J. MOSS LANDING POWER PLANT

DYNEGY, INC—MOSS LANDING, CA

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1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at Moss Landing Power Plant (MLPP) 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 Moss Landing Harbor by approximately 95 percent. Impingement and entrainment impacts would be reduced by a similar proportion.

The preferred option selected for MLPP includes 4 conventional wet cooling towers (without plume abatement), with individual cells arranged in a back-to-back configuration for the larger Unit 6 & 7 towers; towers for Units 1 & 2 are an inline arrangement. The Moss Landing Power Plant Modernization Project, completed in 2002, added two new combined-cycle units to the facility. These units were designed to use once-through cooling and use the existing intake structure previously used by Units 1-5, now retired. The new units are referred to as Unit 1 and Unit 2.

Construction-related shutdowns are estimated to take approximately 4 weeks per unit (concurrent). MLPP would likely incur a financial loss as a result of this shutdown, based on 2006 capacity utilization rates, for Units 1 & 2 only.

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

Because Units 1 and 2 are substantially newer than the other generating units at MLPP and are likely to operate at a higher utilization rate, it is conceivable that a wet cooling system retrofit would be applied to Unit 1 and Unit 2 only instead of all four active units. Accordingly, some aspects of the cost analysis are presented for the facility as a whole and for Units 1 and Unit 2 alone, i.e., as though they operated as an independent facility. Initial capital and 20-year Net Present Cost (NPC_{20}) costs associated with the installation and operation of wet cooling towers at MLPP are summarized in Table J–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table J–2.

Table J–1. Cumulative Cost Summary

MLPP (all units)			
Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Total capital and start-up[a]	268,600,000	12.34	42
NPC_{20}[b]	349,600,000	16.07	55

MLPP (Units 1 & 2)			
Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Total capital and start-up[a]	74,700,000	7.90	14
NPC_{20}[b]	122,600,000	12.96	23

[a] Includes all costs associated with the construction and installation of cooling towers 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 J–2. Annual Cost Summary

MLPP (all units)			
Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up [a]	25,400,000	1.17	3.97
Operations and maintenance	2,600,000	0.12	0.41
Energy penalty	5,800,000	0.27	0.91
Total MLPP annual cost	**33,800,000**	**1.56**	**5.29**

MLPP (Units 1 & 2)			
Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up [a]	7,100,000	0.75	1.32
Operations and maintenance	800,000	0.08	0.15
Energy penalty	4,000,000	0.42	0.75
Units 1 & 2 only annual cost	**11,900,000**	**1.25**	**2.22**

[a] Does not include revenue loss associated with shutdown, which is incurred in Year 0 only. Shutdown loss forecast for MLPP equals $5 million. Shutdown cost is associated with Unit 1 and Unit 2 only.

1.2 ENVIRONMENTAL

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

Table J–3. Environmental Summary

		Units 1 & 2	Units 6 & 7
Water use	Design intake volume (gpm)	214,000	596,000
	Cooling tower makeup water (gpm)	10,400	28,200
	Reduction from capacity (%)	95	95
Energy efficiency [a]	Summer heat rate increase (%)	0.55	1.22
	Summer energy penalty (%)	1.05	1.99
	Annual heat rate increase (%)	0.57	1.22
	Annual energy penalty (%)	1.06	1.99
Direct air emissions [b]	PM_{10} emissions (tons/yr) (maximum capacity)	123	343
	PM_{10} emissions (tons/yr) (2006 capacity utilization)	70	29

[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 Moss Landing.

Depending on capacity utilization, cooling tower PM_{10} air emissions could result in a significant increase in the facility's total emission profile and may conflict with Monterey Bay Unified Air Pollution Control District air permit regulations, thereby requiring emission offsets or credits. If available, emission credits could add substantial cost to the overall total, if these credits are available in sufficient quantity.

In its approval of the Moss Landing Power Plant Project in 2000, the Energy Resources and Development Commission noted concerns over increased PM_{10} emissions and cited them as one of several reasons why once-through cooling was the preferred option for the repowering project. The Commission also noted that wet cooling towers were not preferred because entrainment impacts could be effectively mitigated, in part through habitat restoration and enhancement programs (ERDC 2000). It is unclear how this decision would be affected by the Second Circuit decision prohibiting the use of restoration as an impingement and entrainment compliance option (see Chapter 2).

PM_{10} emission credit availability and cost data were not available for this study and are not included in the final cost evaluation.

2.0 BACKGROUND

MLPP is a natural gas-fired steam electric generating facility located in Monterey County, owned and operated by Dynegy, Inc. The facility site occupies part of a 380-acre industrial site near Moss Landing Harbor along the Monterey Bay coast, approximately half way between Santa Cruz and Monterey. The northern portion of the facility is bordered by Elkhorn Slough. California Highway 1 borders the property's western edge (Figure J–1). MLPP currently operates two conventional steam generating units (Units 6 and 7), and two combined-cycle units (Units 1 and 2), each consisting of two gas combustion turbines, one heat recovery steam generator (HRSG), and one steam turbine. Five other steam units were retired in 1995. (See Table J–4 and Figure J–1.)

Table J–4. General Information

Unit	In-service year	Rated capacity (MW)	2006 capacity utilization [a]	Condenser cooling water flow (gpm)
1	2002	540	56.7%	107,000
2	2002	540	56.6%	107,000
6	1967	702	6.2%	298,000
7	1968	702	10.8%	298,000
MLPP total		**2484**	**29.4%**	**810,000**

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

Figure J–1. General Vicinity of Moss Landing Power Plant

2.1 COOLING WATER SYSTEM

MLPP operates two separate cooling water intake structures (CWISs) to provide condenser cooling water the generating units. The CWIS for Unit 1 and Unit 2 uses the intake previously used by the retired units (Figure J–2). A separate structure serves Unit 6 and Unit 7. Once-through cooling water is combined with low volume wastes generated by MLPP and discharged through a submerged outfall extending 600 feet into Monterey Bay. Surface water withdrawals and discharges are regulated by NPDES Permit CA0006254 as implemented by Central Coast Regional Water Quality Control Board (CCRWQCB) Order 00-041.

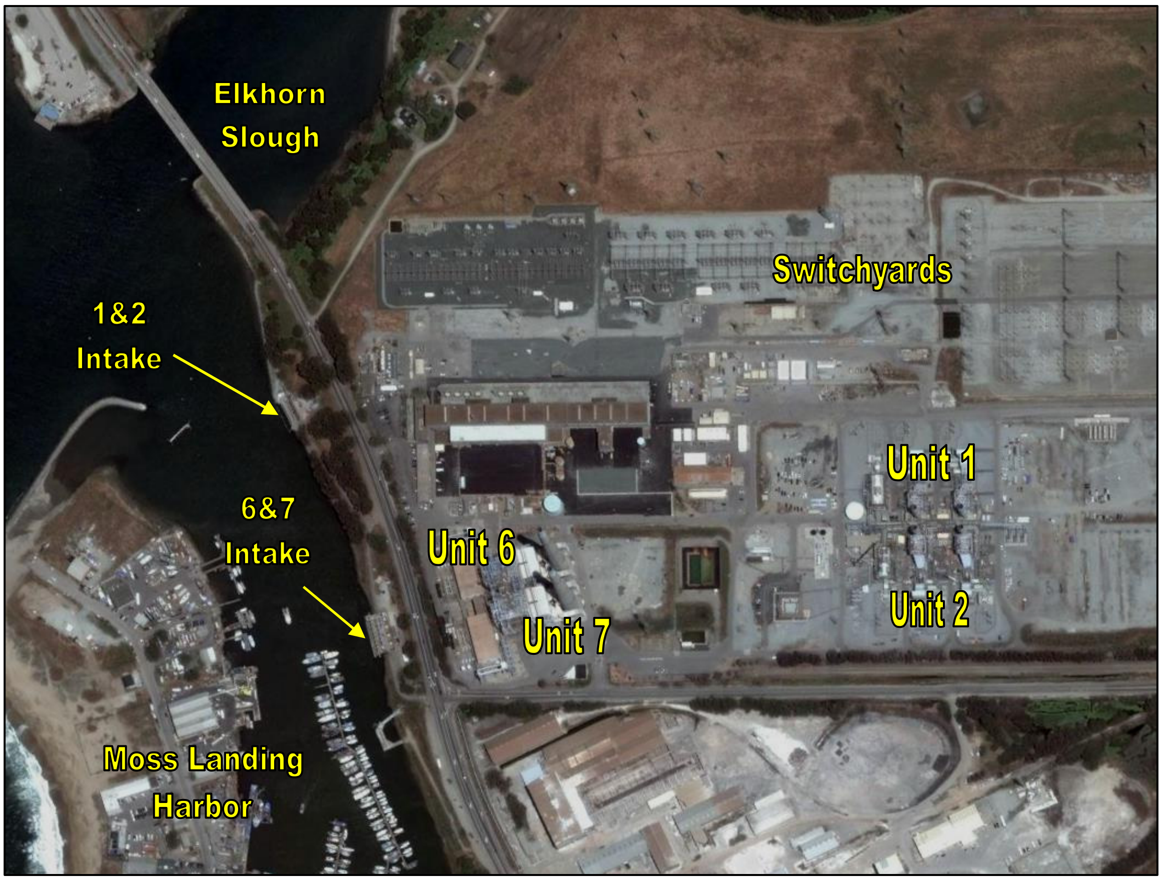

Figure J–2. Site View

The CWIS for Units 1 and 2 is a surface structure located flush with the shoreline along the eastern edge of Moss Landing Harbor. This intake was modified from its original design when it was used for the retired units. Cooling water for Unit 6 and Unit 7 is withdrawn from the harbor through a similar structure approximately 750 feet south of the other intake.

The Unit 1 and 2 CWIS consists of vertical inclined traveling screens fitted with 5/16-inch woven wire mesh panels. The screens are inclined approximately 55 degrees from horizontal to aid in the removal of eelgrass that can accumulate on the screen panels. Screens are rotated periodically at

24-hour intervals or based on pressure differential between the upstream and downstream faces of the screen. A high pressure spray removes any debris or fish that have become impinged on the screen face. Downstream of the screens are six circulating water pumps, three for each unit, that draw water from the wet well to the surface condensers. The pumps for Units 1 and 2 are each rated at 42,000 gallons per minute (gpm), or 60 million gallons per day (mgd) (MLPP 2000).

The Unit 6 and 7 CWIS is essentially the same as the Unit 1 and 2 CWIS except the traveling screens are vertical in the water column and fitted with 3/8-inch mesh panels. Downstream of the screens are four circulating water pumps, two for each unit, that draw water from the wet well to the surface condensers. The pumps for Units 6 and 7 are each rated at 150,000 gpm, or 216 mgd.

At maximum capacity, MLPP maintains a total pumping capacity rated at 1,224 mgd.

2.2 SECTION 316(B) PERMIT COMPLIANCE

As part of the MLPP Modernization Project that added the combined-cycle units in 2002, the CWIS that was used for the retired unites was modified to service Units 1 and 2. The original design placed the intake screens at the end of a 350-foot tunnel extending from Moss Landing Harbor under the Pacific Coast Highway to the facility. The length of the tunnel and lack of light are believed to have contributed to the impingement of fish that could not escape back to the harbor. The updated design moved the intake screens closer to the harbor shoreline and they are now recessed approximately 10 feet. This study did not evaluate the effectiveness of this modification.

Apart from the modifications to the Unit 1 and 2 CWIS, MLPP does not use technologies generally considered to be effective at reducing impingement mortality and/or entrainment.

MLPP's previous owner (Pacific Gas and Electric [PG&E]) conducted studies to demonstrate compliance with CWA Section 316(b) requirements in 1983 (supplemental reports were submitted in 1986 and 1988) and formed the basis for NPDES permitting requirements related to the cooling water withdrawals from Moss Landing Harbor for the facility as it was then configured. CCRWQCB Order 00-041, adopted in 2000, states the following:

> …[t]he reports determined that impacts could be minimized through operation and maintenance procedures. Based on these reports the Regional Board determined that the existing intake system operation complied with the BTA requirements of section 316(b). Report conclusions were re-evaluated as part of the review process for this permit and it was determined that there is no basis for reconsidering the Board's existing determination of compliance regarding the existing intake system operation. (CCRWQCB 2000, Finding 45)

In the discussion of modifications to the Unit 1 and 2 CWIS, Order 00-041 notes that "these modifications are not sufficient to minimize adverse environmental effects of the intake system and to achieve compliance with the BTA requirements of section 316(b) because the modifications do not address entrainment impacts" (CCRWQCB 2000, Finding 49).

MLPP and the California Energy Commission (CEC), as part of the certification process for the modernization project, developed the Elkhorn Slough Enhancement Program (ESEP) to protect aquatic resources in the watershed. The program requires MLPP to fund activities that "mitigate significant effects of larvae entrainment by the cooling water intake system by using the most direct means to increase the biological health and productivity of Elkhorn Slough watershed" (CCRWQCB 2000, Finding 50). These activities included acquisition of sensitive riparian areas and habitat restoration projects in nearby wetlands and upland areas.

Order 00-041 states that the combination of CWIS modifications for Units 1 and 2 and ESEP funding and implementation "constitutes compliance with Clean Water Act section 316(b) by implementing BTA that minimizes adverse environmental effects" (CCRWQCB 2000, Finding 51). In light of the Second Circuit's Phase II determination that restoration or mitigation projects may not be used as an option for Section 316(b) compliance, it is not clear how the ESEP program will be affected or how the CCRWQCB may modify future NPDES permits for MLPP.

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

This study evaluates saltwater cooling towers as a retrofit option at MLPP, with the current source water (Moss Landing Harbor) 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 MLPP but not analyzed in detail because the available volume cannot serve as a replacement for once-through cooling water. Reclaimed water may be an attractive alternative as a makeup water source for a wet cooling tower when considering the additional benefits its use may provide. The availability of reclaimed water in the area surrounding MLPP is limited, however, and may not be sufficient to supply the makeup requirement for Units 1 and 2, let alone all four units.

The wet cooling towers' configuration—their size, arrangement, and location—was based on best professional judgment (BPJ) using the criteria outlined in Chapter 5 and designed to meet the performance benchmarks in the most cost-effective manner. Information not available to this study that offers a more complete facility characterization may lead to different conclusions regarding the cooling towers' physical configuration.

This study developed a conceptual design of wet cooling towers sufficient to meet each active generating unit's cooling demand at its rated output during peak climate conditions. Cost estimates are based on vendor quotes developed using the available information and the various design constraints identified at MLPP.

The overall practicality of retrofitting both units at MLPP 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 San Francisco and Central Coast regions.

3.2 DESIGN BASIS

3.2.1 CONDENSER SPECIFICATIONS

For this study, the wet cooling tower conceptual design selected for MLPP 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.[1] The practicality and difficulty of these modifications are dependent each unit's age and configuration but are assumed to be feasible at MLPP. Additional costs for condenser modifications are included in the discussion of capital expenditures (Section 4.3).

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

Information provided by MLPP was largely used as the basis for the cooling tower design. In some cases, the data were incomplete or conflicted with values obtained from other sources.

Where possible, questionable values were verified or corrected using other known information about the condenser.

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

Table J–5. Condenser Design Specifications

	Units 1 & 2	Units 6 & 7
Thermal load (MMBTU/hr)	1,067.5	2,930
Surface area (ft^2)	96,500	435,000
Condenser flow rate (gpm)	107,000	298,000
Tube material	Titanium	Titanium
Heat transfer coefficient (BTU/hr•ft^2•°F)	563.2	509.5
Cleanliness factor	0.9	0.9
Inlet temperature (°F)	56.1	60
Temperature rise (°F)	19.96	19.67
Steam condensate temperature (°F)	87.3	89.0
Turbine exhaust pressure (in. HgA)	1.305	1.38

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

MLPP is located in Monterey County near Moss Landing Harbor on the Monterey Bay coast. Cooling water is withdrawn at the surface from a shoreline intake structure in the harbor. Inlet temperature data were not available from MLPP. Instead, surface water temperatures used in this analysis were based on monthly average coastal water temperatures as reported in the NOAA *Coastal Water Temperature Guide for Santa Cruz, CA* (NOAA 2007).

The wet bulb temperature used in the development of the overall cooling tower design was obtained from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publications. Data for Monterey indicate a 1 percent ambient wet bulb temperature of 63° F (ASHRAE 2006). The same value is referenced as the 1 percent design criteria in documents provided by MLPP. 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 75° 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 19 in Castroville (CIMIS 2006). Climate data used in this analysis are summarized in Table J–6.

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

	Surface (°F)	Ambient wet bulb (°F)
January	53.0	56.3
February	53.4	57.0
March	55.9	60.0
April	57.7	58.4
May	58.6	61.8
June	59.2	60.0
July	59.4	62.4
August	62.1	63.2
September	60.3	62.0
October	56.8	61.1
November	55.0	61.9
December	53.9	58.8

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Industrial development at MLPP is regulated by Title 20 of the Monterey County Zoning Ordinance (Coastal Implementation Plan). The plan outlines narrative criteria to be used when evaluating the potential impacts from noise on surrounding areas. If a finding of significant impact is made, noise abatement measures may be required including relocating or reorienting structures, low noise fans and landscaped setbacks from noise sources. The use of sound walls for noise control is prohibited.

The areas surrounding MLPP are predominately agricultural and industrial, with Moss Landing Harbor the most likely point of impact. Duke Energy, in an evaluation of alternative cooling options for the MLPP modernization project, conducted a detailed analysis of potential noise levels from mechanical draft wet cooling towers at various locations surrounding the site. That analysis determined that noise associated with wet cooling tower operation was insignificant and would not require additional noise abatement measures (Duke 2000). Accordingly, this study did not include any noise control measures in the cooling tower design.

3.2.3.2 BUILDING HEIGHT

The developed portion of MLPP is located within the heavy industry (HI) zone according to Coastal Implementation Plan. This zone is dedicated to coastal-dependent industrial uses and limits structural height to 35 feet. Exceptions to this limitation are made on a conditional use basis that evaluates the existing character of the site and the surrounding areas. Based on consultation with the Monterey County Planning Department, MLPP, as an industrial site would be eligible for a conditional use exception. This study selected a height restriction of 60 feet above grade level. The height of the wet cooling towers designed for MLPP Units 1 and 2, from grade level to the top of the fan deck, is 44 feet. The height of the Unit 6 and 7 towers is 55 feet.

3.2.3.3 PLUME ABATEMENT

Local zoning ordinances do not contain any specific criteria for addressing impacts associated with a wet cooling tower plume. Using the selection criteria for this study, plume abatement measures were not considered for MLPP; all towers are a conventional design. The plume from wet cooling towers at MLPP is not expected to adversely impact nearby infrastructure.

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 recreational areas (Moss Landing State Beach), 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 MLPP in the future. These guidelines assess the total size and persistence of a visible plume with respect to impacts on the viewshed from surrounding areas.

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 MLPP, with an accepted efficiency of 0.0005 percent. Because cooling tower PM_{10} emissions are a function of the drift rate, drift eliminators are also considered BACT for PM_{10} emissions from wet cooling towers. This efficiency can be verified by a proper in situ test, which accounts for site-specific climate, water, and operating conditions. Testing based on the Cooling Tower Institute's Isokinetic Drift Test Code is required at initial start-up on only one representative cell of each tower for an approximate cost of $60,000 per test, or approximately $240,000 for all four cooling towers at MLPP (CTI 1994). This cost is not itemized in the final analysis and is instead included as part of the indirect cost estimate (Section 4.3).

3.2.3.5 FACILITY CONFIGURATION AND AREA CONSTRAINTS

The existing site's configuration does not present significant challenges to identifying a location for conventional cooling towers, although the selected location results in long distances between the Unit 6 and 7 cooling towers and the generating units. As shown in Figure J–3, the property's total area is relatively large and can accommodate mechanical draft wet cooling towers.

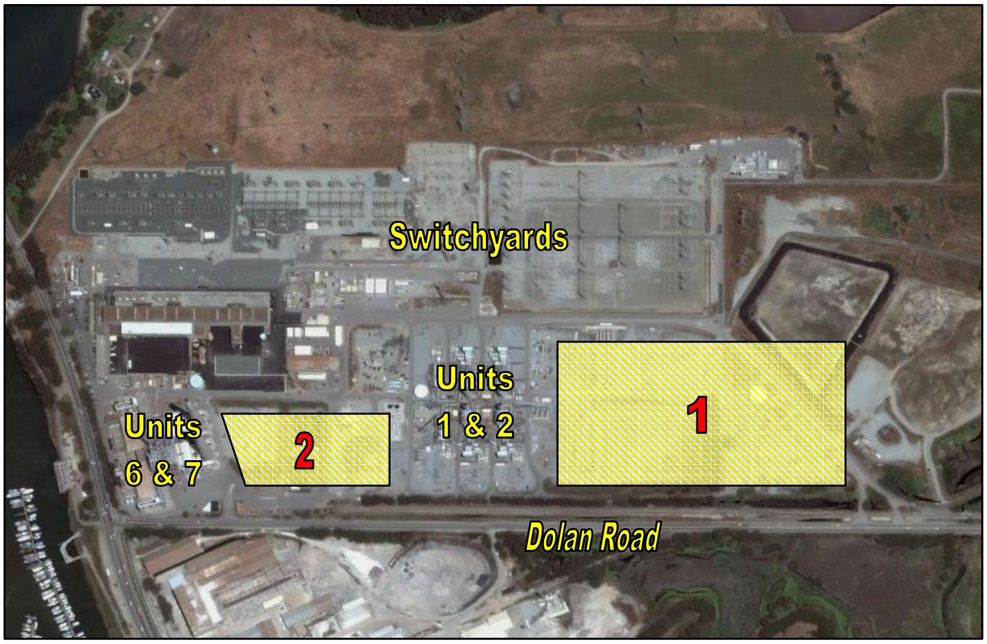

Figure J–3. Cooling Tower Siting Locations

Area 1 is generally unoccupied with a total area of approximately 30 acres. This area extends approximately 1,600 feet alongside Dolan Road heading east from Moss Landing Harbor.

Area 2 is smaller but located much closer to Units 6 and 7. The towers designed for Units 6 and 7, approximately 700 feet long by 100 feet wide, would consume most of the available space in this area and may not be configured in an ideal arrangement. In addition, the area is partially occupied by three hazardous waste surface impoundments that are permitted by a separate order (R3-2004-104). Use of Area 2 would require relocation or removal of these ponds, but their status is unknown to this study. The level of remediation required, if any, cannot be determined. Area 2, therefore, was not considered further. Towers for all four units are placed in Area 1.

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above, four wet cooling towers were selected to replace the current once-through cooling system that serves the four generating units at MLPP. Each unit will be served by an independently-functioning tower with separate pump houses and pumps. The towers for Units 1 and 2 consist of conventional cells arranged in a multi-cell, inline configuration. The towers for Units 6 and 7 are similar but arranged in a back-to-back configuration.

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 MLPP are summarized in Table J–7.

Table J–7. Wet Cooling Tower Design

	Tower Complex 1 (Units 1 & 2)	Tower Complex 2 (Units 6 & 7)
Thermal load (MMBTU/hr)	2,135	5,860
Circulating flow (gpm)	214,000	596,000
Number of cells	20	52
Tower type	Mechanical draft	Mechanical draft
Flow orientation	Counterflow	Counterflow
Fill type	Modular splash	Modular splash
Arrangement	Inline	Back-to-back
Primary tower material	FRP	FRP
Tower dimensions (l x w x h) (ft)	480 x 54 x 44	720 x 96 x 55
Tower footprint with basin (l x w) (ft)	484 x 58	724 x 100

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. At MLPP, the linear distance between Units 6 and 7 and Tower Complex 2 is large (approximately 1,500 feet) but does not present any significant challenges for placing the supply and return pipelines (Figure J–4). This area was also evaluated by Duke Energy, which selected this location "to place the cooling towers downwind of the main equipment areas. This downwind location avoids potential damage from concentrated sea water drift droplets from the cooling tower plumes" (Duke 2000).

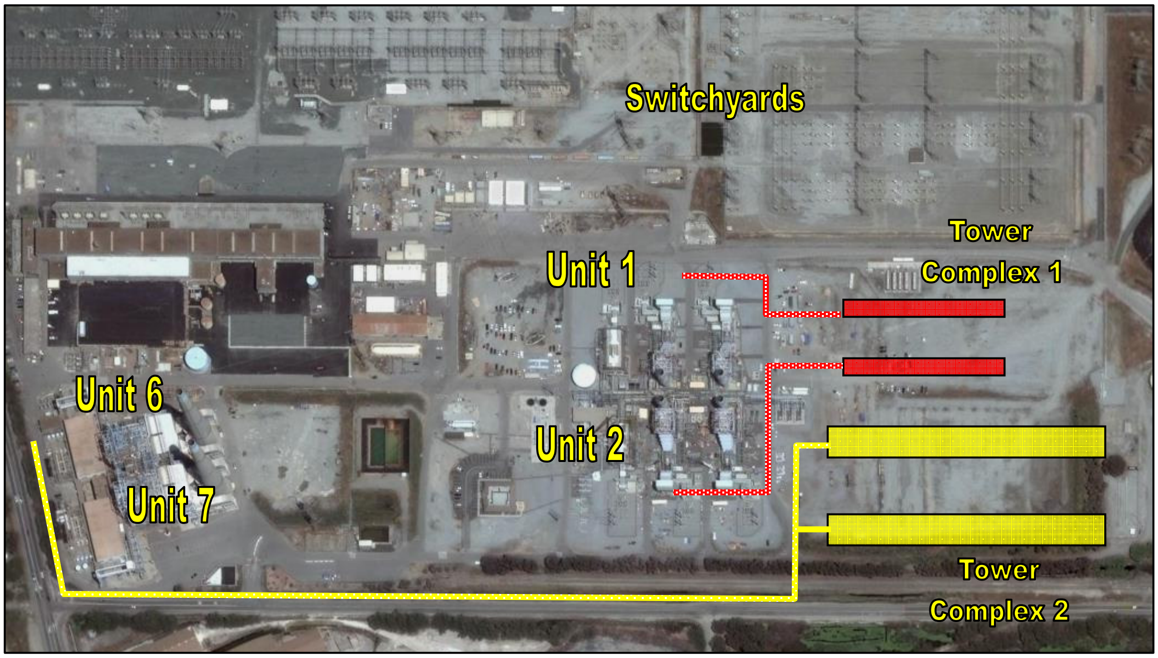

Figure J–4. Cooling Tower Locations

3.3.3 PIPING

The proximity of Tower Complex 1 to Units 1 and 2 allows for most of the supply and return piping (FRP) to be placed above ground on pipe racks. Small sections near the towers will be placed underground and made of prestressed concrete cylinder pipe (PCCP).

The main supply and return pipelines to and from Tower Complex 2 will be located underground and made PCCP suitable for saltwater applications. These pipes range in size from 72 to 120 inches in diameter. The distance between Tower Complex 2 and Units 6 and 7 requires 8,000 feet of PCCP for the supply and return lines. 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 MLPP are all located at grade level, enabling a relatively straightforward connection.

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

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

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

3.3.4 FANS AND PUMPS

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

This analysis includes new pumps to circulate water between the condensers and cooling towers. Pumps are sized according to the flow rate for each tower, the relative distance between the towers and condensers, and the total head required to deliver water to the top of each cooling tower riser. A separate, multilevel pump house is constructed for each tower and sized to accommodate the motor control centers (MCCs) and appropriate electrical switchgear. The electrical installation includes all necessary transformers, cabling, cable trays, lighting, and lightning protection. A 30-ton overhead crane is also included to allow for pump servicing.

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

Table J–8. Cooling Tower Fans and Pumps

		Tower Complex 1 (Units 1 & 2)	Tower Complex 2 (Units 6 & 7)
Fans	Number	20	52
	Type	Single speed	Single speed
	Efficiency	0.95	0.95
	Motor power (hp)	211	211
Pumps	Number	6	4
	Type	50 % recirculating Mixed flow Suspended bowl Vertical	50 % recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88
	Motor power (hp)	932	3,636

3.4 ENVIRONMENTAL EFFECTS

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

Depending on how MLPP 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 reduction credits (ERCs) to meet air quality regulations. The availability of ERCs and their associated cost was not evaluated as part of this study.

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 MLPP retains its NPDES permit to discharge wastewater to the Pacific Ocean with a wet cooling tower system, it may have to address revised effluent limitations resulting from the substantial change in the discharge quantity and characteristics. Thermal impacts from the current once-through system, if any, will be minimized with a wet cooling system.

3.4.1 AIR EMISSIONS

MLPP is located in the North Central Coast air basin. Air emissions are permitted by the Monterey Bay Unified Air Pollution Control District (MBUAPCD) (Facility ID A0012).

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 MLPP, this corresponds to a rate of approximately 4 gpm based on the maximum combined flow in all four towers. Because the area selected for wet cooling towers is located at a substantial distance from sensitive structures, salt drift deposition is not likely to be a significant concern.

Total PM_{10} emissions from the MLPP cooling towers are a function of the number of hours in operation, overall water quality in the tower, and evaporation rate of drift droplets prior to deposition on the ground. Makeup water at MLPP will be obtained from the same source currently used for once-through cooling water (Moss Landing Harbor). 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 MLPP 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 J–9.[2]

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table J–10 (CARB 2005). In 2005, MLPP operated at an annual capacity utilization rate of 28 percent.

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

Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 130 tons/year, or 154 percent.[3]

Table J-9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower Complex 1	28	123	1.1	535
Tower Complex 2	78	343	3.0	1,491
Total MLPP PM_{10} and drift emissions	**106**	**466**	**4.1**	**2,026**

Table J-10. 2005 Emissions of SO_x, NO_x, PM_{10}

Pollutant	Tons/year
NO_x	141
SO_x	9
PM_{10}	85

3.4.2 MAKEUP WATER

The volume of makeup water required by both cooling towers at MLPP is the sum of evaporative loss and the blowdown volume required to maintain the circulating water in each tower at the design TDS concentration. Drift expelled from the towers represents an insignificant volume by comparison and is accounted for by rounding up evaporative loss estimates. Makeup water volumes are based on design conditions, and may fluctuate seasonally depending on climate conditions and facility operations. Wet cooling towers will reduce once-through cooling water withdrawals from Moss Landing Harbor by approximately 95 percent over the current design intake capacity.

Table J-11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower Complex 1	214,000	3,400	6,800	10,200
Tower Complex 2	596,000	9,400	18,800	28,200
Total MLPP makeup water demand	**810,000**	**12,800**	**25,600**	**38,400**

One circulating water pump, rated at 42,00 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 3,000 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 J–5 presents a schematic of this configuration.

[3] 2006 emission data are not currently available from the Air Resources Board website. For consistency, the comparative increase in PM10 emissions estimated here is based on the 2005 MLPP capacity utilization rate instead of the 2006 rate presented in Table J-4. All other calculations in this chapter use the 2006 value.

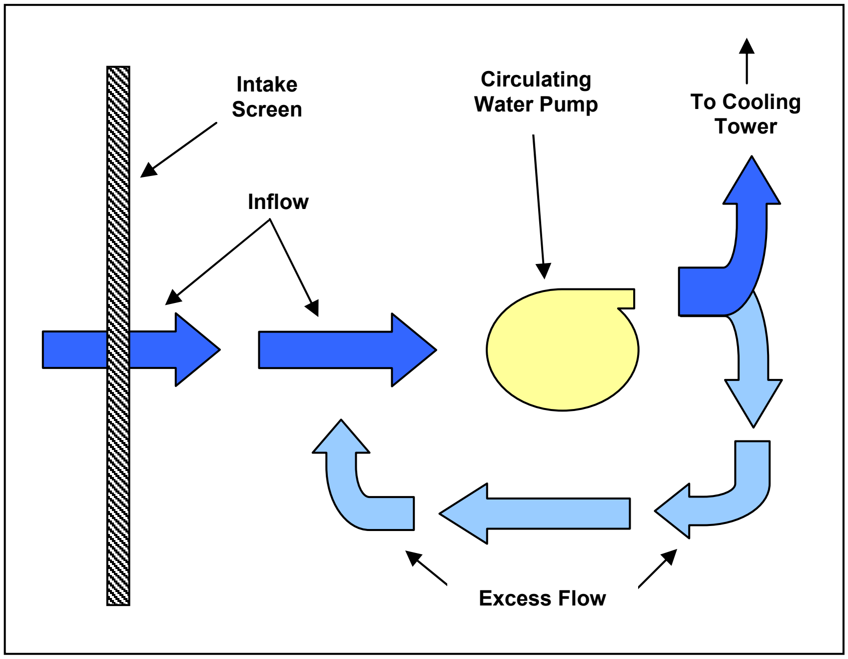

Figure J–5. Schematic of Intake Pump Configuration

The existing once-through cooling system at MLPP does not treat water withdrawn from Moss Landing Harbor with the 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. Conversion to a wet cooling tower system will not interfere with chlorination or heat treatment operations.

Makeup water will continue to be withdrawn from Moss Landing Harbor.

The wet cooling tower system proposed for MLPP includes water treatment for standard operational measures, i.e., corrosion inhibitors, biocides, and anti-scaling agents. An allowance for these additional chemical treatments is included in annual O&M costs. It is assumed that the current once-through cooling water quality will be acceptable for use in a seawater cooling tower (with continued screening and chlorination) and will not require any pretreatment to enable its use.

3.4.3 NPDES PERMIT COMPLIANCE

At maximum operation, wet cooling towers at MLPP will result in an effluent discharge of approximately 37 mgd of blowdown in addition to other in-plant waste streams—such as boiler blowdown, floor drain wastes, and cleaning wastes. These low volume wastes may add an additional 1.0 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, MLPP 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 CA0006254 as implemented by CCRWQCB Order 00-041. All once-through cooling water and process wastewaters are discharged through a submerged outfall extending offshore into the Pacific Ocean. The existing Order contains effluent limitations based on the 1997 Ocean Plan and the 1972 Thermal Plan.

MLPP 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 MLPP operate at 1.5 cycles of concentration, i.e., the blowdown discharge will contain a dissolved solids concentration 50 percent higher than the makeup water.

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

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

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

Thermal discharge standards are based on narrative criteria established for discharges to coastal waters under the Thermal Plan, which requires that existing discharges of elevated-temperature wastes comply with effluent limitations necessary to assure the protection of designated beneficial uses. The CCRWQCB has implemented this provision by establishing a maximum discharge temperature of no more than 26º F to 34º F in excess of the temperature of the receiving water during normal operations, depending on which units are operating (CCRWQCB 2000).

3.4.4 RECLAIMED WATER

Reclaimed or alternative water sources used in conjunction with wet cooling towers could eliminate all surface water withdrawals at MLPP. Doing so would completely eliminate impingement and entrainment concerns, and might enable the facility to avoid possible effluent quality and permit compliance issues, depending on the quality of reclaimed water available for use. In addition, wet cooling towers using reclaimed water would be expected to have lower PM_{10} emissions due to the lower TDS levels. The California State Water Resources Control Board (SWRCB), in 1975, issued a policy statement requiring the consideration of alternative cooling methods in new power plants, including reclaimed water, over the use of freshwater (SWRCB 1975). There is no similar policy regarding marine waters, but the clear preference of state agencies is to encourage alternative cooling methods, including reclaimed water, wherever possible.

The present volume of available reclaimed water within a 15-mile radius of MLPP (5 mgd) does not meet the current once-through cooling demand and can potentially meet the makeup water demand only for Units 1 and 2. This study did not pursue a detailed investigation of reclaimed water's use because the conversion of MLPP's once-through cooling system to saltwater cooling towers meets the performance benchmarks for impingement and entrainment impact reductions discussed in the 2006 California Ocean Protection Council (OPC) Resolution on Once-Through Cooling Water (see Chapter 1).

To be acceptable for use as makeup water in cooling towers, reclaimed water must meet tertiary treatment and disinfection standards under California Code of Regulations (CCR) Title 22. If the reclaimed water is not treated to the required levels, MLPP would be required to arrange for sufficient treatment, either onsite or at the source facility, prior to its use in the cooling towers.

Two publicly owned treatment works (POTWs) were identified within a 15-mile radius of MLPP, with a combined discharge capacity of 40 mgd. The available portion of this volume varies by season. A significant portion of the effluent in the region is treated to either advanced secondary or tertiary standards and recycled for irrigation on many nearby agricultural operations. Figure J–6 shows the relative locations of these facilities to MLPP.

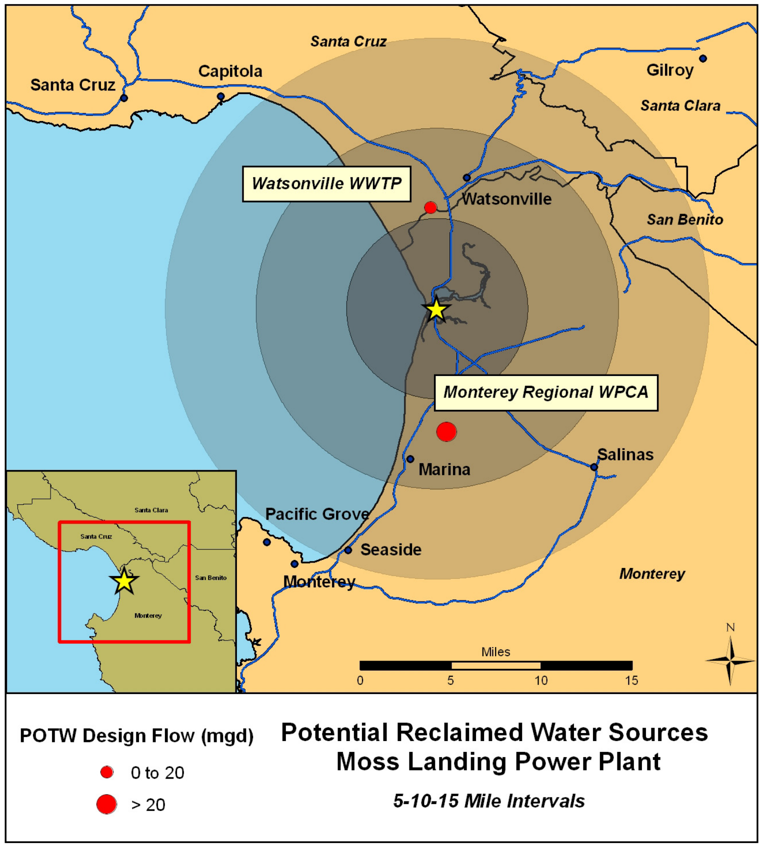

Figure J–6. Reclaimed Water Sources

- *Watsonville Wastewater Treatment Plant—Watsonville*
  Discharge volume: 10 mgd
  Distance: 6 miles N
  Treatment level: Advanced secondary

  All water is treated to advanced secondary standards and discharged to Monterey Bay through a submerged outfall. The Pajaro Valley Water Management Agency is in the process of upgrading the Watsonville WWTP to provide tertiary treatment for approximately 3.5 mgd for use as irrigation water at local agricultural operations during the spring, summer and fall (expected completion 2008). The remaining capacity—approximately 5 to 6 mgd—is sufficient to provide all of the makeup water required for the Unit 1 and 2 cooling towers (4 to 6 mgd). Additional volume would be available during winter months.

- *Monterey Regional Water Pollution Control Agency (MRWPCA)—Marina*
  Discharge volume: 29.6 mgd
  Distance: 7 miles S
  Treatment level: Tertiary

  MRWPCA currently treats the design capacity of 29.6 mgd to tertiary standards for use as irrigation water on approximately 12,000 acres of regional agricultural operations. Any portion not recycled for irrigation is discharged through a submerged outfall to Monterey Bay. The demand for reclaimed water varies seasonally with more water available during winter months. No reclaimed water in any sufficient quantity is available for use as cooling tower makeup water at MLPP.

The costs associated with installing transmission pipelines (excavation/drilling, material, labor), in addition to design and permitting costs, are difficult to quantify in the absence of a detailed analysis of various site-specific parameters that will influence the final configuration. The nearest facility with sufficient capacity to satisfy the makeup demand for Units 1 and 2 (4 to 6 mgd for freshwater towers) is located 6 miles north of the facility (Watsonville). The available volume may vary on a daily basis and future demands from agricultural operations may further limit any excess volume available to MLPP.

Based on data compiled for this study and others, the estimated installed cost of a 24-inch prestressed concrete cylinder pipe, sufficient to provide 6 mgd to MLPP, is $300 per linear foot, or approximately $1.6 million per mile. Additional considerations, such as pump capacity and any required treatment, would increase the total cost.

Regulatory concerns beyond the scope of this investigation, however, may make reclaimed water (as a makeup water source) comparable or preferable to marine water from Moss Landing Harbor. Reclaimed water may enable MLPP to eliminate potential conflicts with water discharge limitations or reduce PM_{10} emissions from the cooling tower, which is a concern given the North Central Coast air basin's current nonattainment status.

At any facility where wet cooling towers are a feasible alternative, reclaimed water may be used as a makeup water source. The practicality of its use, however, depends on the overall cost, availability, and additional environmental benefit that may occur.

3.4.5 THERMAL EFFICIENCY

Wet cooling towers at MLPP will increase the condenser inlet water temperature by a range of 13 to 19° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at MLPP are designed to operate at the conditions described in Table J–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures is described in Figure J–7.

Table J–12. Design Thermal Conditions

	Units 1 & 2	Units 6 & 7
Design backpressure (in. HgA)	1.305	1.38
Design water temperature (°F)	56.1	60
Turbine inlet temp (°F)	1,000	1,000
Turbine inlet pressure (psia)	1,849	3,500
Full load heat rate (BTU/kWh)	6,800	9,130

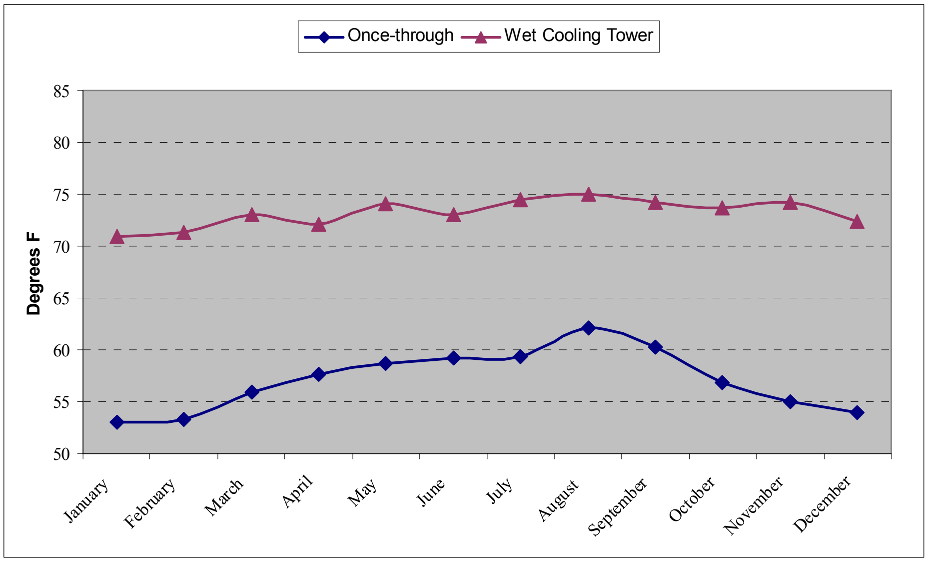

Figure J–7. Condenser Inlet Temperatures

Backpressures for the once-through and wet cooling tower configurations were calculated for each month using the design criteria described in the sections above and ambient climate data (Table J– 6). In general, backpressures associated with the wet cooling tower were elevated by 0.66 to 0.87 inches HgA compared with the current once-through system (Figure J–8 and Figure J–10).

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.[4] The relative change at different backpressures was compared with the value calculated for the design conditions (i.e., at design turbine inlet and exhaust backpressures) and plotted as a percentage of the full load operating heat rate to develop estimated correction curves (Figure J–9 and Figure J–11).

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 J–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.

[4] Changes in thermal efficiency estimated for MLPP 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 MLPP might result in different calculations.

Table J-13. Summary of Estimated Heat Rate Increases

	Units 1 & 2	Units 6 & 7
Peak (July-August-September)	0.55%	1.22%
Annual average	0.57%	1.22%

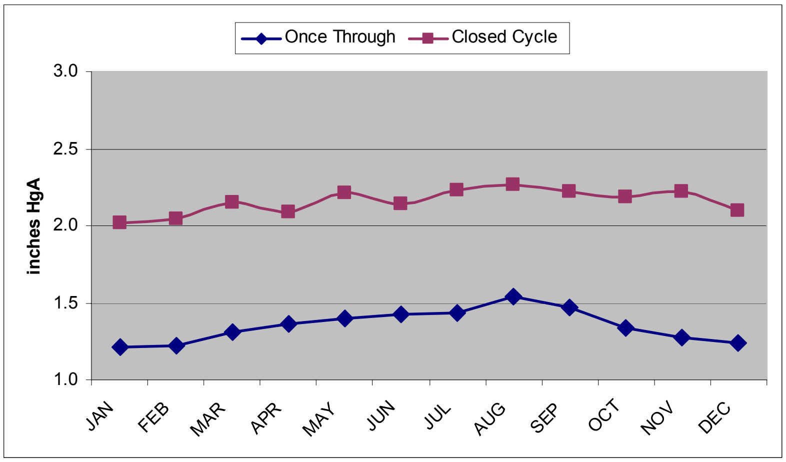

Figure J-8. Estimated Backpressures (Units 1 & 2)

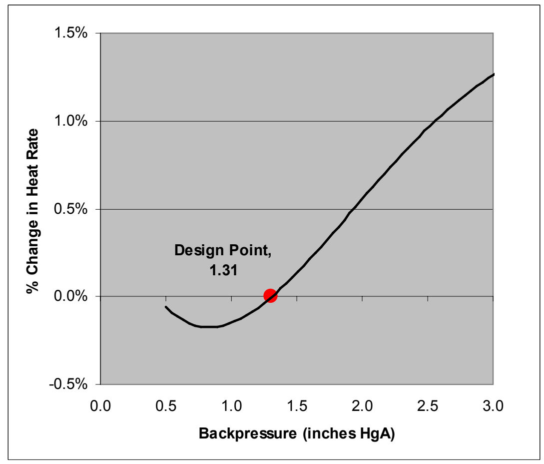

Figure J-9. Estimated Heat Rate Correction (Units 1 & 2)

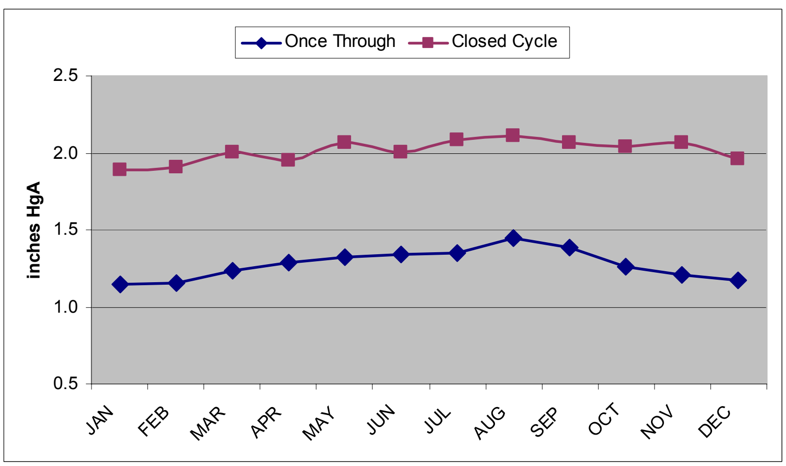

Figure J-10. Estimated Backpressures (Units 6 & 7)

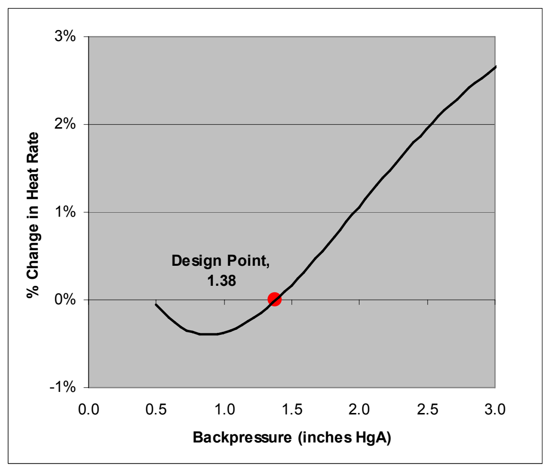

Figure J-11. Estimated Heat Rate Correction (Units 6 & 7)

4.0 RETROFIT COST ANALYSIS

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

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

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

4.1 COOLING TOWER INSTALLATION

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

	Units 1 & 2	Units 6 & 7	MLPP total
Number of cells	20	52	**72**
Cost/cell ($)	560,000	530,769	**538,889**
Total MLPP D&B cost ($)	**11,200,000**	**27,600,000**	**38,800,000**

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 MLPP, these costs comprise approximately 75 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 J–15.

Table J–15. Summary of Other Direct Costs (MLPP Total)

	Equipment ($)	Bulk material ($)	Labor ($)	MLPP total ($)
Civil/structural/piping	9,600,000	48,300,000	43,600,000	**101,500,000**
Mechanical	11,600,000	0	700,000	**12,300,000**
Electrical	3,000,000	5,200,000	4,500,000	**12,700,000**
Demolition	0	0	0	**0**
Total MLPP other direct costs	**24,200,000**	**53,500,000**	**48,800,000**	**126,500,000**

Table J–16. Summary of Other Direct Costs (Units 1 & 2 Only)

	Equipment ($)	Bulk material ($)	Labor ($)	MLPP total ($)
Civil/structural/piping	4,000,000	10,700,000	9,900,000	**24,600,000**
Mechanical	5,000,000	0	300,000	**5,300,000**
Electrical	1,300,000	1,800,000	1,700,000	**4,800,000**
Demolition	0	0	0	**0**
Total MLPP other direct costs	**10,300,000**	**12,500,000**	**11,900,000**	**34,700,000**

- *Civil, Structural, and Piping*
  The distance between Cooling Tower Complex 2 and Units 6 and 7 requires more than 8,000 feet of large diameter pipe to service both cooling towers.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect the new pumps (ten total) to circulate cooling water between the towers and condensers. No new pumps are required to provide makeup water from Moss Landing Harbor. Electrical costs are based on the battery limit after the main feeder breakers.
- *Demolition*
  No demolition costs are required.

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 MLPP, potential costs in this category include relocating or demolishing small buildings and structures and potential interferences from underground structures.

Soils were not characterized for this analysis. MLPP is situated near sea level adjacent to Moss Landing Harbor and Elkhorn Slough. Subsidence and groundwater intrusion may require additional pilings to support any large structures built at the site. Initial capital costs are summarized in Table J–17.

Table J–17. Summary of Initial Capital Costs

	MLPP cost ($)	Units 1 & 2 cost ($)
Cooling towers	38,800,000	11,200,000
Civil/structural/piping	101,500,000	24,600,000
Mechanical	12,300,000	5,300,000
Electrical	12,700,000	4,800,000
Demolition	0	0
Indirect cost	41,300,000	11,500,000
Condenser modification	8,300,000	2,300,000
Contingency	53,700,000	14,900,000
Total capital cost	**268,600,000**	**74,600,000**

4.4 SHUTDOWN

A portion of the work relating to installing the Unit 6 and 7 wet cooling towers can be completed without significant disruption to the operations of MLPP. Units will be offline depending on the length of time it takes to integrate the new cooling system and conduct acceptance testing. For MLPP, a conservative estimate of 4 weeks per unit was developed. Based on 2006 generating output, however, no shutdown is forecast for either unit.

Units 1 and 2 are combined-cycle units and, as such, typically operate at higher capacity utilization rates than Units 6 and 7. This study assumed some downtime loss during tie-in. If construction were scheduled to coincide with the lowest generating period of the year, Units 1 and 2 would be offline for an estimated 4 weeks during April (based on 2006 output data) and incur an estimated revenue loss of $2 million.

Table J–18. Estimated Revenue Loss from Construction Shutdown (Units 1 & 2)

Estimated output (MWh)	Heat rate (BTU/kWh)	Wholesale fuel price ($/MMBTU)	Wholesale electricity price ($/MWh)	Fuel cost ($)	Gross revenue ($)	Difference ($)
75,342	6,800	5.00	60	2,561,628	10,500,000.00	**1,958,892**

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 MLPP 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 four cooling towers at MLPP (810,000 gpm), as well as an annual cost for Units 1 and 2 alone (based on a flow of 214,000 gpm) are presented in Table J–19. These costs reflect maximum operation.

Table J–19. Annual O&M Costs (Full Load)

	MLPP total	
	Year 1 ($)	Year 12 ($)
Management/labor	810,000	1,174,500
Service/parts	1,296,000	1,879,200
Fouling	1,134,000	1,644,300
Total MLPP O&M cost	**3,240,000**	**4,698,000**

	Units 1 & 2 only	
	Year 1 ($)	Year 12 ($)
Management/labor	214,000	310,300
Service/parts	342,400	496,480
Fouling	299,600	434,420
Units 1 & 2 O&M cost	**856,000**	**1,241,200**

4.6 ENERGY PENALTY

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

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

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

4.6.1 INCREASED PARASITIC USE (FANS AND PUMPS)

Depending on ambient conditions or the operating load at a given time, MLPP 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 J–20.

Table J–20. Cooling Tower Fan Parasitic Use

	Tower Complex 1	Tower Complex 2	MLPP total
Units served	Units 1&2	Units 6&7	--
Generating capacity (MW)	1,080	1,404	**2,484**
Number of fans (one per cell)	20	52	**72**
Motor power per fan (hp)	211	211	--
Total motor power (hp)	4,211	10,947	**15,158**
MW total	3.14	8.16	**11.30**
Fan parasitic use (% of capacity)	**0.29%**	**0.58%**	**0.46%**

Additional circulating water pump capacity for the wet cooling towers will also increase the parasitic electricity usage at MLPP. Makeup water will continue to be withdrawn from Moss Landing Harbor 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

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

tower based on the proportion of the facility's generating capacity it services. Operating 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 J–21.

Table J–21. Cooling Tower Pump Parasitic Use

	Tower Complex 1	Tower Complex 2	MLPP total
Units served	Units 1 & 2	Units 6 & 7	--
Generating capacity (MW)	1080	1404	**2,484**
Existing pump configuration (hp)	3,600	12,060	**15,660**
New pump configuration (hp)	6,591	15,545	**22,136**
Difference (hp)	2,991	3,485	**6,476**
Difference (MW)	2.2	2.6	**4.8**
Net pump parasitic use (% of capacity)	**0.21%**	**0.19%**	**0.19%**

4.6.2 HEAT RATE CHANGE

Heat rate adjustments were calculated based on each month's ambient climate conditions and reflect the estimated difference between operations with once-through and wet cooling tower systems. As noted above, the energy penalty analysis assumes MLPP will increase its fuel consumption to compensate for lost efficiency and the increased parasitic load from fans and pumps. The higher turbine firing rate will increase the thermal load rejected to the condenser, which, in turn, results in a higher backpressure value and corresponding increase in the heat rate. No data are available describing the changes in turbine backpressures above the design thermal loads. For the purposes of monetizing the energy penalty only, this study conservatively assumed an additional increase in the heat rate of 0.5 percent at the higher firing rate; the actual effect at MLPP may be greater or less. Changes in the heat rate for each unit at MLPP are presented in Figure J–12 and Figure J–13.

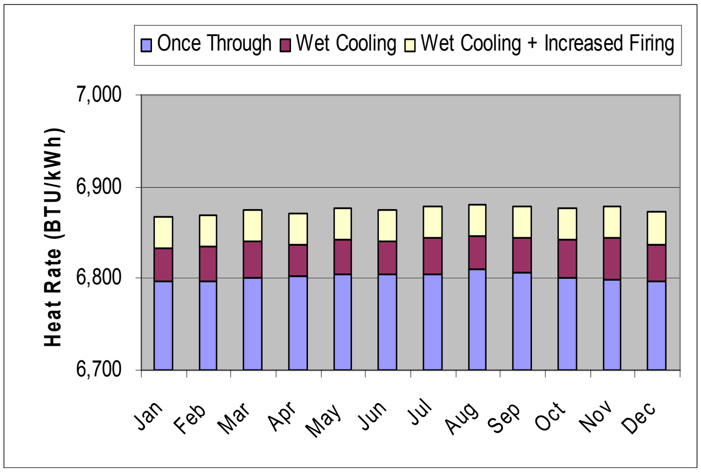

Figure J–12. Estimated Heat Rate Change (Units 1 & 2)

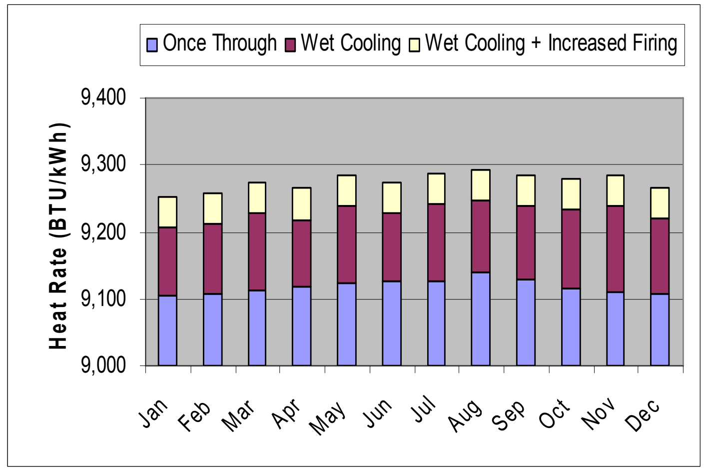

Figure J–13. Estimated Heat Rate Change (Units 6 & 7)

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 ($/MWh) for the once-through system and the wet cooling system adjusted for a higher turbine firing rate. The cost of generation for MLPP is based on the relative heat rates developed in Section 4.6.2 and the average monthly wholesale natural gas cost ($/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 MLPP will be approximately $3.2 million. In contrast, the energy penalty's value calculated with the production loss option would be approximately $5.2 million. Together, these values represent the range of potential energy penalty costs for MLPP. Table J–22 and Table J–23 summarize the Year 1 energy penalty estimate for each unit using the increased fuel option.

Table J–22. 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	6,796	40.78	6,868	41.21	0.43	292,626	124,756
February	5.50	6,797	37.38	6,869	37.78	0.40	317,274	125,491
March	4.75	6,800	32.30	6,874	32.65	0.35	203,065	71,602
April	4.75	6,802	32.31	6,871	32.64	0.33	75,342	24,666
May	4.75	6,804	32.32	6,877	32.67	0.35	187,163	65,528
June	5.00	6,805	34.02	6,874	34.37	0.35	416,025	144,340
July	6.50	6,805	44.23	6,878	44.71	0.48	586,207	279,840
August	6.50	6,810	44.26	6,880	44.72	0.46	682,917	312,275
September	4.75	6,806	32.33	6,878	32.67	0.34	665,273	225,397
October	5.00	6,801	34.01	6,876	34.38	0.38	687,946	258,446
November	6.00	6,799	40.79	6,878	41.27	0.47	626,008	296,723
December	6.50	6,797	44.18	6,872	44.67	0.48	622,298	300,757
							Units 1 & 2 total	**2,229,821**

Table J–23. Units 6 & 7 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	9,105	54.63	9,254	55.52	0.89	0	0
February	5.50	9,106	50.08	9,257	50.92	0.83	0	0
March	4.75	9,113	43.29	9,274	44.05	0.76	0	0
April	4.75	9,119	43.31	9,265	44.01	0.69	22,064	15,287
May	4.75	9,123	43.33	9,284	44.10	0.77	209,176	160,939
June	5.00	9,125	45.62	9,274	46.37	0.74	146,878	109,281
July	6.50	9,126	59.32	9,288	60.37	1.05	373,329	393,157
August	6.50	9,138	59.40	9,293	60.40	1.00	211,717	212,737
September	4.75	9,130	43.37	9,286	44.11	0.74	62,095	46,037
October	5.00	9,116	45.58	9,281	46.40	0.82	0	0
November	6.00	9,110	54.66	9,285	55.71	1.05	0	0
December	6.50	9,107	59.20	9,267	60.24	1.04	17,955	18,618
							Units 6 & 7 total	**956,056**

4.7 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at MLPP 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 MLPP 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 J–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 MLPP overall has a relatively low capacity utilization factor, O&M costs for the NPC calculation were estimated at 60 percent of their maximum value. (See Table J–17.)
- *Annual Energy Penalty.* Insufficient information is available to this study to forecast future generating output at MLPP. 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 J–20 and Table J–21.)

Using these values, the NPC_{20} for MLPP is \$350 million. For Units 1 and 2 only, the NPC_{20} is \$123 million. Appendix C and Appendix D contain detailed annual calculations for MLPP used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by MLPP 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 J–24.

Table J–24. Annual Cost

	Discount rate (%)	Capital Cost ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
MLPP total	7.00	25,400,000	2,600,000	5,800,000	**33,800,000**
Units 1 & 2 only	7.00	7,100,000	800,000	4,000,000	**11,900,000**

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 MLPP'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 MLPP 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 MLPP is summarized in Table J–25. A comparison of annual costs to annual gross revenue is summarized in Table J–26.

Table J–25. Estimated Gross Revenue

	Wholesale price ($/MWh)	Net generation (MWh)		Estimated gross revenue ($)		
		Units 1 & 2	Units 6 & 7	Units 1 & 2	Units 6 & 7	MLPP total
January	66	292,626	0	19,313,316	0	**19,313,316**
February	61	317,274	0	19,353,714	0	**19,353,714**
March	51	203,065	0	10,356,315	0	**10,356,315**
April	51	75,342	22,064	3,842,442	1,125,264	**4,967,706**
May	51	187,163	209,176	9,545,313	10,667,976	**20,213,289**
June	55	416,025	146,878	22,881,375	8,078,290	**30,959,665**
July	91	586,207	373,329	53,344,837	33,972,939	**87,317,776**
August	73	682,917	211,717	49,852,941	15,455,341	**65,308,282**
September	53	665,273	62,095	35,259,469	3,291,035	**38,550,504**
October	57	687,946	0	39,212,922	0	**39,212,922**
November	66	626,008	0	41,316,528	0	**41,316,528**
December	67	622,298	17,955	41,693,966	1,202,985	**42,896,951**
MLPP total		**5,362,144**	**1,043,214**	**345,973,138**	**73,793,830**	**419,766,968**

Table J–26. 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
MLPP total	419,800,000	25,400,000	6.1	2,600,000	0.6	5,800,000	1.4	**33,800,000**	**8.1**
Units 1 & 2 only	346,000,000	7,100,000	2.1	800,000	0.2	4,000,000	1.2	**11,900,000**	**3.4**

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 MLPP. As with many existing facilities, the location and configuration of the site complicates the use of some technologies that might be used successfully elsewhere. A more detailed analysis that also comprises a biological evaluation may determine the applicability of one or more of these technologies to MLPP. A brief summary of the applicability of these technologies follows.

5.1 MODIFIED RISTROPH SCREENS—FINE MESH

The principal concern with this technology is the successful return of viable organisms captured on the screens to the source water body. MLPP currently withdraws its cooling water through a shoreline CWIS on the eastern bank of Moss Landing Harbor. Modifying the existing traveling screens to include fine mesh panels and a return system would require expanding the existing CWIS and identifying a suitable return location to prevent re-impingement. These modifications, and the potential for success, are plausible but require detailed investigation of the potentially affected species in Moss Landing Harbor before a conclusive determination can be made.

5.2 BARRIER NETS

The confined area within Moss Landing Harbor is a significant constraint on the use of a barrier net. For this reason, in addition to their ineffectiveness in reducing entrainment, barrier nets were not considered further in this study.

5.3 AQUATIC FILTRATION BARRIERS

Aquatic filtration barriers (AFBs), which are larger than barrier nets, are more limited than barrier nets for deployment at MLPP. Placement within Moss Landing Harbor is infeasible.

5.4 VARIABLE SPEED DRIVES

Variable speed drives (VSDs) were not considered for analysis at MLPP because the technology alone cannot be expected to achieve the desired level of reductions in impingement and entrainment, nor could it be combined with another technology to yield the desired reductions. Pumps that have been retrofitted with VSDs can reduce overall flow intake volumes by 10–35 percent over the current once-through configuration (USEPA 2001). The actual reduction, however, will vary based on the cooling water demand at different times of the year. At peak demand, the pumps will essentially function as standard circulating water pumps and withdraw water at the maximum rated capacity, 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 MLPP (approximately 1,224 mgd). To function as intended, cylindrical wedgewire screens must be submerged in a water body with a consistent ambient current of 0.5 fps. Ideally, this current would be unidirectional so that screens may be oriented properly and any debris impinged on the screens will be carried downstream when the airburst cleaning system is activated.

MLPP currently withdraws cooling water from Moss Landing Harbor. Space constraints and navigation concerns prohibit the placement of any large cylindrical screens in the channel or bay, let alone the 10 to 12 84-inch-diameter screens that would be required to supply the facility with adequate volumes of water. The only theoretical location available for MLPP would be offshore in Monterey Bay, west of the entrance to Moss Landing Harbor.

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. The bathymetry of Monterey Bay in the area west of Moss Landing Harbor is rocky and drops rapidly into the Monterey submarine canyon, complicating placement of wedgewire screens. Discussions with vendors who design these systems indicated that distances more than 1,000 to 1,500 feet become problematic due to the airburst system's inability to maintain adequate pressure for sufficient cleaning (Someah 2007). Together, these considerations preclude further evaluation of fine-mesh cylindrical wedgewire screens at MLPP.

6.0 REFERENCES

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

		Units 1 & 2			Units 6 & 7		
		Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase
JAN	Backpressure (in. HgA)	1.21	2.02	**0.81**	1.15	1.89	**0.74**
	Heat rate Δ (%)	*-0.15*	*1.39*	***1.54***	*-0.27*	*0.85*	***1.12***
FEB	Backpressure (in. HgA)	1.22	2.04	**0.82**	1.16	1.91	**0.75**
	Heat rate Δ (%)	*-0.13*	*1.45*	***1.58***	*-0.26*	*0.89*	***1.15***
MAR	Backpressure (in. HgA)	1.31	2.15	**0.84**	1.23	2.00	**0.77**
	Heat rate Δ (%)	*-0.01*	*1.67*	***1.67***	*-0.19*	*1.07*	***1.26***
APR	Backpressure (in. HgA)	1.37	2.09	**0.72**	1.29	1.95	**0.66**
	Heat rate Δ (%)	*0.09*	*1.54*	***1.45***	*-0.12*	*0.97*	***1.09***
MAY	Backpressure (in. HgA)	1.40	2.21	**0.81**	1.32	2.06	**0.74**
	Heat rate Δ (%)	*0.15*	*1.80*	***1.65***	*-0.08*	*1.19*	***1.27***
JUN	Backpressure (in. HgA)	1.43	2.15	**0.72**	1.34	2.00	**0.66**
	Heat rate Δ (%)	*0.19*	*1.66*	***1.47***	*-0.06*	*1.07*	***1.12***
JUL	Backpressure (in. HgA)	1.43	2.23	**0.80**	1.35	2.08	**0.73**
	Heat rate Δ (%)	*0.20*	*1.84*	***1.64***	*-0.05*	*1.22*	***1.27***
AUG	Backpressure (in. HgA)	1.54	2.27	**0.73**	1.45	2.11	**0.67**
	Heat rate Δ (%)	*0.40*	*1.91*	***1.51***	*0.09*	*1.28*	***1.19***
SEP	Backpressure (in. HgA)	1.47	2.22	**0.75**	1.38	2.07	**0.69**
	Heat rate Δ (%)	*0.27*	*1.82*	***1.55***	*-0.01*	*1.20*	***1.20***
OCT	Backpressure (in. HgA)	1.34	2.19	**0.85**	1.26	2.04	**0.78**
	Heat rate Δ (%)	*0.04*	*1.75*	***1.71***	*-0.16*	*1.14*	***1.30***
NOV	Backpressure (in. HgA)	1.27	2.22	**0.95**	1.20	2.07	**0.86**
	Heat rate Δ (%)	*-0.06*	*1.81*	***1.87***	*-0.22*	*1.19*	***1.41***
DEC	Backpressure (in. HgA)	1.24	2.10	**0.86**	1.17	1.96	**0.79**
	Heat rate Δ (%)	*-0.10*	*1.57*	***1.68***	*-0.25*	*1.00*	***1.24***

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	106	424,000	**924,000**
Allocation for pipe racks (approx 3000 ft) and cable racks	t	300	--	--	2,500	750,000	17.00	105	535,500	**1,285,500**
Allocation for sheet piling and dewatering	lot	2	--	--	500,000	1,000,000	5,000.00	100	1,000,000	**2,000,000**
Allocation for testing pipes	lot	2	--	--	--	--	2,000.00	95	380,000	**380,000**
Allocation for Tie-Ins to existing condenser's piping	lot	1	--	--	250,000	250,000	2,000.00	106	212,000	**462,000**
Allocation for trust blocks	lot	2	--	--	25,000	50,000	250.00	95	47,500	**97,500**
Backfill for PCCP pipe (reusing excavated material)	m3	52,000	--	--	--	--	0.04	200	416,000	**416,000**
Bedding for PCCP pipe	m3	7,700	--	--	25	192,500	0.04	200	61,600	**254,100**
Bend for PCCP pipe 120" diam (allocation)	ea	15	--	--	35,000	525,000	100.00	95	142,500	**667,500**
Bend for PCCP pipe 42" & 48" diam (allocation)	ea	30	--	--	5,000	150,000	25.00	95	71,250	**221,250**
Bend for PCCP pipe 72" diam (allocation)	ea	6	--	--	18,000	108,000	40.00	95	22,800	**130,800**
Bend for PCCP pipe 84" diam (allocation)	ea	8	--	--	20,000	160,000	50.00	95	38,000	**198,000**
Building architectural (siding, roofing, doors, painting…etc)	ea	4	--	--	57,500	230,000	690.00	75	207,000	**437,000**
Butterfly valves 120" c/w allocation for actuator & air lines	ea	4	252,000	1,008,000	--	--	80.00	106	33,920	**1,041,920**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	72	30,800	2,217,600	--	--	50.00	106	381,600	**2,599,200**
Butterfly valves 48" c/w allocation for actuator & air lines	ea	16	46,200	739,200	--	--	50.00	106	84,800	**824,000**
Butterfly valves 60" c/w allocation for actuator & air lines	ea	8	75,600	604,800	--	--	60.00	106	50,880	**655,680**
Butterfly valves 72" c/w allocation for actuator & air lines	ea	12	96,600	1,159,200	--	--	75.00	106	95,400	**1,254,600**
Butterfly valves 84" c/w allocation for actuator & air lines	ea	8	124,600	996,800	--	--	75.00	106	63,600	**1,060,400**
Butterfly valves 96" c/w allocation for actuator & air lines	ea	8	151,200	1,209,600	--	--	75.00	106	63,600	**1,273,200**
Check valves 48"	ea	14	66,000	924,000	--	--	24.00	106	35,616	**959,616**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Check valves 84"	ea	4	178,000	712,000	--	--	36.00	106	15,264	**727,264**
Concrete basin walls (all in)	m3	1,082	--	--	225	243,450	8.00	75	649,200	**892,650**
Concrete elevated slabs (all in)	m3	1,117	--	--	250	279,250	10.00	75	837,750	**1,117,000**
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	8,872	--	--	200	1,774,400	4.00	75	2,661,600	**4,436,000**
Ductile iron cement pipe 12" diam. for fire water line	ft	3,000	--	--	100	300,000	0.60	95	171,000	**471,000**
Excavation and backfill for fire line, blowdown & make-up (using excavated material for backfill except for bedding)	m3	29,000	--	--	--	--	0.08	200	464,000	**464,000**
Excavation for PCCP pipe	m3	87,500	--	--	--	--	0.04	200	700,000	**700,000**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	**5,250**
Flange for PCCP joints 120"	ea	8	--	--	39,795	318,360	40.00	95	30,400	**348,760**
Flange for PCCP joints 30"	ea	72	--	--	2,260	162,720	16.00	95	109,440	**272,160**
Flange for PCCP joints 48"	ea	2	--	--	5,000	10,000	20.00	95	3,800	**13,800**
Flange for PCCP joints 72"	ea	4	--	--	9,860	39,440	25.00	95	9,500	**48,940**
Flange for PCCP joints 84"	ea	8	--	--	13,210	105,680	30.00	95	22,800	**128,480**
Foundations for pipe racks and cable racks	m3	700	--	--	250	175,000	8.00	75	420,000	**595,000**
FRP flange 30"	ea	288	--	--	1,679	483,595	50.00	106	1,526,400	**2,009,995**
FRP flange 48"	ea	60	--	--	3,000	180,000	75.00	106	477,000	**657,000**
FRP flange 60"	ea	24	--	--	7,786	186,854	100.00	106	254,400	**441,254**
FRP flange 72"	ea	8	--	--	20,888	167,101	200.00	106	169,600	**336,701**
FRP flange 84"	ea	16	--	--	33,382	534,104	300.00	106	508,800	**1,042,904**
FRP flange 96"	ea	8	--	--	40,000	320,000	500.00	106	424,000	**744,000**
FRP pipe 120" diam.	ft	3,000	--	--	4,257	12,771,000	2.00	106	636,000	**13,407,000**
FRP pipe 72" diam.	ft	4,000	--	--	851	3,405,600	1.20	106	508,800	**3,914,400**
FRP pipe 84" diam.	ft	80	--	--	946	75,680	1.50	106	12,720	**88,400**
Harness clamp 120" c/w internal testable joint for PCCP pipe	ea	500	--	--	4,310	2,155,000	25.00	95	1,187,500	**3,342,500**
Harness clamp 48" & 42" c/w internal testable joint	ea	310	--	--	2,000	620,000	16.00	95	471,200	**1,091,200**
Harness clamp 72" c/w internal testable joint	ea	50	--	--	2,440	122,000	18.00	95	85,500	**207,500**
Harness clamp 84" c/w internal testable joint	ea	180	--	--	2,845	512,100	20.00	95	342,000	**854,100**
Joint for FRP pipe 120" diam.	ea	150	--	--	22,562	3,384,315	1,200.00	106	19,080,000	**22,464,315**
Joint for FRP pipe 72" diam.	ea	100	--	--	3,122	312,180	200.00	106	2,120,000	**2,432,180**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Joint for FRP pipe 84" diam.	ea	4	--	--	5,014	20,055	300.00	106	127,200	**147,255**
PCCP pipe 120" diam.	ft	8,000	--	--	1,285	10,280,000	3.50	95	2,660,000	**12,940,000**
PCCP pipe 42" dia. for blowdown	ft	3,000	--	--	195	585,000	0.90	95	256,500	**841,500**
PCCP pipe 48" dia. for make-up water line	ft	3,200	--	--	260	832,000	1.00	95	304,000	**1,136,000**
PCCP pipe 72" diam.	ft	1,000	--	--	507	507,000	1.30	95	123,500	**630,500**
PCCP pipe 84" diam.	ft	3,600	--	--	562	2,023,200	1.50	95	513,000	**2,536,200**
Riser (FRP pipe 30" diam X 40ft)	ea	72	--	--	14,603	1,051,445	100.00	106	763,200	**1,814,645**
Structural steel for building	t	190	--	--	2,500	475,000	20.00	105	399,000	**874,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**9,571,200**	**--**	**48,378,530**	**--**	**--**	**43,566,390**	**101,516,120**
ELECTRICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
4.16 kv cabling feeding MCC's	m	5,000	--	--	75	375,000	0.40	106	212,000	**587,000**
4.16kV switchgear - 7 breakers	ea	1	325,000	325,000	--	--	230.00	106	24,380	**349,380**
480 volt cabling feeding MCC's	m	2,000	--	--	70	140,000	0.40	106	84,800	**224,800**
480V Switchgear - 1 breaker 3000A	ea	12	30,000	360,000	--	--	80.00	106	101,760	**461,760**
Allocation for automation and control	lot	1	--	--	1,300,000	1,300,000	13,000.00	106	1,378,000	**2,678,000**
Allocation for cable trays and duct banks	m	4,500	--	--	75	337,500	1.00	106	477,000	**814,500**
Allocation for lighting and lightning protection	lot	1	--	--	200,000	200,000	2,000.00	106	212,000	**412,000**
Dry Transformer 2MVA xxkV-480V	ea	12	100,000	1,200,000	--	--	100.00	106	127,200	**1,327,200**
Lighting & electrical services for pump house building	ea	4	--	--	20,000	80,000	250.00	106	106,000	**186,000**
Local feeder for 1000 HP motor 4160 V (up to MCC)	ea	6	--	--	40,000	240,000	150.00	106	95,400	**335,400**
Local feeder for 200 HP motor 460 V (up to MCC)	ea	72	--	--	15,000	1,080,000	140.00	106	1,068,480	**2,148,480**
Local feeder for 4000 HP motor 4160 V (up to MCC)	ea	4	--	--	50,000	200,000	200.00	106	84,800	**284,800**
Oil Transformer 10/13.3MVA xx-4.16kV	ea	4	190,000	760,000	--	--	150.00	106	63,600	**823,600**
Primary breaker(xxkV)	ea	8	45,000	360,000	--	--	60.00	106	50,880	**410,880**
Primary feed cabling (assumed 13.8 kv)	m	7,000	--	--	175	1,225,000	0.50	106	371,000	**1,596,000**
ELECTRICAL TOTAL	**--**	**--**	**--**	**3,005,000**	**--**	**5,177,500**	**--**	**--**	**4,457,300**	**12,639,800**
MECHANICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Allocation for ventilation of buildings	ea	4	25,000	100,000	--	--	250.00	106	106,000	**206,000**
Cooling tower for unit 6	lot	1	13,800,000	13,800,000	--	--	--	--	--	**13,800,000**
Cooling tower for unit 1	lot	1	5,600,000	5,600,000	--	--	--	--	--	**5,600,000**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Cooling tower for unit 2	lot	1	5,600,000	5,600,000	--	--	--	--	--	**5,600,000**
Cooling tower for unit 7	lot	1	13,800,000	13,800,000	--	--	--	--	--	**13,800,000**
Overhead crane 30 ton in (in pump house)	ea	4	75,000	300,000	--	--	100.00	106	42,400	**342,400**
Pump 4160 V 1000 HP	ea	6	800,000	4,800,000	--	--	400.00	106	254,400	**5,054,400**
Pump 4160 V 4000 HP	ea	4	1,600,000	6,400,000	--	--	800.00	106	339,200	**6,739,200**
MECHANICAL TOTAL	**--**	**--**	**--**	**50,400,000**	**--**	**0**	**--**	**--**	**742,000**	**51,142,000**

Appendix C. Net Present Cost Calculation—All Units

Project year	Capital/start-up ($)	O & M ($)	Energy penalty ($)		Total ($)	Annual discount factor	Present value ($)
			Units 1 & 2	Units 6 & 7			
0	270,558,892	--	--		270,558,892	1	**270,558,892**
1	--	1,944,000	2,229,820	956,057	5,129,877	0.9346	**4,794,383**
2	--	1,982,880	2,359,818	1,011,795	5,354,493	0.8734	**4,676,615**
3	--	2,022,538	2,497,396	1,070,783	5,590,716	0.8163	**4,563,701**
4	--	2,062,988	2,642,994	1,133,209	5,839,192	0.7629	**4,454,719**
5	--	2,104,248	2,797,080	1,199,275	6,100,604	0.713	**4,349,731**
6	--	2,146,333	2,960,150	1,269,193	6,375,676	0.6663	**4,248,113**
7	--	2,189,260	3,132,727	1,343,187	6,665,174	0.6227	**4,150,404**
8	--	2,233,045	3,315,365	1,421,495	6,969,905	0.582	**4,056,485**
9	--	2,277,706	3,508,651	1,504,368	7,290,725	0.5439	**3,965,425**
10	--	2,323,260	3,713,205	1,592,073	7,628,538	0.5083	**3,877,586**
11	--	2,369,725	3,929,685	1,684,891	7,984,301	0.4751	**3,793,341**
12	--	2,875,176	4,158,786	1,783,120	8,817,081	0.444	**3,914,784**
13	--	2,932,680	4,401,243	1,887,076	9,220,998	0.415	**3,826,714**
14	--	2,991,333	4,657,835	1,997,092	9,646,260	0.3878	**3,740,820**
15	--	3,051,160	4,929,387	2,113,523	10,094,069	0.3624	**3,658,091**
16	--	3,112,183	5,216,770	2,236,741	10,565,694	0.3387	**3,578,601**
17	--	3,174,427	5,520,908	2,367,143	11,062,478	0.3166	**3,502,380**
18	--	3,237,915	5,842,777	2,505,147	11,585,839	0.2959	**3,428,250**
19	--	3,302,673	6,183,411	2,651,198	12,137,282	0.2765	**3,355,958**
20	--	3,368,727	6,543,904	2,805,762	12,718,393	0.2584	**3,286,433**
Total							**349,781,426**

Appendix D. Net Present Cost Calculation—Units 1 & 2

Project year	Capital / startup ($)	O & M ($)	Energy penalty ($) Units 1 & 2	Total ($)	Annual discount factor	Present value ($)
0	76,658,892	--	--	76,658,892	1	**76,658,892**
1	--	642,000	2,229,820	2,871,820	0.9346	**2,684,003**
2	--	654,840	2,359,818	3,014,658	0.8734	**2,633,003**
3	--	667,937	2,497,396	3,165,333	0.8163	**2,583,861**
4	--	681,296	2,642,994	3,324,289	0.7629	**2,536,100**
5	--	694,921	2,797,080	3,492,002	0.713	**2,489,797**
6	--	708,820	2,960,150	3,668,970	0.6663	**2,444,635**
7	--	722,996	3,132,727	3,855,723	0.6227	**2,400,959**
8	--	737,456	3,315,365	4,052,821	0.582	**2,358,742**
9	--	752,205	3,508,651	4,260,856	0.5439	**2,317,480**
10	--	767,249	3,713,205	4,480,455	0.5083	**2,277,415**
11	--	782,594	3,929,685	4,712,279	0.4751	**2,238,804**
12	--	949,518	4,158,786	5,108,304	0.444	**2,268,087**
13	--	968,508	4,401,243	5,369,751	0.415	**2,228,447**
14	--	987,879	4,657,835	5,645,714	0.3878	**2,189,408**
15	--	1,007,636	4,929,387	5,937,023	0.3624	**2,151,577**
16	--	1,027,789	5,216,770	6,244,559	0.3387	**2,115,032**
17	--	1,048,345	5,520,908	6,569,253	0.3166	**2,079,825**
18	--	1,069,311	5,842,777	6,912,088	0.2959	**2,045,287**
19	--	1,090,698	6,183,411	7,274,109	0.2765	**2,011,291**
20	--	1,112,512	6,543,904	7,656,415	0.2584	**1,978,418**
Total						**122,691,063**