I. MORRO BAY POWER PLANT

DYNEGY, INC—MORRO BAY, CA

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1.0 GENERAL SUMMARY

This study did not analyze a potential retrofit of the existing once-through cooling system at Morro Bay Power Plant (MBPP), but instead updated an analysis conducted by Tetra Tech in 2002 at the request of the Central Coast Regional Water Quality Control Board (CCRWQCB). That study evaluated the cost and feasibility of alternative cooling system technologies, including wet and dry towers, for the proposed repowered facility that would have replaced the existing generating units with two combined cycle systems. The basis for this analysis, therefore, is not a conversion of the existing system but rather a comparison of the costs and logistical constraints that MBPP might face if the repowered units were designed with closed-cycle cooling instead continued use of the once-through system, as proposed by Duke Energy (former owner) in 2000.

Wet cooling towers are both technically and logistically feasible at MBPP, although a potential concern exists over the ability of a retrofitted MBPP to meet the PM_{10} emission goals established by the San Luis Obispo Air Pollution Control District, principally due to the increased emission from the towers themselves.

As designed, the wet cooling tower system selected as a replacement for MBPP conforms to all identified local use restrictions, such as noise, building height, and visual impact. Conventional (non plume-abated) wet cooling towers serve as the basis for analysis in this chapter. If required, plume-abated towers could be located at the site, although additional area would be required and would result in an increased tower capital cost (2 to 3 times the cost of conventional towers) as well as marginal increases in parasitic energy usage. The general design basis of the selected cooling tower, including plume abatement technologies, is discussed further in Section 3.2.3.

An energy penalty analysis was not developed for MBPP in the same manner as for other facilities in this study. Because this evaluation addresses the *proposed* MBPP repowering project, any changes to thermal efficiency that would occur with a closed-cycle system could be addressed in the initial design (e.g., reconfiguration of the condenser or including a turbine designed for different operating conditions). Comparing the efficiency of the current system to that of the repowered facility skews any resulting difference.

This study, therefore, is limited to a capital cost evaluation with an allowance for annual operations and maintenance (O&M) costs.

1.1 COST

Initial capital and Net Present Cost (NPC) costs associated with installing and operating wet cooling towers at MBPP are summarized in Table I–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table I–2.

Table I–1. Cumulative Cost Summary

Cost category	Cost ($)	Cost per MWh (rated capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Total capital and start-up [a]	94,012,500	10.40	46
NPC_{20}[b]	104,300,000	11.54	51

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

Table I–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up	8,400,000	0.93	4.07
Operations and maintenance	1,000,000	0.11	0.48
Total MBPP annual cost	**9,400,000**	**1.04**	**4.55**

2.0 BACKGROUND

MBPP is a natural gas-fired steam electric generating facility in Morro Bay, San Luis Obispo County. The existing facility consists of four conventional units (Units 1-4) with a combined generating capacity of 1,002 MW. The repowered facility, as proposed, would include two new combined-cycle units, each comprised of two gas combustion turbines, one heat recovery steam generator (HRSG) and one steam turbine. The combined capacity of the new units is 1,200 MW, although this includes duct firing, which increases the operating heat rate, thus decreasing the unit's efficiency by approximately 4 percent. Without duct firing, each unit is rated at 516 MW for a facility total of 1,032 MW. Duct firing is typically used during peak demand periods when ambient conditions warrant.

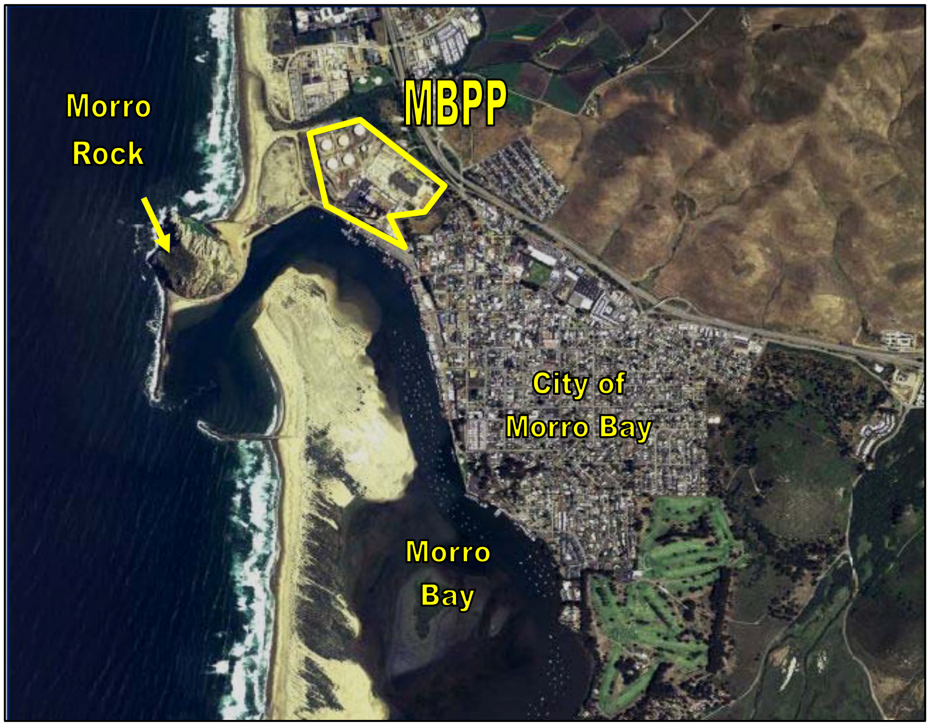

Figure I–1. General Vicinity of Morro Bay Power Plant

2.1 COOLING WATER SYSTEM

MBPP operates one cooling water intake structure (CWIS) to provide condenser cooling water to Units 1–4. The existing facility has a once-through cooling water capacity of 668 million gallons per day (MGD) and an average flow rate of 567 MGD. The proposed facility will have a design cooling water flow rate of 475 MGD and an average flow rate of 372 MGD.

Surface water withdrawals and discharges are permitted by National Pollutant Discharge Elimination System (NPDES) Permit CA CA0050610 as implemented by CCRWQCB Order R3-2001-0014. Cooling water is withdrawn through a surface intake located along the shoreline of Morro Bay, and discharged, along with other low-volume wastes, through a submerged outfall extending offshore into Estero Bay north of Morro Rock (Figure I–2).

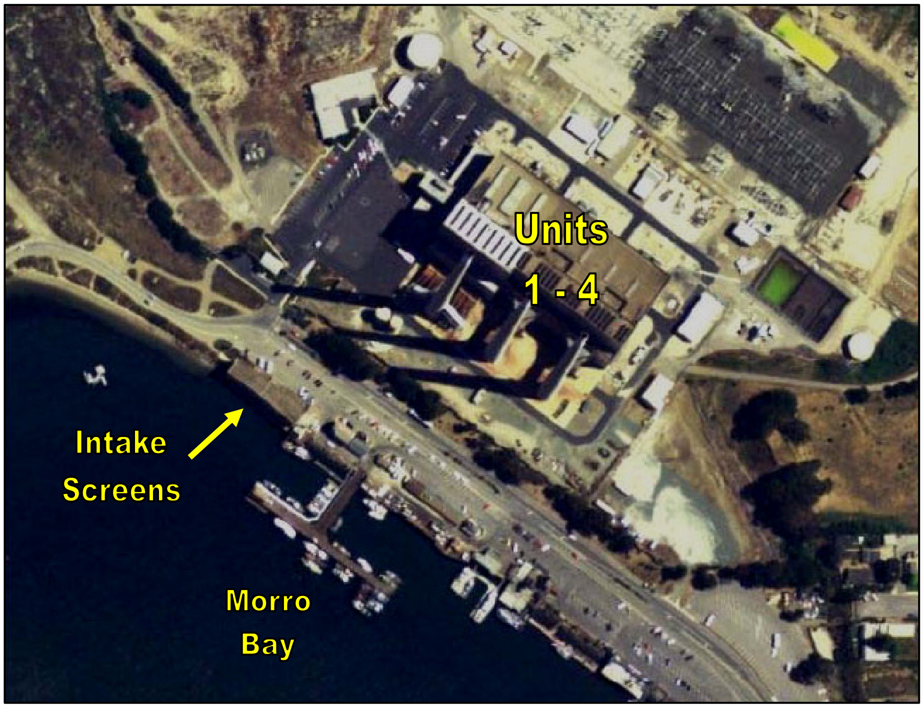

Figure I–2. Site View

2.2 SECTION 316(B) PERMIT COMPLIANCE

The CWIS currently in operation at MBPP does not use technologies generally considered to be effective at reducing impingement mortality and/or entrainment. Based on the low capacity utilization of the existing facility, the findings from the 2002 Tetra Tech report and the anticipated repowered facility in the next several years, the CCRWQCB did not include any numeric limitations or requirements regarding impingement mortality or entrainment in the current order. Instead, the order established a compliance schedule that required MBPP to conduct monitoring in Morro Bay with the intent of establishing a biological baseline and possibly evaluating the long-term effects of the facility's cooling water intake. MBPP was also required to comply with Comprehensive Demonstration Study schedule outlined in the Phase II rule (CCRWQCB 2007). It is not clear how the CCRWQCB intends to proceed with this requirement in light of the Second Circuit decision.

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

This study evaluates saltwater cooling towers as part of a repowering of the existing MBPP, with the current source water (Morro Bay) continuing to provide makeup water to the facility. Use of wet cooling towers, combined with the reduced cooling water demand from the new combine-cycle units, results in a cooling water intake demand that is 98 percent lower than the current facility; rates of impingement and entrainment will decline by a similar proportion. Use of reclaimed water was considered for MBPP but not analyzed in detail because the available volume cannot serve as a replacement for once-through cooling water.

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.

Cost estimates are based on vendor quotes developed using the available information and the various design constraints identified at MBPP.

3.2 DESIGN BASIS

3.2.1 CONDENSER SPECIFICATIONS

Limited information describing the design specifications of the new combined-cycle units was available. For this study, the wet cooling tower conceptual design selected for MBPP is based on the standard assumptions regarding condenser thermal loads in combined-cycle units and basic information describing the existing condensers. It is noted, however, that the condenser specifications in the new units may be different from the current configuration (i.e., optimized for service with wet cooling towers).

Parameters used in the development of the cooling tower design are summarized in Table I–3.

Table I–3. Condenser Design Specifications

	Unit 1	Unit 2
Thermal load (MMBTU/hr)	1650	1650
Surface area (ft^2)	90,000	90,000
Condenser flow rate (gpm)	165,000	165,000
Tube material	Al Brass	Al Brass
Heat transfer coefficient (BTU/hr•ft^2•°F)	485	485
Cleanliness factor	0.85	0.85
Inlet temperature (°F)	56.5	56.5
Temperature rise (°F)	20.01	20.01
Steam condensate temperature (°F)	91.7	91.7
Turbine exhaust pressure (in. HgA)	1.5	1.5

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

MBPP is located in San Luis Obispo County adjacent to Morro Bay. Surface water temperatures were obtained from the NOAA *Coastal Water Temperature Guide for Morro Bay, 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 coastal San Luis Obispo County indicate a 1 percent ambient wet bulb temperature of 64° F (ASHRAE 2006). An approach temperature of 12° F was selected based on the site configuration and vendor input. At the design wet bulb and approach temperatures, the cooling towers will yield “cold” water at a temperature of 76° F.

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 *NOISE*

Limitations on noise are contained in the city of Morro Bay Noise Element to the General Plan. Noise is limited to 65 dBA in areas where outdoor uses may be affected. The wet cooling towers designed for this study include low noise fans in order to comply with this regulation.

3.2.3.2 *PLUME ABATEMENT*

Local zoning ordinances do not contain any specific criteria for addressing any impact associated with a wet cooling tower plume. Using the selection criteria for this study, plume abatement measures were not considered for MBPP; all towers are a conventional design. The plume from wet cooling towers at MBPP 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. CEC siting guidelines and Coastal Act provisions evaluate the total size and persistence of a visual plume with respect to aesthetic standards for coastal resources; significant visual changes resulting from a persistent plume would likely be subject to additional controls.

Plume abatement towers for MBPP, if necessary, would be a feasible alternative given the relatively small size of the generating units and available land on which to locate them. The principal difference would be an escalation of the total cost (approximately 2 to 3 times the capital cost of conventional towers). The additional height required for plume-abated towers (approximately 15-20 feet) may conflict with height restrictions under local zoning ordinances, but this cannot be precisely determined.

3.2.3.3 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 MBPP, 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 $120,000 for both cooling towers at MBPP (CTI 1994).

3.2.3.4 FACILITY CONFIGURATION AND AREA CONSTRAINTS

The area selected for wet cooling towers is the same as in the 2002 Tetra Tech report and is based on the proposed configuration of the new generating units in the area currently occupied by the fuel tanks. These tanks would be removed for the construction of the new combined-cycle units (Figure I–3). Cooling towers would be located in Area 1.

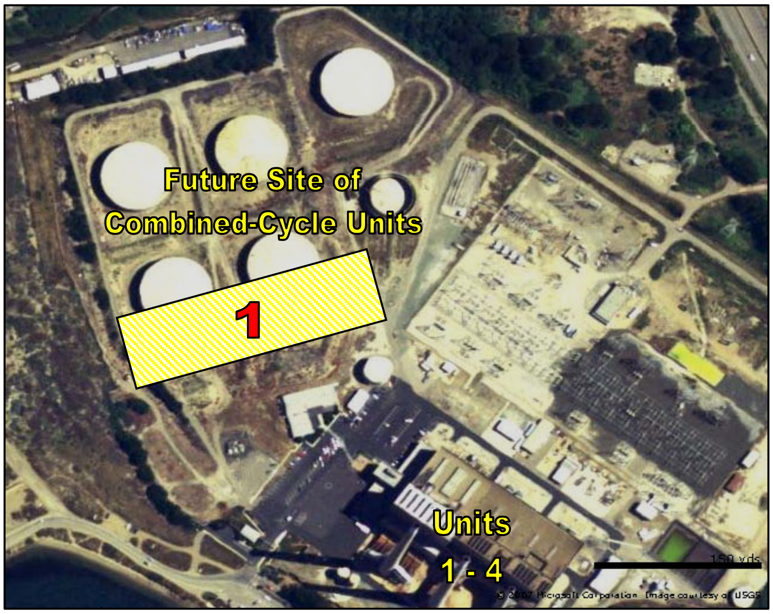

Figure I–3. Cooling Tower Siting Locations

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above, two wet cooling towers were selected to replace the current once-through cooling system that serves Units 1 and 2 at MBPP. Each unit will be served by an independently-functioning tower with separate pump houses and pumps. Both towers at MBPP consist of conventional cells arranged in a multi-cell, 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. The flow rate through each condenser remains unchanged.

General characteristics of the wet cooling towers selected for MBPP are summarized in Table I–4.

Table I–4. Wet Cooling Tower Design

	Tower 1 (Unit 1)	**Tower 2 (Unit 2)**
Thermal load (MMBTU/hr)	3300	3300
Circulating flow (gpm)	330,000	330,000
Number of cells	12	12
Tower type	Mechanical draft	Mechanical draft
Flow orientation	Counterflow	Counterflow
Fill type	Modular splash	Modular splash
Arrangement	Back-to-back	Back-to-back
Primary tower material	FRP	FRP
Tower dimensions (l x w x h) (ft)	324 x 96 x 54	324 x 96 x 54
Tower footprint with basin (l x w) (ft)	328 x 100	328 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 its respective generating unit to minimize the supply and return pipe distances and any increases in pump head and brake horsepower. Tower 1, serving Unit 1, is located at an approximate distance of 550 feet. Tower 2, serving Unit 2, is located at approximate distance of 200 feet. (Figure I–4).

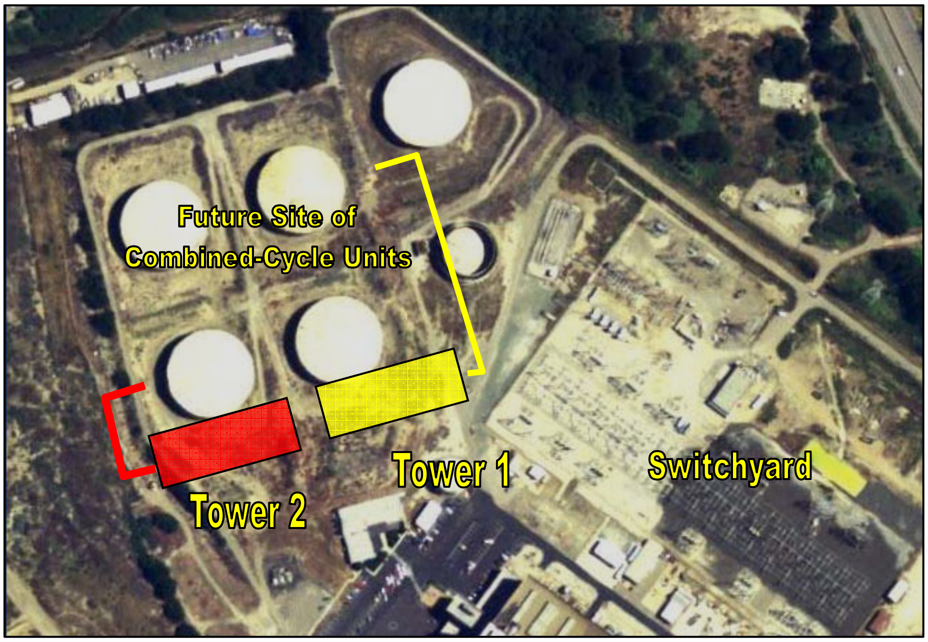

Figure I–4. Cooling Tower Locations

3.3.3 PIPING

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

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

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

3.3.4 FANS AND PUMPS

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

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

Fan and pump characteristics associated with wet cooling towers at MBPP are summarized in Table I–8. The net electrical demand of fans and new pumps is discussed further as part of the energy penalty analysis in Section Table I–5.

Table I–5. Cooling Tower Fans and Pumps

		Tower 1 (Unit 1)	**Tower 2 (Unit 2)**
Fans	Number	12	12
	Type	Single speed	Single speed
	Efficiency	0.95	0.95
	Motor power (hp)	211	211
Pumps	Number	2	2
	Type	50% recirculating Mixed flow Suspended bowl Vertical	50% recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88
	Motor power (hp)	2,273	2,273

3.4 ENVIRONMENTAL EFFECTS

Converting the existing once-through cooling system at MBPP to wet cooling towers will significantly reduce the intake of seawater from Morro Bay and will presumably reduce impingement and entrainment by a similar proportion.

If MBPP 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

MBPP is located in the South Central Coast air basin. Air emissions are permitted by the San Luis Obispo County Air Pollution Control District (SLOCAPCD) (Facility ID 8).

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 MBPP, this corresponds to a rate of approximately 1.6 gpm based on the maximum combined flow both two towers.

Total PM_{10} emissions from the MBPP cooling towers are a function of the number of hours in operation, the overall water quality in the tower, and the evaporation rate of drift droplets prior to deposition on the ground. Makeup water at MBPP will be obtained from the same source currently used for once-through cooling water (Morro Bay). 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 MBPP 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 I–6.

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table I–7 (CARB 2005). In 2005, MBPP operated at an annual capacity utilization rate of 6.1 percent. Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 12 tons/year, or 100 percent. [1]

Table I–6. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower 1	22	95	0.8	413
Tower 2	22	95	0.8	413
Total MBPP PM_{10} and drift emissions	**44**	**190**	**1.60**	**826**

Table I–7. 2005 Emissions of SO_x, NO_x, PM_{10}

Pollutant	Tons/year
NO_x	49.5
SO_x	1.0
PM_{10}	11.8

3.4.2 MAKEUP WATER

The volume of makeup water required by both cooling towers at MBPP 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 Morro Bay by approximately 95 over the current design intake capacity.

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[1] 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 MBPP capacity utilization rate instead of the 2006 rate presented in Table I-1. All other calculations in this chapter use the 2006 value.

Table I–8. Makeup Water Demand

	Tower circulating flow (gpm)	**Evaporation (gpm)**	**Blowdown (gpm)**	**Total makeup water (gpm)**
Tower 1	330,000	2,800	5,400	8,200
Tower 2	330,000	2,800	5,400	8,200
Total MBPP makeup water demand	**660,000**	**5,600**	**10,800**	**16,400**

One circulating water pump, rated at 37,000 gpm, which is currently used to provide once-through cooling water to the facility, will be retained in a wet cooling system to provide makeup water to each cooling tower. The retained pump's capacity exceeds the makeup demand by approximately 21,000 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 I–5 presents a schematic of this configuration.

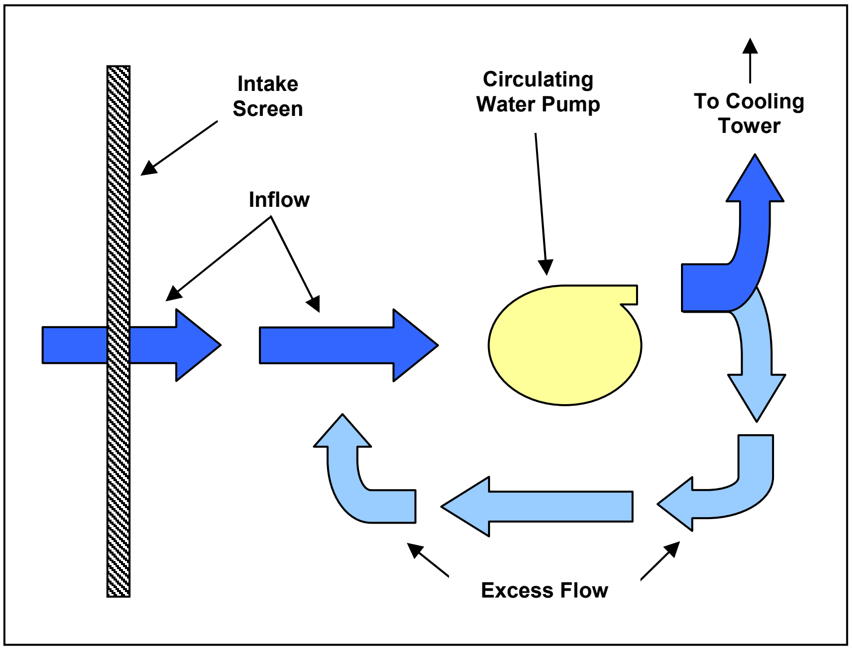

Figure I–5. Schematic of Intake Pump Configuration

The existing once-through cooling system at MBPP does not treat water withdrawn from Morro Bay, 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 the Morro Bay.

The wet cooling tower system proposed for MBPP 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 will not require any pretreatment to enable its use.

3.4.3 NPDES PERMIT COMPLIANCE

At maximum operation, wet cooling towers at MBPP will result in an effluent discharge of 15 mgd of blowdown in addition to other in-plant waste streams—such as boiler blowdown, regeneration wastes, and cleaning wastes. These low volume wastes may add an additional 0.5 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, MBPP will be required to modify its existing individual wastewater discharge (NPDES) permit. All wastewaters are discharged to the Estero Bay through a submerged conduit. The existing Order contains effluent limitations based on the 1997 Ocean Plan and the 1972 Thermal Plan.

MBPP will be required to meet technology-based effluent limitations for cooling tower blowdown established under the Effluent Limitation Guidelines (ELGs) for Steam Electric Facilities at 40 CFR 423.13(d)(1). These ELGs set numeric limitations for chromium (total) and zinc (0.2 mg/L and 1.0 mg/L, respectively) while establishing narrative criteria for priority pollutants (no detectable quantity.

The presence of chromium or zinc in the makeup water source may trigger ELG exceedances when concentrated in the cooling tower and discharged with the final effluent. Effluent limitations for cooling tower blowdown must be met at the point of discharge from the cooling tower prior to combination with any other waste stream. The potential for an exceedance could necessitate treatment of the blowdown for metals prior to discharge.

Assuming the same source water, any reasonable potential associated with wet cooling tower operations would likely increase and may require an effluent treatment system, such as filtration or precipitation technologies, to meet NPDES permit conditions. In the event treatment methods such as filtration or precipitation technologies are required to meet NPDES permit conditions, 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.

Use of reclaimed water as the cooling tower makeup source has the potential to reduce or eliminate conflicts with effluent limitations. During its review of the Morro Bay Power Plant Project in 2004, the California Energy Commission determined that sufficient volumes of reclaimed water were not available in the vicinity of MBPP.

In the event treatment methods such as filtration or precipitation technologies were required to meet NPDES permit conditions, 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.

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for MBPP 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)
- Operations and maintenance (non–energy related cooling tower operations)

4.1 COOLING TOWER INSTALLATION

In general, the cooling tower configuration selected for MBPP conforms to a typical design; no significant variations from a conventional arrangement were needed. Table I–9 summarizes the design-and-build cost estimate for each tower developed by vendors, inclusive of all labor and management required for their installation.

Table I–9. Wet Cooling Tower Design-and-Build Cost Estimate

	Unit 1	Unit 2	MBPP total
Number of cells	12	12	**24**
Cost/cell ($)	566,667	566,667	12
Total MBPP D&B cost ($)	**6,800,000**	**6,800,000**	**13,600,000**

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 MBPP, these costs comprise approximately 50 percent of the initial capital cost. Line item costs are detailed in Appendix A.

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 I–10.

- *Civil, Structural, and Piping*
  The MBPP site configuration allows each tower to be located within relative proximity to the generating unit it services.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect the new pumps (four total) to circulate cooling water between the towers and condensers. No new pumps are required to provide makeup

water from Morro Bay. Electrical costs are based on the battery limit after the main feeder breakers.

- *Demolition*
  No demolition costs are required.

Table I–10. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	MBPP total ($)
Civil/structural/piping	4,500,000	13,500,000	12,000,000	**30,000,000**
Mechanical	6,000,000	0	700,000	**6,700,000**
Electrical	1,300,000	1,700,000	1,600,000	**4,600,000**
Demolition	0	0	0	**0**
Total MBPP other direct costs	**11,800,000**	**15,200,000**	**14,300,000**	**41,300,000**

4.3 INDIRECT AND CONTINGENCY

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

An additional allowance is included for condenser water box and tube sheet reinforcement to withstand the increased pressures associated with a recirculating system. Each condenser may require reinforcement of the tube sheet bracing with 6-inch x 1-inch steel, and water box reinforcement/replacement with 5/8-inch carbon steel. Based on the estimates outlined in Chapter 5, a conservative estimate of 5 percent of all direct costs is included to account for possible condenser modifications.

The contingency cost is calculated as 25 percent of the sum of all direct and indirect costs, including condenser reinforcement. At MBPP, 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. MBPP is situated at sea level adjacent to Morro Bay with wetlands bordering the northern portion of the property. Seawater intrusion or the instability of marshy soils may require additional pilings to support any large structures built at the site. Initial capital costs are summarized in Table I–11.

Table I–11. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	13,600,000
Civil/structural/piping	30,000,000
Mechanical	6,700,000
Electrical	4,600,000
Demolition	0
Indirect cost	13,700,000
Condenser modification	2,700,000
Contingency	17,800,000
Total MBPP capital cost	**89,100,000**

4.4 SHUTDOWN

No shutdown loss is associated with a new construction project.

4.5 OPERATIONS AND MAINTENANCE

Operations and maintenance (O&M) costs for a wet cooling tower system at MBPP include routine maintenance activities; chemicals and treatment systems to control fouling and corrosion in the towers; management and labor; and an allowance for spare parts and replacement. Annual costs are calculated based on the combined tower flow rate using a base cost of $4.00/gpm in Year 1 and $5.80/gpm in Year 12, with an annual escalator of 2 percent (USEPA 2001). Year 12 costs increase based on the assumption that maintenance needs, particularly for spare parts and replacements, will be greater for years 12–20. Annual O&M costs, based on the design circulating water flow for the two cooling towers at MBPP (330,400 gpm), are presented in Table I–12. These costs reflect maximum operation.

Table I–12. Annual O&M Costs (Full Load)

	Year 1 cost ($)	Year 12 cost ($)
Management/labor	330,000	478,500
Service/parts	528,000	765,600
Fouling	462,000	669,900
Total MBPP O&M cost	**1,320,000**	**1,914,000**

4.6 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at MBPP 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 MBPP 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 I–11.)
- *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 MBPP (with combined cycle units) will have a higher capacity utilization factor than it currently has, O&M costs for the NPC calculation were estimated at 60 percent of their maximum value. (See Table I–12.)

Using these values, the NPC_{20} for MBPP is $104 million. Appendix B contains detailed annual calculations used to develop this cost.

4.7 ANNUAL COST

The annual cost incurred by MBPP for a wet cooling tower retrofit is the sum of annual amortized capital costs plus the annual average of O&M expenditures. Capital costs are amortized at a 7 percent discount rate over 20 years. O&M 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 I–13.

Table I–13. Annual Cost

Discount rate	Capital Cost ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00%	8,400,000	1,000,000	0	**9,400,000**

4.8 COST-TO-GROSS REVENUE COMPARISON

Revenue cannot be estimated for the new combined-cycle facility. No comparison is made as part of this study.

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

5.1 MODIFIED RISTROPH SCREENS—FINE MESH

The principal concern with this technology is the successful return of viable organisms captured on the screens to the source water body. MBPP currently withdraws its cooling water from Morro Bay. Returning any collected organisms to the harbor is feasible, but the circulating patterns in the bay would have to be characterized to understand how they might affect reimpingement of eggs and larvae. Successful deployment of this technology might be feasible with a better understanding of the biological conditions in Morro Bay and a detailed evaluation of a proposed return system.

5.2 BARRIER NETS

Placement of a barrier net at the entrance to Morro Bay or in front of the intake structures is not possible due to the likely conflicts with other uses of the marina. Barrier nets are ineffective as an entrainment reduction technology, however, and are not evaluated further in this study.

5.3 AQUATIC FILTRATION BARRIERS

The 2002 Tetra Tech report evaluated the feasibility of aquatic filtration barriers (AFBs) at Morro Bay, but concluded that performance data for the technology were insufficient to make a conclusive determination. The lack of available space within Morro Bay would appear to preclude the use of AFBs at MBPP.

5.4 VARIABLE SPEED DRIVES

Variable speed drives (VSDs) were not considered for analysis at MBPP because the technology alone cannot be expected to achieve the desired level of reductions in impingement and entrainment, nor could it be combined with another technology to yield the desired reductions. Pumps that have been retrofitted with VSDs can reduce overall flow intake volumes by 10 to 50 percent over the current once-through configuration (USEPA 2001). The actual reduction, however, will vary based on the cooling water demand at different times of the year. At peak demand, the pumps will essentially function as standard circulating water pumps and withdraw water at the maximum rated capacity, thus negating any potential benefit. Use of VSDs may be an economically desirable option when pumps are retrofitted or replaced for other reasons, but they were not considered further for this study.

5.5 CYLINDRICAL FINE MESH WEDGEWIRE

Fine-mesh cylindrical wedgewire screens have not been deployed or evaluated at open coastal facilities for applications as large as would be required at MBPP (approximately 250 mgd). To function as intended, cylindrical wedgewire screens must be submerged in a water body with a consistent ambient current of 0.5 feet per second (fps). Ideally, this current would be unidirectional so that screens may be oriented properly, and any debris impinged on the screens will be carried downstream when the airburst cleaning system is activated.

Fine-mesh wedgewire screens for MBPP would be located offshore in Estero Bay, west of the facility. No data are available describing the currents in this area. Thus, no determination can be made as to the potential effectiveness of cylindrical wedgewire screens at MBPP.

6.0 REFERENCES

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

		Unit 1			Unit 2		
		Once through	**Closed cycle**	**Net increase**	**Once through**	**Closed cycle**	**Net increase**
JAN	Backpressure (in. HgA)	1.49	2.41	**0.92**	1.49	2.41	**0.92**
	Heat rate Δ (%)	*-0.03*	*3.38*	***3.41***	*-0.03*	*3.38*	***3.41***
FEB	Backpressure (in. HgA)	1.53	2.43	**0.90**	1.53	2.43	**0.90**
	Heat rate Δ (%)	*0.08*	*3.42*	***3.34***	*0.08*	*3.42*	***3.34***
MAR	Backpressure (in. HgA)	1.49	2.46	**0.97**	1.49	2.46	**0.97**
	Heat rate Δ (%)	*-0.03*	*3.55*	***3.58***	*-0.03*	*3.55*	***3.58***
APR	Backpressure (in. HgA)	1.46	2.47	**1.02**	1.46	2.47	**1.02**
	Heat rate Δ (%)	*-0.13*	*3.59*	***3.72***	*-0.13*	*3.59*	***3.72***
MAY	Backpressure (in. HgA)	1.49	2.54	**1.05**	1.49	2.54	**1.05**
	Heat rate Δ (%)	*-0.03*	*3.83*	***3.86***	*-0.03*	*3.83*	***3.86***
JUN	Backpressure (in. HgA)	1.55	2.58	**1.04**	1.55	2.58	**1.04**
	Heat rate Δ (%)	*0.14*	*3.97*	***3.83***	*0.14*	*3.97*	***3.83***
JUL	Backpressure (in. HgA)	1.63	2.61	**0.99**	1.63	2.61	**0.99**
	Heat rate Δ (%)	*0.39*	*4.06*	***3.67***	*0.39*	*4.06*	***3.67***
AUG	Backpressure (in. HgA)	1.69	2.65	**0.97**	1.69	2.65	**0.97**
	Heat rate Δ (%)	*0.59*	*4.20*	***3.61***	*0.59*	*4.20*	***3.61***
SEP	Backpressure (in. HgA)	1.69	2.63	**0.94**	1.69	2.63	**0.94**
	Heat rate Δ (%)	*0.59*	*4.12*	***3.53***	*0.59*	*4.12*	***3.53***
OCT	Backpressure (in. HgA)	1.65	2.58	**0.93**	1.65	2.58	**0.93**
	Heat rate Δ (%)	*0.45*	*3.95*	***3.50***	*0.45*	*3.95*	***3.50***
NOV	Backpressure (in. HgA)	1.57	2.54	**0.97**	1.57	2.54	**0.97**
	Heat rate Δ (%)	*0.19*	*3.83*	***3.63***	*0.19*	*3.83*	***3.63***
DEC	Backpressure (in. HgA)	1.49	2.49	**1.00**	1.49	2.49	**1.00**
	Heat rate Δ (%)	*-0.03*	*3.65*	***3.68***	*-0.03*	*3.65*	***3.68***

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 800 ft) and cable racks	t	80	--	--	2,500	200,000	17.00	105	142,800	**342,800**
Allocation for sheet piling and dewatering	lot	1	--	--	500,000	500,000	5,000.00	100	500,000	**1,000,000**
Allocation for testing pipes	lot	1	--	--	--	--	2,000.00	95	190,000	**190,000**
Allocation for Tie-Ins to condenser's piping	lot	1	--	--	250,000	250,000	2,000.00	106	212,000	**462,000**
Allocation for trust blocks	lot	1	--	--	50,000	50,000	500.00	95	47,500	**97,500**
Backfill for PCCP pipe (reusing excavated material)	m3	4,752	--	--	--	--	0.04	200	38,016	**38,016**
Bedding for PCCP pipe	m3	1,345	--	--	25	33,625	0.04	200	10,760	**44,385**
Bend for PCCP pipe 24" diam (allocation)	ea	14	--	--	3,000	42,000	20.00	95	26,600	**68,600**
Bend for PCCP pipe 30" & 36" diam (allocation)	ea	14	--	--	5,000	70,000	25.00	95	33,250	**103,250**
Bend for PCCP pipe 72" diam (allocation)	ea	16	--	--	18,000	288,000	40.00	95	60,800	**348,800**
Building architectural (siding, roofing, doors, painting…etc)	ea	2	--	--	250,000	500,000	3,000.00	75	450,000	**950,000**
Butterfly valves 24" c/w allocation for actuator & air lines	ea	4	28,000	112,000	--	--	50.00	106	21,200	**133,200**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	28	30,800	862,400	--	--	50.00	106	148,400	**1,010,800**
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 96" c/w allocation for actuator & air lines	ea	10	151,200	1,512,000	--	--	75.00	106	79,500	**1,591,500**
Check valves 24"	ea	4	40,000	160,000	--	--	12.00	106	5,088	**165,088**
Check valves 30"	ea	4	44,000	176,000	--	--	16.00	106	6,784	**182,784**
Check valves 72"	ea	4	138,000	552,000	--	--	32.00	106	13,568	**565,568**
Concrete basin walls (all in)	m3	372	--	--	225	83,700	8.00	75	223,200	**306,900**
Concrete elevated slabs (all in)	m3	646	--	--	250	161,500	10.00	75	484,500	**646,000**
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	2,932	--	--	200	586,400	4.00	75	879,600	**1,466,000**
Ductile iron cement pipe 12" diam. for fire water line	ft	1,400	--	--	100	140,000	0.60	95	79,800	**219,800**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Excavation and backfill for fire line & make-up (using excavated material for backfill except for bedding)	m3	9,870	--	--	--	--	0.08	200	157,920	**157,920**
Excavation for PCCP pipe	m3	7,126	--	--	--	--	0.04	200	57,008	**57,008**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	**5,250**
Flange for PCCP joints 24"	ea	2	--	--	1,725	3,450	14.00	95	2,660	**6,110**
Flange for PCCP joints 30"	ea	26	--	--	2,260	58,760	16.00	95	39,520	**98,280**
Flange for PCCP joints 72"	ea	8	--	--	9,860	78,880	25.00	95	19,000	**97,880**
Flange for PCCP joints 96"	ea	8	--	--	15,080	120,640	35.00	95	26,600	**147,240**
Foundations for pipe racks and cable racks	m3	190	--	--	250	47,500	8.00	75	114,000	**161,500**
FRP flange 30"	ea	108	--	--	1,679	181,348	50.00	106	572,400	**753,748**
FRP flange 72"	ea	24	--	--	20,888	501,304	200.00	106	508,800	**1,010,104**
FRP flange 96"	ea	12	--	--	40,000	480,000	500.00	106	636,000	**1,116,000**
FRP pipe 72" diam.	ft	240	--	--	851	204,336	1.20	106	30,528	**234,864**
FRP pipe 96" diam.	ft	1,600	--	--	2,838	4,540,800	1.75	106	296,800	**4,837,600**
Harness clamp 24" c/w external testable joint	ea	80	--	--	1,715	137,200	14.00	95	106,400	**243,600**
Harness clamp 30" & 36"c/w internal testable joint	ea	80	--	--	2,000	160,000	16.00	95	121,600	**281,600**
Harness clamp 72" c/w internal testable joint	ea	90	--	--	2,440	219,600	18.00	95	153,900	**373,500**
Joint for FRP pipe 72" diam.	ea	12	--	--	3,122	37,462	200.00	106	254,400	**291,862**
Joint for FRP pipe 96" diam.	ea	50	--	--	17,974	898,700	600.00	106	3,180,000	**4,078,700**
PCCP pipe 24" dia. For blowdown line	ft	1,400	--	--	98	137,200	0.50	95	66,500	**203,700**
PCCP pipe 30" dia. for make-up	ft	1,400	--	--	125	175,000	0.70	95	93,100	**268,100**
PCCP pipe 72" diam.	ft	1,600	--	--	507	811,200	1.30	95	197,600	**1,008,800**
Riser (FRP pipe 30" diam X 55 ft)	ea	24	--	--	15,350	368,400	150.00	106	381,600	**750,000**
Structural steel for building	t	320	--	--	2,500	800,000	20.00	105	672,000	**1,472,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**4,533,600**	**--**	**13,418,505**	**--**	**--**	**12,014,852**	**29,966,957**
ELECTRICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
4.16 kv cabling feeding MCC's	m	1,000	--	--	75	75,000	0.40	106	42,400	**117,400**
4.16kV switchgear - 4 breakers	ea	1	250,000	250,000	--	--	150.00	106	15,900	**265,900**
460 volt cabling feeding MCC's	m	500	--	--	70	35,000	0.40	106	21,200	**56,200**
480V Switchgear - 1 breaker 3000A	ea	4	30,000	120,000	--	--	80.00	106	33,920	**153,920**
Allocation for automation and control	lot	1	--	--	500,000	500,000	5,000.00	106	530,000	**1,030,000**
Allocation for cable trays	m	800	--	--	75	60,000	1.00	106	84,800	**144,800**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Allocation for lighting and lightning protection	lot	1	--	--	150,000	150,000	1,500.00	106	159,000	**309,000**
Dry Transformer 2MVA xxkV-480V	ea	4	100,000	400,000	--	--	100.00	106	42,400	**442,400**
Lighting & electrical services for pump house building	ea	2	--	--	50,000	100,000	500.00	106	106,000	**206,000**
Local feeder for 200 HP motor 460 V (up to MCC)	ea	24	--	--	18,000	432,000	150.00	106	381,600	**813,600**
Local feeder for 2500 HP motor 4160 V (up to MCC)	ea	4	--	--	45,000	180,000	175.00	106	74,200	**254,200**
Oil Transformer 10/13.33MVA xx-4.16kV	ea	2	190,000	380,000	--	--	150.00	106	31,800	**411,800**
Primary breaker(xxkV)	ea	4	45,000	180,000	--	--	60.00	106	25,440	**205,440**
Primary feed cabling (assumed 13.8 kv)	m	1,000	--	--	175	175,000	0.50	106	53,000	**228,000**
ELECTRICAL TOTAL	**--**	**--**	**--**	**1,330,000**	**--**	**1,707,000**	**--**	**--**	**1,601,660**	**4,638,660**
MECHANICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Allocation for ventilation of buildings	ea	2	100,000	200,000	--	--	1,000.00	106	212,000	**412,000**
Cooling towers for the two combined cycle units	lot	2	6,800,000	13,600,000	--	--	--	--	--	**13,600,000**
Overhead crane 50 ton in (in pump house) Including additional structure to reduce the span	ea	2	500,000	1,000,000	--	--	1,000.00	106	212,000	**1,212,000**
Pump 4160 V 2500 HP	lot	4	1,200,000	4,800,000	--	--	580.00	106	245,920	**5,045,920**
MECHANICAL	**--**	**--**	**--**	**19,600,000**	**--**	**0**	**--**	**--**	**669,920**	**20,269,920**

Appendix C. Net Present Cost Calculation

Project year	Capital / start-up ($)	O&M ($)	Total ($)	Annual discount factor	Present value ($)
0	94,012,500	--	94,012,500	1	**94,012,500**
1	--	792,000	792,000	0.9346	**740,203**
2	--	807,840	807,840	0.8734	**705,567**
3	--	823,997	823,997	0.8163	**672,629**
4	--	840,477	840,477	0.7629	**641,200**
5	--	857,286	857,286	0.713	**611,245**
6	--	874,432	874,432	0.6663	**582,634**
7	--	891,921	891,921	0.6227	**555,399**
8	--	909,759	909,759	0.582	**529,480**
9	--	927,954	927,954	0.5439	**504,714**
10	--	946,513	946,513	0.5083	**481,113**
11	--	965,444	965,444	0.4751	**458,682**
12	--	1,171,368	1,171,368	0.444	**520,087**
13	--	1,194,795	1,194,795	0.415	**495,840**
14	--	1,218,691	1,218,691	0.3878	**472,608**
15	--	1,243,065	1,243,065	0.3624	**450,487**
16	--	1,267,926	1,267,926	0.3387	**429,447**
17	--	1,293,285	1,293,285	0.3166	**409,454**
18	--	1,319,151	1,319,151	0.2959	**390,337**
19	--	1,345,534	1,345,534	0.2765	**372,040**
20	--	1,372,444	1,372,444	0.2584	**354,640**
Total					**104,390,306**