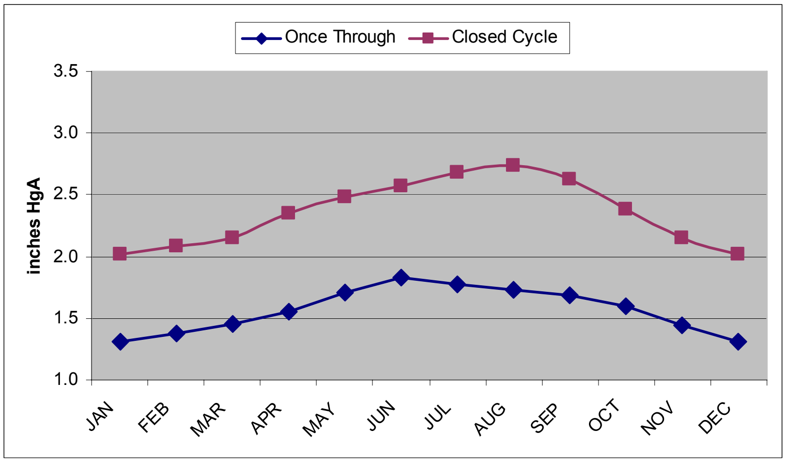

Figure A–13. Estimated Backpressures (Units 5 & 6)

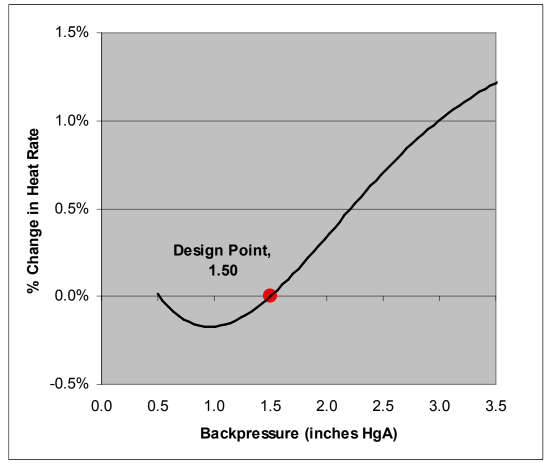

Figure A–14. Estimated Heat Rate Correction (Units 5 & 6)

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for AGS is based on incorporating conventional 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)
- 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)

4.1 COOLING TOWER INSTALLATION

The wet cooling towers selected for AGS are arranged in a back-to-back configuration instead of the more common in-line layout. This results in a taller structure and increases the per-cell cost. In addition, the inclusion of low noise fans and fan deck barrier walls represent a modest increase in cost for the towers over a conventional system. Table A–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 A–14. Wet Cooling Tower Design-and-Build Cost Estimate

	Units 1 & 2	Units 3 & 4	Units 5 & 6	AGS Total
Number of cells	10	16	24	**50**
Cost/cell ($)	640,000	612,500	612,500	**618,000**
Total AGS D&B cost ($)	**6,400,000**	**9,800,000**	**14,700,000**	**30,900,000**

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 AGS, these costs comprise approximately 45 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 A–15.

- *Civil, Structural, and Piping*
The configuration of the AGS site allows Towers 2 and 3 to be located relatively close to their respective units. Tower 1, however, must be placed at a substantial distance from Units 1 and 2. The distance (approximately 3,700 ft) required for Tower 1 notably increases material and labor costs—primarily as they relate to installing supply and return piping (approximately 7,500 ft total). Total costs are also affected by the necessity of constructing a 35-foot high concrete barrier wall to meet Long Beach noise control ordinances.
- *Mechanical and Electrical*
Initial capital costs in this category reflect the new pumps (eight total) required to circulate cooling water between the towers and condensers. Overall pump capacity is larger than a baseline 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*
A small cost is included for the demolition and backfilling of the two retention basins that will be removed to make room for Tower 2. The nature of materials treated in these basins is unknown; the estimate does not include an allowance for hazardous materials clean up and disposal.

Table A–15. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	AGS total ($)
Civil/structural/piping	8,900,000	37,000,000	30,500,000	**76,400,000**
Mechanical	10,600,000	0	900,000	**11,500,000**
Electrical	2,600,000	4,100,000	2,800,000	**9,500,000**
Demolition	0	600,000	200,000	**800,000**
Total AGS other direct costs	**22,100,000**	**41,700,000**	**34,400,000**	**98,200,000**

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 AGS, potential costs in this category include relocation or demolition of small buildings and structures and the potential interference with underground structures. Soils were not characterized for this analysis. AGS lies within the coastal plain at approximately 10 feet above sea level and is bordered by water to the east and west. Groundwater intrusion or the instability of soils may require additional pilings to support any large structures built at the site. Initial capital costs are summarized in Table A–16.

Table A–16. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	30,900,000
Civil/structural/piping	76,400,000
Mechanical	11,500,000
Electrical	9,500,000
Demolition	800,000
Indirect cost	32,300,000
Condenser modification	6,500,000
Contingency	42,000,000
Total AGS capital cost	**209,900,000**

4.4 SHUTDOWN

A portion of the work relating to installing wet cooling towers can be completed without significant disruption to the operations of AGS. Units will be offline depending on the length of time it takes to integrate the new cooling system and conduct acceptance testing. For AGS, 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 AGS does not include any loss of revenue associated with shutdown at AGS.

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 AGS 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 AGS (800,200 gpm), are presented in Table A–17. These costs reflect maximum operation.

Table A-17. Annual O&M Costs (Full Load)

	Year 1 Cost ($)	Year 12 Cost ($)
Management/labor	800,200	1,160,290
Service/parts	1,280,320	1,856,464
Fouling	1,120,280	1,624,406
Total AGS O&M cost	**3,200,800**	**4,641,160**

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. Monetizing the energy penalty at AGS 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 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"). A more likely option, however, is some combination of the two.

Ultimately, the manner in which AGS 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.[8]

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

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[8] 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.

4.6.1 INCREASED PARASITIC USE (FANS AND PUMPS)

Depending on ambient conditions or the operating load at a given time, AGS 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 A–18.

Table A–18. Cooling Tower Fan Parasitic Use

	Tower 1	Tower 2	Tower 3	AGS Total
Units served	Units 1&2	Units 3&4	Units 5&6	--
Generating capacity (MW)	350	650	950	**1,950**
Number of fans (one per cell)	10	16	24	**50**
Motor power per fan (hp)	263	263	263	--
Total motor power (hp)	2,632	4,211	6,316	**13,158**
MW total	1.96	3.14	4.71	**9.81**
Fan parasitic use (% of capacity)	**0.56%**	**0.48%**	**0.50%**	**0.50%**

The addition of new circulating water pump capacity for the wet cooling towers will also increase the parasitic use of electricity at AGS. Makeup water will continue to be withdrawn from Los Cerritos Channel 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. Operation of fewer 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 A–19.

Table A–19. Cooling Tower Pump Parasitic Use

	Tower 1	Tower 2	Tower 3	AGS Total
Units served	Units 1&2	Units 3&4	Units 5&6	--
Generating capacity (MW)	350	650	950	**1,950**
Existing pump configuration (hp)	2,140	3,440	5,200	**10,780**
New pump configuration (hp)	4,195	7,035	10,857	**22,087**
Difference (hp)	2,055	3,595	5,657	**11,307**
Difference (MW)	1.5	2.7	4.2	**8.4**
Net pump parasitic use (% of capacity)	**0.44%**	**0.41%**	**0.44%**	**0.43%**

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 AGS will increase its fuel consumption to compensate for lost efficiency as well as 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 AGS may be greater or less. Changes in the heat rate for each unit at AGS are presented in Figure A–15, Figure A–16 and Figure A–17.

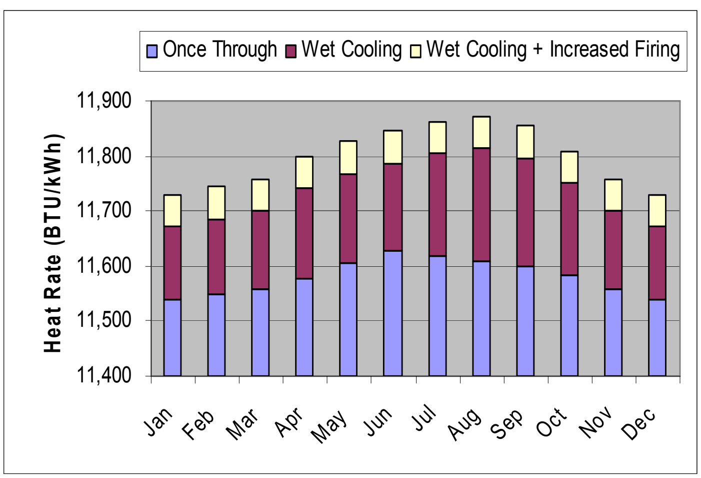

Figure A–15. Estimated Heat Rate Change (Units 1 & 2)

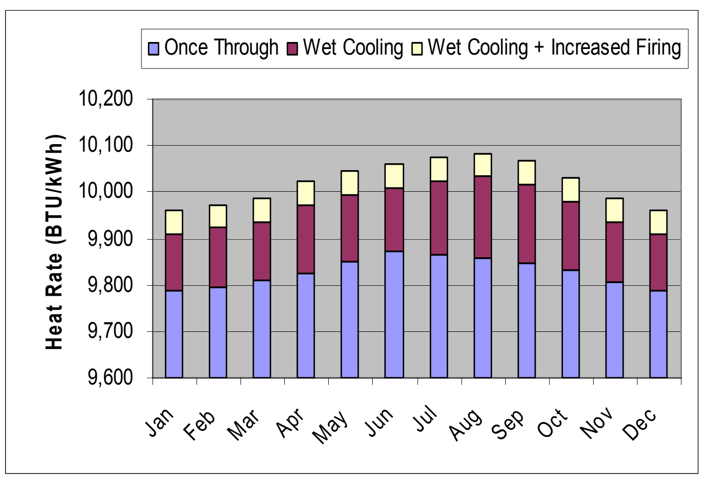

Figure A–16. Estimated Heat Rate Change (Units 3 & 4)

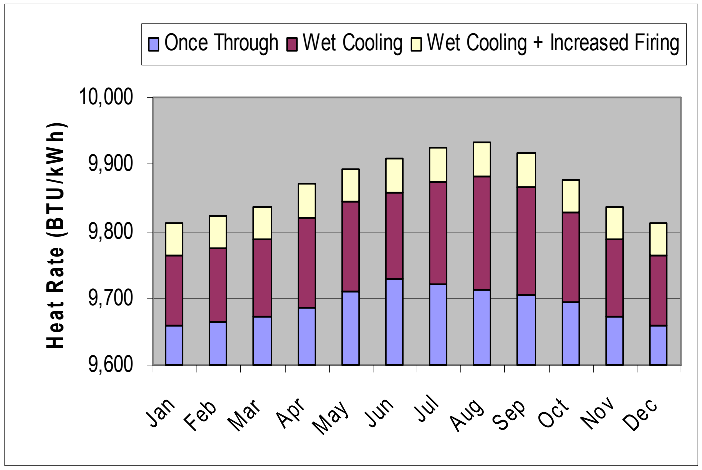

Figure A–17. Estimated Heat Rate Change (Units 5 & 6)

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 ($/MWh) for the once-through system and the wet cooling system adjusted for a higher turbine firing rate. The cost of generation for AGS is based on the relative heat rates developed in Section 4.6.2 and the average monthly wholesale natural gas cost ($/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 AGS will be approximately $1.9 million. In contrast, the energy penalty's value calculated using the production loss option would be approximately $2.9 million. Together, these values represent the range of potential energy penalty costs for AGS. Table A–20, Table A–21 and Table A–22 summarize the energy penalty estimates for each unit using the increased fuel option.

Table A–20. Units 1 & 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	11,541	69.24	11,729	70.37	1.13	2,283	2,581
February	5.50	11,548	63.51	11,744	64.59	1.08	2,391	2,577
March	4.75	11,559	54.91	11,759	55.85	0.95	3,454	3,273
April	4.75	11,576	54.99	11,800	56.05	1.07	12,171	12,967
May	4.75	11,604	55.12	11,827	56.18	1.06	301	318
June	5.00	11,629	58.15	11,845	59.22	1.08	5,667	6,116
July	6.50	11,617	75.51	11,863	77.11	1.60	61,916	99,048
August	6.50	11,609	75.46	11,873	77.17	1.71	241	413
September	4.75	11,600	55.10	11,854	56.31	1.21	1,210	1,462
October	5.00	11,583	57.92	11,809	59.05	1.13	0	0
November	6.00	11,557	69.34	11,759	70.55	1.21	0	0
December	6.50	11,540	75.01	11,729	76.24	1.23	1,725	2,122
							Units 1 & 2 total	**130,877**

Table A–21. Units 3 & 4 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	9,789	58.73	9,960	59.76	1.03	20,640	21,250
February	5.50	9,797	53.88	9,973	54.85	0.97	27,072	26,284
March	4.75	9,808	46.59	9,986	47.43	0.84	9,331	7,871
April	4.75	9,825	46.67	10,022	47.60	0.93	63,683	59,511
May	4.75	9,852	46.80	10,044	47.71	0.91	66,633	60,940
June	5.00	9,874	49.37	10,060	50.30	0.93	112,281	104,184
July	6.50	9,863	64.11	10,075	65.49	1.38	178,206	245,351
August	6.50	9,856	64.06	10,083	65.54	1.47	63,338	93,399
September	4.75	9,847	46.77	10,067	47.82	1.05	64,159	67,068
October	5.00	9,832	49.16	10,029	50.15	0.99	31,980	31,537
November	6.00	9,806	58.84	9,986	59.92	1.08	29,243	31,561
December	6.50	9,788	63.62	9,960	64.74	1.12	46,593	52,275
							Units 3 & 4 total	**801,231**

Table A–22. Units 5 & 6 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	9,659	57.95	9,811	58.87	0.92	0	0
February	5.50	9,664	53.15	9,823	54.03	0.87	0	0
March	4.75	9,674	45.95	9,836	46.72	0.77	2,716	2,088
April	4.75	9,687	46.01	9,870	46.88	0.87	80,889	70,292
May	4.75	9,710	46.12	9,892	46.99	0.87	86,529	75,128
June	5.00	9,729	48.65	9,908	49.54	0.89	154,428	138,137
July	6.50	9,720	63.18	9,924	64.51	1.33	348,953	464,002
August	6.50	9,713	63.14	9,933	64.56	1.42	108,156	154,062
September	4.75	9,706	46.10	9,916	47.10	1.00	90,536	90,456
October	5.00	9,693	48.46	9,877	49.39	0.92	0	0
November	6.00	9,672	58.03	9,836	59.01	0.98	0	0
December	6.50	9,658	62.78	9,811	63.77	1.00	0	0
							Units 5 & 6 total	**994,165**

4.7 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at AGS 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 AGS 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 A–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 AGS has a relatively low capacity utilization factor, O&M costs for the NPC calculation were estimated at 50 percent of their maximum value. (See Table A–17.)
- *Annual Energy Penalty.* Insufficient information is available to this study to forecast future generating output at AGS. 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 A– 20, Table A–21, and Table A–22.)

Using these values, the NPC_{20} for AGS is $263 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by AGS 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 A–23.

Table A–23. Annual Cost

Discount Rate (%)	Capital Cost ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00	19,800,000	2,100,000	3,500,000	**25,400,000**

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 AGS'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 AGS 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 AGS is summarized in Table A–24. A comparison of annual costs to annual gross revenue is summarized in Table A–25.

Table A-24. Estimated Gross Revenue

	Wholesale price ($/MWh)	Net generation (MWh)			Estimated gross revenue ($)			
		Units 1 & 2	Units 3 & 4	Units 5 & 6	Units 1 & 2	Units 3 & 4	Units 5 & 6	AGS total
January	66	2,283	20,640	0	150,678	1,362,240	0	**1,512,918**
February	61	2,391	27,072	0	145,851	1,651,392	0	**1,797,243**
March	51	3,454	9,331	2,716	176,154	475,881	138,516	**790,551**
April	51	12,171	63,683	80,889	620,721	3,247,833	4,125,339	**7,993,893**
May	51	301	66,633	86,529	15,351	3,398,283	4,412,979	**7,826,613**
June	55	5,667	112,281	154,428	311,685	6,175,455	8,493,540	**14,980,680**
July	91	61,916	178,206	348,953	5,634,356	16,216,746	31,754,723	**53,605,825**
August	73	241	63,338	108,156	17,593	4,623,674	7,895,388	**12,536,655**
September	53	1,210	64,159	90,536	64,130	3,400,427	4,798,408	**8,262,965**
October	57	0	31,980	0	0	1,822,860	0	**1,822,860**
November	66	0	29,243	0	0	1,930,038	0	**1,930,038**
December	67	1,725	46,593	0	115,575	3,121,731	0	**3,237,306**
AGS total		**91,359**	**713,159**	**872,207**	**7,252,094**	**47,426,560**	**61,618,893**	**116,297,547**

Table A-25. 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
116,300,000	19,800,000	17	2,100,000	1.8	3,100,000	2.7	**25,000,000**	**21**

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 AGS. 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 AGS. 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. AGS currently withdraws its cooling water from Los Cerritos Channel, which primarily consists of water drawn through Alamitos Bay. Water within Los Cerritos Channel primarily flows towards AGS due to the action of the circulating water pumps. Returning any collected organisms to Los Cerritos Channel would be problematic because there is a high likelihood of reimpingement due to the flow patterns within the channel. Use of Alamitos Bay as the return location may address this concern, but potential obstacles remain over the long-term viability of fragile organisms (eggs and larvae) transported over the long distance from the facility to the bay. Discharging organisms to the San Gabriel River may also be problematic because of the elevated temperatures (90ºF and higher) that can dominate the near-discharge area (AGS and HnGS have the capacity to introduce over 2,000 mgd of elevated temperature water into this section of the San Gabriel River). Successful deployment of this technology might be feasible with a better understanding of the biological conditions in Los Cerritos Channel and Alamitos Bay.

5.2 BARRIER NETS

The entrance to the north and south intake canals is the beginning of each CWIS at AGS and the likely location for any deployment of a barrier net. At the junction with Los Cerritos Channel, the canals are approximately 150 feet wide, which should be sufficient area for a barrier net. The nature of flows within Los Cerritos Channel, however, makes deployment problematic. Storm events often produce heavy debris loads at AGS and could damage or destroy a barrier net in this location. For this reason, plus its ineffectiveness in reducing entrainment, barrier nets were not considered further in this study.

5.3 AQUATIC FILTRATION BARRIERS (AFBS)

AFBs require large areas of relatively clean, low turbulence water in which to function properly. To protect each intake canal, AGS would require two AFBs, each approximately 35,000 ft^2 in total area. The available space within Los Cerritos Channel, combined with the heavy debris issues identified for barrier nets, precludes the use of AFBs at AGS.

5.4 VARIABLE SPEED DRIVES

VSDs were not considered for analysis at AGS 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 35 percent over the current once-through configuration (US EPA, 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 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 coastal facilities for applications as large as would be required at AGS (approximately 1,100 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 is unidirectional so that screens may be oriented properly and any debris impinged on the screens will be carried downstream when the air-burst cleaning system is activated.

AGS currently withdraws cooling water from Los Cerritos Channel and, by extension, Alamitos Bay. Space constraints and navigation concerns prohibit the placement of any large cylindrical screens in the channel or bay, let alone the 12 to 14 84-inch diameter screens that would be required to supply the facility with adequate volumes of water. The only theoretical location available for AGS would be offshore in the Pacific Ocean, west of the entrance to Alamitos Bay. Limited information regarding the subsurface currents in the near-shore environment near Alamitos Bay is available. Data suggest that these currents are multi-directional 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 inability of the air burst system to maintain adequate pressure for sufficient cleaning (Someah, 2007). Together, these considerations preclude further evaluation of fine mesh cylindrical wedgewire screens at AGS.

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

		Units 1 & 2			Units 3 & 4			Units 5 & 6		
		Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase
JAN	Backpressure (in. HgA)	1.49	2.28	**0.79**	1.42	2.17	**0.75**	1.31	2.02	**0.70**
	Heat rate Δ (%)	*-0.22*	*0.91*	***1.12***	*-0.11*	*1.13*	***1.25***	*-0.22*	*0.85*	***1.08***
FEB	Backpressure (in. HgA)	1.55	2.35	**0.80**	1.48	2.24	**0.76**	1.37	2.08	**0.71**
	Heat rate Δ (%)	*-0.16*	*1.03*	***1.19***	*-0.04*	*1.26*	***1.30***	*-0.16*	*0.97*	***1.14***
MAR	Backpressure (in. HgA)	1.65	2.43	**0.78**	1.57	2.31	**0.74**	1.45	2.15	**0.70**
	Heat rate Δ (%)	*-0.06*	*1.16*	***1.22***	*0.09*	*1.39*	***1.31***	*-0.07*	*1.10*	***1.17***
APR	Backpressure (in. HgA)	1.76	2.64	**0.88**	1.68	2.52	**0.84**	1.56	2.35	**0.79**
	Heat rate Δ (%)	*0.09*	*1.52*	***1.43***	*0.25*	*1.75*	***1.50***	*0.07*	*1.46*	***1.38***
MAY	Backpressure (in. HgA)	1.93	2.79	**0.86**	1.84	2.66	**0.82**	1.71	2.48	**0.77**
	Heat rate Δ (%)	*0.33*	*1.75*	***1.41***	*0.53*	*1.98*	***1.45***	*0.31*	*1.69*	***1.38***
JUN	Backpressure (in. HgA)	2.06	2.90	**0.83**	1.96	2.76	**0.80**	1.83	2.57	**0.75**
	Heat rate Δ (%)	*0.54*	*1.90*	***1.36***	*0.75*	*2.14*	***1.38***	*0.51*	*1.85*	***1.34***
JUL	Backpressure (in. HgA)	2.00	3.01	**1.01**	1.90	2.87	**0.97**	1.77	2.68	**0.91**
	Heat rate Δ (%)	*0.44*	*2.06*	***1.62***	*0.65*	*2.30*	***1.65***	*0.41*	*2.01*	***1.60***
AUG	Backpressure (in. HgA)	1.96	3.08	**1.12**	1.86	2.93	**1.07**	1.73	2.73	**1.00**
	Heat rate Δ (%)	*0.37*	*2.14*	***1.77***	*0.57*	*2.37*	***1.80***	*0.35*	*2.10*	***1.75***
SEP	Backpressure (in. HgA)	1.90	2.96	**1.05**	1.81	2.81	**1.00**	1.68	2.62	**0.94**
	Heat rate Δ (%)	*0.29*	*1.98*	***1.69***	*0.48*	*2.22*	***1.73***	*0.27*	*1.93*	***1.66***
OCT	Backpressure (in. HgA)	1.81	2.69	**0.89**	1.72	2.56	**0.84**	1.60	2.39	**0.79**
	Heat rate Δ (%)	*0.15*	*1.59*	***1.44***	*0.33*	*1.83*	***1.50***	*0.13*	*1.53*	***1.40***
NOV	Backpressure (in. HgA)	1.63	2.43	**0.80**	1.55	2.31	**0.76**	1.44	2.15	**0.71**
	Heat rate Δ (%)	*-0.08*	*1.16*	***1.24***	*0.06*	*1.39*	***1.33***	*-0.08*	*1.10*	***1.19***
DEC	Backpressure (in. HgA)	1.48	2.28	**0.80**	1.41	2.17	**0.76**	1.31	2.02	**0.71**
	Heat rate Δ (%)	*-0.23*	*0.91*	***1.13***	*-0.12*	*1.13*	***1.26***	*-0.23*	*0.85*	***1.08***

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 3100 ft) and cable racks	t	310	--	--	2,500	775,000	17.00	105	553,350	**1,328,350**
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	27,202	--	--	--	--	0.04	200	217,616	**217,616**
Bedding for PCCP pipe	m3	5,275	--	--	25	131,875	0.04	200	42,200	**174,075**
Bend for PCCP pipe 24" diam (allocation)	ea	6	--	--	3,000	18,000	20.00	95	11,400	**29,400**
Bend for PCCP pipe 42" & 48" diam (allocation)	ea	18	--	--	5,000	90,000	25.00	95	42,750	**132,750**
Bend for PCCP pipe 72" diam (allocation)	ea	3	--	--	18,000	54,000	40.00	95	11,400	**65,400**
Bend for PCCP pipe 96" diam (allocation)	ea	4	--	--	30,000	120,000	75.00	95	28,500	**148,500**
Building architectural (siding, roofing, doors, painting…etc)	ea	3	--	--	250,000	750,000	3,000.00	75	675,000	**1,425,000**
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 30" c/w allocation for actuator & air lines	ea	56	30,800	1,724,800	--	--	50.00	85	238,000	**1,962,800**
Butterfly valves 48" c/w allocation for actuator & air lines	ea	7	46,200	323,400	--	--	50.00	85	29,750	**353,150**
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 60" c/w allocation for actuator & air lines	ea	6	75,600	453,600	--	--	60.00	85	30,600	**484,200**
Butterfly valves 72" c/w allocation for actuator & air lines	ea	10	96,600	966,000	--	--	75.00	85	63,750	**1,029,750**
Butterfly valves 84" c/w allocation for actuator & air lines	ea	10	124,600	1,246,000	--	--	75.00	85	63,750	**1,309,750**
Butterfly valves 96" c/w allocation for actuator & air lines	ea	8	151,200	1,209,600	--	--	75.00	85	51,000	**1,260,600**
Check valves 48"	ea	7	66,000	462,000	--	--	24.00	85	14,280	**476,280**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Check valves 60"	ea	2	108,000	216,000	--	--	30.00	85	5,100	**221,100**
Check valves 84"	ea	2	178,000	356,000	--	--	36.00	85	6,120	**362,120**
Check valves 96"	ea	2	216,000	432,000	--	--	40.00	85	6,800	**438,800**
Concrete barrier walls (all in)	m3	1,912	--	--	250	478,000	8.00	75	1,147,200	**1,625,200**
Concrete basin walls (all in)	m3	658	--	--	225	148,050	8.00	75	394,800	**542,850**
Concrete elevated slabs (all in)	m3	748	--	--	250	187,000	10.00	75	561,000	**748,000**
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	6,499	--	--	200	1,299,800	4.00	75	1,949,700	**3,249,500**
Ductile iron cement pipe 12" diam. for fire water line	ft	4,200	--	--	100	420,000	0.60	95	239,400	**659,400**
Excavation and backfill for fire line, blowdown & make-up (using excavated material for backfill except for bedding)	m3	22,472	--	--	--	--	0.08	200	359,552	**359,552**
Excavation for PCCP pipe	m3	48,849	--	--	--	--	0.04	200	390,792	**390,792**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	**5,250**
Flange for PCCP joints 24"	ea	12	--	--	1,725	20,700	14.00	95	15,960	**36,660**
Flange for PCCP joints 30"	ea	50	--	--	2,260	113,000	16.00	95	76,000	**189,000**
Flange for PCCP joints 72"	ea	2	--	--	9,860	19,720	25.00	95	4,750	**24,470**
Flange for PCCP joints 84"	ea	8	--	--	13,210	105,680	30.00	95	22,800	**128,480**
Flange for PCCP joints 96"	ea	4	--	--	15,080	60,320	35.00	95	13,300	**73,620**
Foundations for pipe racks and cable racks	m3	720	--	--	250	180,000	8.00	75	432,000	**612,000**
FRP flange 120"	ea	8	--	--	236,500	1,892,000	1,200.00	85	816,000	**2,708,000**
FRP flange 30"	ea	150	--	--	1,679	251,873	50.00	85	637,500	**889,373**
FRP flange 48"	ea	20	--	--	3,000	60,000	75.00	85	127,500	**187,500**
FRP flange 54"	ea	16	--	--	5,835	93,359	80.00	85	108,800	**202,159**
FRP flange 60'	ea	16	--	--	7,785	124,565	100.00	85	136,000	**260,565**
FRP flange 72"	ea	16	--	--	20,888	334,203	200.00	85	272,000	**606,203**
FRP flange 84"	ea	16	--	--	33,381	534,096	300.00	85	408,000	**942,096**
FRP flange 96"	ea	20	--	--	40,000	800,000	500.00	85	850,000	**1,650,000**
FRP pipe 120" diam.	ft	1,900	--	--	4,257	8,088,300	2.00	85	323,000	**8,411,300**
FRP pipe 60" diam.	ft	680	--	--	615	418,132	0.90	85	52,020	**470,152**
FRP pipe 84" diam.	ft	680	--	--	946	643,280	1.50	85	86,700	**729,980**
FRP pipe 96" diam.	ft	680	--	--	2,838	1,929,840	1.75	85	101,150	**2,030,990**
Harness clamp 24" c/w external testable joint	ea	60	--	--	1,715	102,900	14.00	95	79,800	**182,700**
Harness clamp 42" & 48" c/w internal testable joint	ea	340	--	--	2,000	680,000	16.00	95	516,800	**1,196,800**
Harness clamp 72" c/w internal testable joint	ea	20	--	--	2,440	48,800	18.00	95	34,200	**83,000**
Harness clamp 84" c/w internal testable joint	ea	500	--	--	2,845	1,422,500	20.00	95	950,000	**2,372,500**
Harness clamp 96" c/w internal testable joint	ea	80	--	--	3,300	264,000	22.00	95	167,200	**431,200**

Description	Unit	Qty	Equipment Unit price ($)	Equipment Total price ($)	Bulk material Unit price ($)	Bulk material Total price ($)	Labor Unit (Mhr)	Labor Rate ($)	Labor Total price ($)	Total cost ($)
Joint for FRP pipe 120" diam.	ea	100	--	--	22,562	2,256,210	1,200.00	85	10,200,000	**12,456,210**
Joint for FRP pipe 84" diam.	ea	20	--	--	5,014	100,276	300.00	85	510,000	**610,276**
Joint for FRP pipe 60" diam.	ea	20	--	--	1,797	35,948	100.00	85	170,000	**205,948**
Joint for FRP pipe 96" diam.	ea	20	--	--	17,974	359,480	600.00	85	1,020,000	**1,379,480**
PCCP pipe 24" dia. For blowdown	ft	1,200	--	--	98	117,600	0.50	95	57,000	**174,600**
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	3,400	--	--	260	884,000	1.00	95	323,000	**1,207,000**
PCCP pipe 72" diam.	ft	400	--	--	507	202,800	1.30	95	49,400	**252,200**
PCCP pipe 84" diam.	ft	9,700	--	--	562	5,451,400	1.50	95	1,382,250	**6,833,650**
PCCP pipe 96" diam.	ft	1,600	--	--	890	1,424,000	2.00	95	304,000	**1,728,000**
Riser (FRP pipe 30" diam X55 ft)	ea	50	--	--	15,350	767,490	150.00	85	637,500	**1,404,990**
Structural steel for barrier wall	t	209	--	--	2,500	522,500	15.00	105	329,175	**851,675**
Structural steel for building	t	315	--	--	2,500	787,500	20.00	105	661,500	**1,449,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**8,884,600**	**--**	**36,997,696**	**--**	**--**	**30,509,165**	**76,391,461**
DEMOLITION	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Filling up with granular material of 2 ponds measuring approximately 50 m X 50 m and assuming 5m deep.	m3	25,000	--	--	25	625,000	0.04	200	200,000	**825,000**
DEMOLITION TOTAL	**--**	**--**	**--**	**0**	**--**	**625,000**	**--**	**--**	**200,000**	**825,000**
ELECTRICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
4.16 kv cabling feeding MCC's	m	3,000	--	--	75	225,000	0.40	85	102,000	**327,000**
4.16kV switchgear - 4 breakers	ea	2	250,000	500,000	--	--	150.00	85	25,500	**525,500**
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	9	30,000	270,000	--	--	80.00	85	61,200	**331,200**
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	3,555	--	--	75	266,625	1.00	85	302,175	**568,800**
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	9	100,000	900,000	--	--	100.00	85	76,500	**976,500**
Lighting & electrical services for pump house building	ea	3	--	--	45,000	135,000	500.00	85	127,500	**262,500**
Local feeder for 2000 HP motor 4160 V (up to MCC)	ea	2	--	--	40,000	80,000	160.00	85	27,200	**107,200**
Local feeder for 250 HP motor 460 V (up to MCC)	ea	50	--	--	18,000	900,000	150.00	85	637,500	**1,537,500**
Local feeder for 4000 HP motor 4160 V (up to MCC)	ea	2	--	--	50,000	100,000	200.00	85	34,000	**134,000**
Local feeder for 6000 HP motor 4160 V (up to MCC)	ea	2	--	--	60,000	120,000	250.00	85	42,500	**162,500**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Oil Transformer 10/13.33MVA xx-4.16kV	ea	2	190,000	380,000	--	--	150.00	85	25,500	**405,500**
Oil Transformer 20MVA xx-4.16kV	ea	1	250,000	250,000	--	--	200.00	85	17,000	**267,000**
Primary breaker(xxkV)	ea	6	45,000	270,000	--	--	60.00	85	30,600	**300,600**
Primary feed cabling (assumed 13.8 kv)	m	6,000	--	--	175	1,050,000	0.50	85	255,000	**1,305,000**
ELECTRICAL TOTAL	**--**	**--**	**--**	**2,570,000**	**--**	**4,131,625**	**--**	**--**	**2,792,675**	**9,494,300**
MECHANICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Allocation for ventilation of buildings	ea	3	100,000	300,000	--	--	1,000.00	85	255,000	**555,000**
Cooling tower for units 1 and 2	lot	1	6,400,000	6,400,000	--	--	--	--	--	**6,400,000**
Cooling tower for units 3 and 4	lot	1	9,800,000	9,800,000	--	--	--	--	--	**9,800,000**
Cooling tower for units 5 and 6	lot	1	14,700,000	14,700,000	--	--	--	--	--	**14,700,000**
Overhead crane 50 ton in (in pump house) Including additional structure to reduce the span	ea	3	500,000	1,500,000	--	--	1,000.00	85	255,000	**1,755,000**
Pump 4160 V 2000 HP	ea	2	1,000,000	2,000,000	--	--	500.00	85	85,000	**2,085,000**
Pump 4160 V 4000 HP	ea	2	1,600,000	3,200,000	--	--	800.00	85	136,000	**3,336,000**
Pump 4160 V 6000 HP	ea	2	1,800,000	3,600,000	--	--	1,100.00	85	187,000	**3,787,000**
MECHANICAL TOTAL	**--**	**--**	**--**	**41,500,000**	**--**	**0**	**--**	**--**	**918,000**	**42,418,000**

Appendix C. Net Present Cost Calculation

Project Year	Capital / Startup ($)	O & M ($)	Energy Penalty ($)			Total ($)	Annual Discount Factor	Present Value ($)
			Units 1 & 2	Units 3 & 4	Units 5 & 6			
0	209,800,000	--	--	--		209,800,000	1	**209,800,000**
1	--	1,600,400	130,877	801,230	994,165	3,526,672	0.9346	**3,296,028**
2	--	1,632,408	138,507	847,942	1,052,125	3,670,982	0.8734	**3,206,236**
3	--	1,665,056	146,582	897,377	1,113,464	3,822,479	0.8163	**3,120,290**
4	--	1,698,357	155,128	949,694	1,178,378	3,981,558	0.7629	**3,037,531**
5	--	1,732,324	164,172	1,005,062	1,247,078	4,148,636	0.713	**2,957,977**
6	--	1,766,971	173,743	1,063,657	1,319,783	4,324,153	0.6663	**2,881,183**
7	--	1,802,310	183,872	1,125,668	1,396,726	4,508,576	0.6227	**2,807,490**
8	--	1,838,357	194,592	1,191,294	1,478,155	4,702,398	0.582	**2,736,796**
9	--	1,875,124	205,937	1,260,747	1,564,331	4,906,139	0.5439	**2,668,449**
10	--	1,912,626	217,943	1,334,248	1,655,532	5,120,349	0.5083	**2,602,674**
11	--	1,950,879	230,649	1,412,035	1,752,049	5,345,612	0.4751	**2,539,700**
12	--	2,366,992	244,096	1,494,357	1,854,194	5,959,638	0.444	**2,646,079**
13	--	2,414,331	258,327	1,581,477	1,962,293	6,216,429	0.415	**2,579,818**
14	--	2,462,618	273,387	1,673,678	2,076,695	6,486,378	0.3878	**2,515,417**
15	--	2,511,870	289,326	1,771,253	2,197,766	6,770,215	0.3624	**2,453,526**
16	--	2,562,108	306,193	1,874,517	2,325,896	7,068,714	0.3387	**2,394,174**
17	--	2,613,350	324,044	1,983,801	2,461,496	7,382,692	0.3166	**2,337,360**
18	--	2,665,617	342,936	2,099,457	2,605,001	7,713,011	0.2959	**2,282,280**
19	--	2,718,929	362,929	2,221,855	2,756,873	8,060,587	0.2765	**2,228,752**
20	--	2,773,308	384,088	2,351,390	2,917,598	8,426,384	0.2584	**2,177,378**
Total								**263,269,138**