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MIDWEST GENERATION EME, LLC
CHICAGO AREA WATERWAYS AND LOWER DES PLAINES RIVER
GENERATING UNITS

COOLING TOWER COST STUDY

REPORT NO. SL-009359

Date: February 1, 2011

S&L Project No. 10683-130

Sargent & Lundy LLC

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TABLE OF CONTENTS

PAGE

EXHIBITS

1. EXECUTIVE SUMMARY

Proposed rules by the Illinois Environmental Protection Agency ("Illinois EPA" or "Agency") seek to change the use designation for the Upper Illinois Waterway ("UIW") from the existing "secondary contact and indigenous aquatic life" use (the "Proposed UAA Rules"). The Proposed UAA Rules include more stringent thermal water quality standards ("Proposed UAA Thermal Standards") for the UIW. Five electrical generating stations owned and operated by Midwest Generation EME, LLC ("MWGen") are located along and discharge to those portions of the UIW known as the South Branch of the Chicago River, Chicago Sanitary and Ship Canal ("CSSC") and the Upper Dresden Island Pool ("UDIP") of the Lower Des Plaines River. These stations are Fisk, Crawford, Will County and Joliet (2 stations) generating stations. Joliet 6 is located on the south side of the Des Plaines River, while Joliet 7&8 is located on the north side of the Des Plaines River. Will County Units 1&2 were retired effective December 31, 2010. Therefore, these two units were not included in this study. The MWGen generating stations operate based on a once-through, open-cycle circulating water system design. None of the MWGen generating stations are capable of achieving and consistently maintaining compliance with the proposed thermal standards at existing operating levels.

MWGen requested that Sargent & Lundy (S&L) evaluate the various technologies that are available for cooling the Fisk, Crawford, Will County and Joliet units. S&L has been designing power plants since its beginning in 1891. The original Fisk unit was designed by S&L in the early 1900's. Since that time, S&L has designed many power plants that incorporate different types of cooling tower designs.

This report addresses the potential cost and operational impacts associated with revised limits on thermal discharges from the subject MWGen generating stations. This particular study expands and updates earlier work prepared in 2005, that presented proposed cost estimates and other information developed by S&L for the installation of thermal control technology at the MWGen stations. In 2008, after this rule-making was initiated, S&L began work to review and update its prior 2005 study. The proposed thermal control technology evaluated consisted of multi-cell cooling towers designed for closed-cycle operation, with provisions to permit operation in open-cycle mode when conditions allow. The incremental capital costs for the provisions to permit open-cycle mode constitute a small percentage of the overall project cost. Those incremental costs are discussed further in Section 5.

At the time of the 2005 S&L study, it was not known what new thermal standards the Illinois EPA would propose for the UIW. Accordingly, in the absence of any suggested thermal standards on which to base the study, the 2005 S&L study used the existing Illinois General Use thermal standards as the design basis for evaluating the control options and associated costs for achieving compliance. In the 2005 study, the estimated capital costs for wet towers ranged from about $59,500,000 for Joliet 6 to about $170,000,000 for Joliet 7/8, and the costs for wet/dry (plume abated) towers ranged from about $84,500,000 for Joliet 6 to about $257,000,000 for Joliet 7/8. Annual Operation and Maintenance (O&M) costs were also estimated in the 2005 study. O&M costs are, to a great extent, proportional to a plant's electrical output, so it is to be expected that O&M costs for the largest plant, Joliet 7/8 at 1,138 MW, would be considerably higher than O&M costs for Fisk at 348 MW. The 2005 estimated O&M costs for wet/dry towers ranged from about $1,400,000 for Fisk to about $7,000,000 for Joliet 7/8.

In this study, the Proposed UAA Thermal Standards are used as the design basis for determining the feasibility of add-on thermal control technology and the associated costs of compliance for each of the MWGen stations. As part of the design basis, the proposed cooling systems were designed with the goal of allowing the stations to run at full capacity under the most demanding conditions. Under the Proposed UAA Thermal Standards, it is generally expected that the most demanding thermal conditions will occur during the hot summer months. However, because the Proposed UAA Thermal Standards include stringent seasonal thermal criteria throughout the year, the design also needed to address the need to operate without capacity restrictions during the cooler times of the year. The following information was developed in this study for cooling towers at Fisk, Crawford, Joliet and Will County:

- Evaluation of capability for meeting the proposed thermal standards;
- Review of regulatory and permitting issues and risks;
- Order-of-magnitude (-30%/+50%) capital and O&M cost estimates; and
- Review of schedule requirements and layout feasibility.

Several alternative types of closed loop cooling technologies were evaluated as part of this study, including radiator type towers (external water required), air cooled condensers (new condenser is located external to the turbine room), and hyperbolic natural draft cooling towers. These options have either not been proven on such large scale installations or are considerably more expensive than the conventional wet cooling tower design.

The advantage of the closed-cycle wet cooling tower approach is that it virtually eliminates thermal discharges to the adjacent river. There is still a small discharge that is required to control the water chemistry of the tower (referred to as "cooling tower blowdown"), but this is a fraction of a percent of the total open loop cooling compared to the current open-cycle operation of these stations. If a mixing zone is granted for discharging cooling tower blowdown, it is assumed that the cooling tower blowdown will meet the Proposed UAA Thermal Standards at the edge of the mixing zone. However, S&L recognizes that, if the ambient temperature of the river is above the Proposed UAA Thermal Standards, an allowed mixing zone may not be applicable under the existing mixing zone regulation in 35 IAC § 302.102. Accordingly, it is currently not known whether and to what extent each of the MWGen stations would be granted an allowed mixing zone. In any event, the estimated costs of the proposed cooling towers and associated circulating water system modifications discussed in this report are not significantly affected. If the stations' cooling tower blowdown discharge is not subject to an allowed mixing zone, the temperature of the cooling tower blowdown discharge must comply with the Proposed UAA Thermal Standards at the point of discharge to the river. In the absence of an allowed mixing zone, an additional cooling mechanism (likely a chiller totaling approximately $3 million per station) may be required to guarantee compliance at each of the MWGen stations under all operating and receiving water scenarios. However, for purposes of this report, we have not included any supplemental cooling of the cooling tower blowdown discharge for any of the stations in the study cost estimates.

Three different design scenarios were evaluated for the Joliet and Will County Stations. These are wet towers (which yield a visible, fog-like discharge plume), wet/dry towers (plume-abated towers), and wet towers with provisions to convert to wet/dry operation. The cooling tower design for Fisk and Crawford was based solely on the wet/dry (plume-abated) design, in order to prevent icing on the nearby interstate highway, high voltage power lines, and in nearby commercial and residential areas. The estimated compliance capital costs for all of the stations covered by this study range from $93,400,000 at Joliet 6 to $223,800,000 at Joliet 7/8 for wet towers to between $115,700,000 at Joliet 6 and $300,900,000 at Joliet 7/8 for the wet/dry options. Annual Operation and Maintenance (O&M) costs for wet/dry towers ranged from $2,127,000 at Fisk to $9,080,000 at Joliet 7/8.

The estimated capital costs for the various designs considered are summarized in Table ES-1. Table ES-1 also provides the capital cost per kilowatt for the wet/dry tower designs for each of the five MWGen stations, which ranges from $264/kW to $394/kW, with an average cost across all five stations of $301/kW. Annual O&M costs, based on 75 percent capacity factors, are summarized in Table ES-2. Table ES-3 summarizes the portion of each station's gross capacity which is lost due to the cooling tower systems' auxiliary power demand.

Table ES-1

Cost Summary of All Wet/Dry, Wet/Dry Convertible, and Wet Non-Convertible Towers

Unit	Station Total Gross MW	Capital Cost Wet/Dry Tower ($)	Capital Cost Wet Convertible to Wet/Dry ($)	Capital Cost Wet Only ($)	Wet/Dry Capital Cost ($ per kW)
Fisk 19	348	$137,100,000	N/A	N/A	$394
Crawford 7&8	585	$165,200,000	N/A	N/A	$282
Will County 3&4	832	$257,100,000	$230,200,000	$210,700,000	$309
Joliet 6	341	$115,700,000	$103,600,000	$93,400,000	$339
Joliet 7&8	1,138	$300,900,000	$257,900,000	$223,800,000	$264
Totals	**3,244**	**$976,000,000**	-	-	**$301 (average)**

Table ES-2
Estimated Annual Operating and Maintenance Costs

Unit	Station Total Gross MW	Wet/Dry Towers	Wet or Wet Convertible Towers
Fisk 19	348	$2,127,000	N/A
Crawford 7&8	585	$3,960,000	N/A
Will County 3&4	832	$5,750,000	$5,710,000
Joliet 6	341	$2,660,000	$2,350,000
Joliet 7&8	1,138	$9,080,000	$8,280,000
Totals	**3,244**	**$23,577,000**	N/A

Auxiliary power use increases for the cooling tower operation. Each cooling tower cell is provided with a fan, and additional pumps are required to move cooling water through the closed cooling loop. The power demands of the fans and additional pumps contribute to the additional auxiliary power requirements. The auxiliary power requirements for the MWGen plants are shown in Table ES-3.

Table ES-3
Cooling Tower Auxiliary Power Use (Annual-Average MW)

	Fisk 348 MW	Crawford 585 MW	Will County 3&4 832 MW	Joliet 6 341 MW	Joliet 7&8 1,138 MW
Cooling Tower Fan Power	3.24	6.08	9.32	4.28	16.20
Supply Pump Power	3.89	6.48	9.72	4.78	17.01
Discharge Pump Power	0.65	0.97	0.81	0.81	1.94
Average Aux Power Use	**7.78**	**13.53**	**19.85**	**9.87**	**35.15**
Percentage of MW Output	**2.2**	**2.3**	**2.4**	**2.9**	**3.1**

From the data in Table ES-3, it can be seen that the cooling tower systems consume between 2.2 percent and 3.1 percent of the stations' gross output, which represents lost generating capacity for each affected station. The economic effects of station generating capacity loss are discussed in Section 5.

The costs presented above are based on the preliminary design criteria prepared by S&L for this report. For each of the MWGen stations, cooling tower design is based on a 7°F approach temperature and a 1% wet bulb occurrence. These numbers drive the performance and cost of the tower. Smaller approach temperatures require larger and more expensive towers to accommodate a given cooling water flow requirement. But, smaller (or lower) approach temperatures also increase the likelihood that the unit can remain running at its full rated load under all operating conditions. Conversely, higher approach temperatures would reduce the size of the tower required but would increase the risk that the unit would need to be operated at much less than its rated load on hot days when the demand for power is typically at its greatest. A higher approach temperature would also increase the temperature of the cooling tower blowdown, increasing the risk of not meeting the applicable temperature limits, especially if these apply at the end-of-pipe. The potential capital cost savings realized for designing to a 12°F approach temperature, instead of the 7°F approach temperature selected for this study, would be approximately 20 percent. Even with this potential cost savings, the overall cost of the cooling tower installation still represents a substantial capital expense. The use of a 7°F approach temperature yields the lowest practical cooling tower blowdown temperature, and thus minimizes the overall thermal impact on the river. Please refer to Section 2.C.2 for a more detailed discussion of cooling tower design and function.

There are several concerns associated with the proposed cooling tower installations. The feasibility of siting cooling towers poses significant constructability difficulties at many of the MWGen stations. "Constructability" is an industry term used to indicate both the economic feasibility and the ease with which equipment can actually be installed. Installation of cooling towers at Fisk, Crawford, and Will County stations will require relocation of ComEd high voltage lines to prevent ice buildup caused by the cooling towers' operation and potentially catastrophic snapping of these power lines during the winter months. Based on S&L's past professional experience, the estimated capital costs include an allowance for transmission line relocation where applicable, but there was no study performed to define the scope of this necessary modification. This study also assumes that if requested, ComEd would agree to and allow the relocation of the high voltage lines. If relocation of the ComEd high voltage lines is not possible, the towers would pose a safety concern at Fisk, Crawford, and Will County which may prevent their installation unless another alternative approach to their installation can be identified.

Many of the MWGen stations have very limited available space for locating new cooling towers. The limited availability of space can affect the towers' performance. These tight arrangements promote interference (when the hot air discharge of one tower enters the intake of a nearby tower, leading to poor performance). Another negative impact of the tight tower arrangement is recirculation (when the hot air discharge of a tower enters its own intake, leading to poor performance) when winds are blowing in an unfavorable direction.

Noise emissions from the cooling towers are expected to be below the regulatory limits for all of the units except for Joliet 7&8 due to the proximity of an existing office building west of the proposed Joliet 7&8 cooling tower location. The cost of noise abatement was not included in the Joliet 7&8 capital cost estimates.

Particulate emissions from the cooling tower are estimated to be greater than the 25 ton/year threshold for New Source Review (NSR) for overall particulate matter for the Joliet 7&8 and Will County 3&4 cooling towers. These emission levels would trigger requirements for Best Available Control Technology (BACT); however, drift eliminators (included in the design) meet the BACT standards.

Particulate emissions with an aerodynamic diameter less than 10 microns (PM_{10}) are estimated to fall below the NSR PM_{10} threshold of 15 tons/year at all stations except Joliet 7&8, based on use of published ratios of PM_{10}:PM emissions that have been accepted by the Illinois EPA in the past. Using this method, Joliet 7&8 have predicted combined PM_{10} emissions of approximately 15.06 tons/year, which is slightly above the threshold. Will County 3&4 have predicted combined emissions of approximately 10 tons/year, based on a conservative 100% capacity factor and 100% closed-cycle operation. If a methodology different from the ratio method is used to calculate PM_{10} emissions, the 15 tons/year threshold possibly could be exceeded at Will County, depending on the final calculation methods and assumptions. Fisk, Crawford and Joliet 6 should not have issues related to PM_{10} emissions.

Lastly, S&L estimates that a single tower installation will require a minimum of 29 months to complete after additional studies are completed and critical design criteria are finalized. This schedule is based on a single tower installation; the overall duration for a multiple station cooling tower installation will be longer. From a design standpoint, much of the required effort will be largely repetitive. For example, once a cooling tower specification is prepared for one station, it will take considerably less time to prepare a comparable specification for another station. However, it is likely that MWGen's ability to pursue multiple cooling tower projects in parallel will be limited by the time required to fabricate and deliver the cooling tower material and equipment and/or by the time required to construct the tower and other structures.

At present, there are few utility-size cooling tower projects underway nationally, and the construction labor market is favorable. With such conditions, assuming funding can be acquired when needed, one might be able to execute projects at Fisk and Crawford in parallel, and to start projects at the next stations in sequence with a 12- to 15-month lag. Assuming such "best case" scenario circumstances, after the time required to complete the final design criteria, the time required to implement closed-cycle cooling at the five MWGen stations is estimated to be a minimum of 60 months. However, as the economy improves, lead times will lengthen and construction labor will become less available. Therefore, it is not possible to predict accurately the overall time required to design, fabricate and install cooling towers at five power stations. Again, assuming that funding can be obtained when needed, for planning purposes, S&L recommends that at least 72 months should be allowed for that process.

The extent of transmission line relocation was not examined in any detail during this study. The time required to obtain permission for line relocation and to actually relocate the lines has not been considered in the schedule discussion above.

2. APPROACH AND SCOPE OF COOLING TOWER STUDY

This section addresses:

- The Proposed UAA Thermal Standards which will force installation of closed-cycle cooling at Crawford, Fisk, Joliet 6, Joliet 7/8 and Will County 3/4;
- A discussion of cooling tower design and performance considerations; and
- A description of the scope of this cooling tower cost study report.

A. PROPOSED UAA THERMAL WATER QUALITY STANDARDS

In October 2007, the Agency filed the Proposed UAA Rules with the Illinois Pollution Control Board. If adopted, the Proposed UAA Rules would reclassify the subject waters into which each of the MwGen stations discharge from their current "secondary contact" use designation and impose more stringent thermal standards for the associated waterways. The Proposed UAA Rules include thermal standards that are stricter than the existing General Use standards.

Table 2-1 below lists the Proposed UAA Thermal Standards, which would apply on a period average basis with a daily maximum limit. Under the Proposed UAA Rules, the CAWS Aquatic Life Use B ("ALU B") standards would apply to Fisk, Crawford, and Will County, while the Upper Dresden Island Pool ("UDIP") standards would apply to Joliet. The Proposed UAA Thermal Standards may be applied at the edge of an approved mixing zone pursuant to the requirements of 35 Ill. Adm. Code §302.102. However, a final determination of whether any mixing zone will be allowed, and, if so, how large, is not currently known because it would be determined by the Agency in future NPDES permitting if any revised thermal water quality standards are ultimately adopted. For the purpose of this study, it is assumed that the small (~650 to ~3000 gpm) cooling tower blowdown flows generated by a closed-cycle cooling system either will comply with the Proposed UAA Thermal Standards or will not contribute to any significant water temperature rise within the receiving stream, thus making any need for a mixing zone limited to a very small area of the receiving stream. However, based on existing receiving stream data, it is expected that there may be times when no mixing is available due to low river flow and/or ambient river temperatures which are higher than the Proposed UAA Thermal Standards. In the absence of an allowed mixing zone, an additional cooling mechanism (likely a chiller at a total approximate cost of $3 million per station) may be required to ensure compliance at each of the MWGen stations under all operating and receiving water scenarios. However, for purposes of this report, we have not included any supplemental cooling of the blowdown discharge for any of the stations in the study cost estimates.

Table 2-1
Proposed IEPA Water Temperature Limits

Month	October 2007 Final IEPA Average CAW Aquatic Life Use B Temp Limit	October 2007 Final IEPA Maximum CAW Aquatic Life Use B Temp Limit	October 2007 Final IEPA Average Upper Dresden Island Pool Temp Limit	October 2007 Final IEPA Maximum Upper Dresden Island Pool Temp Limit
Jan 1-31	54.3	90.3	54.3	88.7
Feb 1-29	53.6	90.3	53.6	88.7
Mar 1-15	57.2	90.3	57.2	88.7
Mar 16-31	57.2	90.3	57.2	88.7
Apr 1-15	60.8	90.3	60.8	88.7
Apr 16-30	62.1	90.3	62.1	88.7
May 1-15	69.2	90.3	69.2	88.7
May 16-31	71.4	90.3	71.4	88.7
Jun 1-15	74.2	90.3	74.2	88.7
Jun 16-30	86.7	90.3	85.1	88.7
Jul 1-15	86.7	90.3	85.1	88.7
Jul 16-31	86.7	90.3	85.1	88.7
Aug 1-15	86.7	90.3	85.1	88.7
Aug 16-31	86.7	90.3	85.1	88.7
Sep 1-15	86.7	90.3	85.1	88.7
Sep 16-30	77	90.3	77	88.7
Oct 1-15	73.2	90.3	73.2	88.7
Oct 16-31	69.6	90.3	69.6	88.7
Nov 1-30	66.2	90.3	66.2	88.7
Dec 1-31	59.9	90.3	59.9	88.7

The MWGen stations that are impacted by the Proposed UAA Rules are Fisk, Crawford, Will County and the two Joliet stations. Thermal discharges from the MWGen stations in their current once-through, open-cycle design do not meet the Proposed UAA Thermal Standards either for the CAWS Aquatic Life Use B or the UDIP. Based on the Proposed UAA Thermal Standards, as summarized in Table 2-1 above, it was determined that closed-cycle cooling tower control technology would be the most effective means of complying with the Proposed UAA Thermal Standards while maintaining the capability to operate at the design electrical output of each unit.

B. COOLING TOWER DESIGN AND PERFORMANCE

1) Cooling Tower Function and Physical Characteristics

Cooling towers are used to transfer the heat from the power plant circulating water into the atmosphere. Steam from the turbine-generator exhaust is cooled and condensed to water in one side of a large heat exchanger, called the condenser, and is pumped back (recycled) to the boiler. The other side of the condenser is cooled by the circulating water system, and the circulating water gains heat as it passes through the condenser. The circulating water is sprayed into the top of the cooling tower, where it comes into contact with air from the atmosphere which flows upward through the tower. Some of the warm circulating water is evaporated and absorbed by the cooler air. This evaporation of a portion of the circulating water is the primary mechanism for heat transfer between the water and the air. The air cools the circulating water so it can be pumped back to the condenser and the cycle is repeated. "Fill" is used to break up falling water droplets in the tower and promote interaction between the water and the ambient air.

Cooling towers of a type called "mechanical draft" were evaluated for installation at the MWGen stations. A mechanical-draft tower is typically 40 to 60 feet tall and anywhere from 40 to several hundred feet long, depending on the volume of circulating water flow the tower is designed to process. A cooling tower is actually comprised of several semi-independent modules referred to as "cells". Each cell consists of 1) a structural steel or fiberglass frame, 2) walls (to confine the air and water flow), 3) piping near the top of the framework to distribute the water evenly, 4) material called "fill" (installed within the tower framework) to improve heat transfer between the water flowing down and the air flowing up, 5) a large-diameter fan to pull air upward through the tower, and 6) an exhaust stack to help direct warm air upward and away from the sides of the tower. A group of cells is typically linked end-to-end to form a single cooling tower assembly. The group of cells is constructed inside a concrete basin which collects the cool water. The pumps which return the cool water to the condenser are installed on one end of the basin.

The number of individual cells in the cooling towers evaluated for this study ranged from a low of 16 at Fisk Station to a high of 64 at Joliet 7/8. The cooling tower equipment arrangement drawings presented in Exhibit A show that it was necessary to break the total number of cells required into two or more groups owing to space limitations at the stations.

2) Cooling Tower Performance Considerations

Sizing of wet and plume-abated (wet/dry) cooling towers depends primarily on two key parameters: wet bulb temperature, which is determined by weather conditions, and approach temperature, a value which is selected by the cooling system designer.

The amount of humidity in the atmosphere air determines the wet bulb temperature, which, in turn influences the effectiveness of cooling tower in removing heat from the circulating water. Higher humidity levels result in higher wet bulb temperatures, and lower humidity levels result in lower wet bulb temperatures. In general, the lower the wet bulb temperature, the lower the cold water temperature – the temperature of the circulating cooling water after it has passed through the cooling tower. Thus cooling towers are more effective on cool, dry days and less effective on warm, humid days.

Wet bulb temperature changes continually (hour to hour and day to day) as weather changes. Therefore, tower design for cooling performance and the ability to meet thermal discharge limits involves consideration of meteorology probabilities. A conservative approach that accounts for reasonably expected weather conditions was used in this study to ensure that the tower design will remove the heat from the generating station even during the most hot and humid days. The cooling towers were designed based on the "Summer

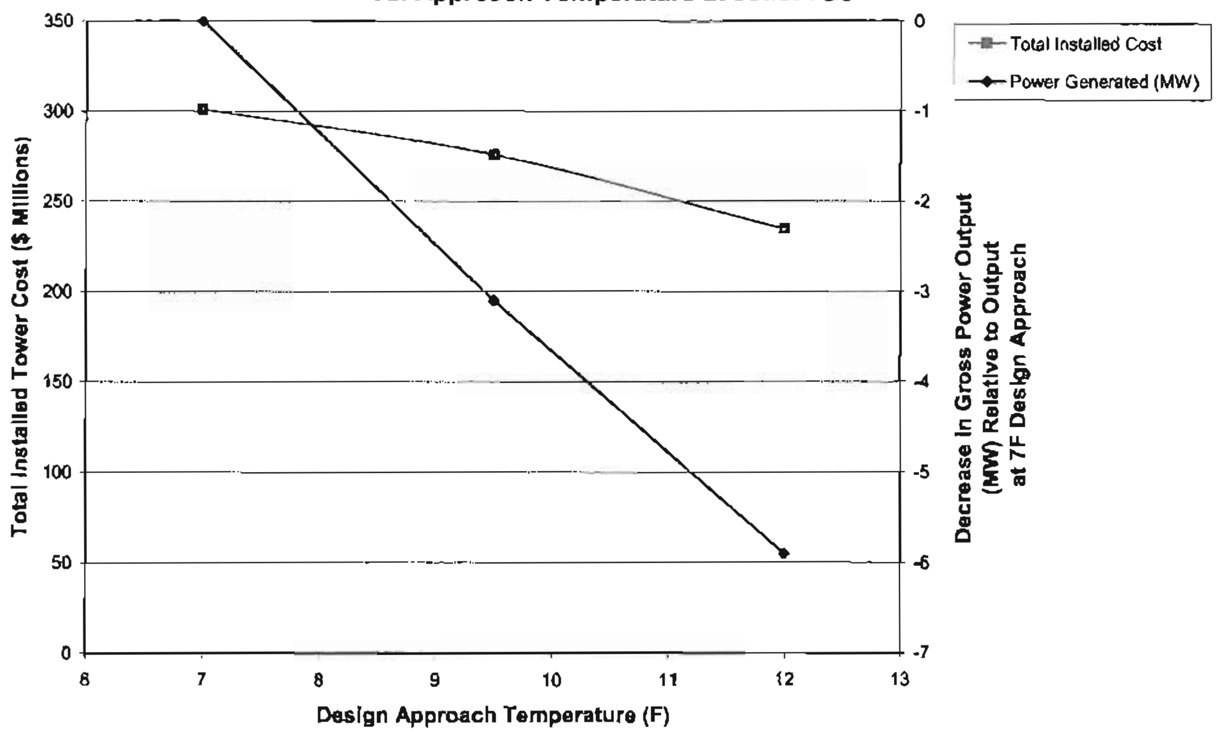
1%" wet bulb temperature which means that the historical wet bulb temperatures exceed this value only 1% of the time during the hottest months. Historical wet bulb data was obtained from a U.S. Air Force publication. (See paragraph 3.a.6 below for a complete reference to this publication.)

A second important parameter that defines the design of a cooling tower is "approach temperature." The approach temperature is defined as how close the water being cooled approaches the wet bulb temperature. Design for a lower approach temperature results in a larger tower, which is usually effected by increasing the number of cells in the tower. A larger tower will provide greater contact time between the circulating water and the airflow, which increases heat removal and lowers cold water temperature. A larger tower is more expensive for a given circulating water flow rate, but it will increase the likelihood that the generating station can remain running at full load during the most hot and humid days.

Figure 2-1 illustrates the capital costs for the Joliet 7&8 towers as a function of approach temperature. This same general relationship among cooling tower approach temperature, cooling tower cost, and auxiliary power demand is typical of the towers evaluated for the other generating stations considered in this study. Cooling tower cost decreases with higher approach temperatures although the cost is still in the order of hundreds of millions of dollars. With this decrease in cost, however, comes an increased risk that the unit will generate less electrical power during a time when demand is high and the cost for purchased power also is almost always relatively high. To minimize the risk that the cooling towers chosen would necessitate unit deratings to maintain compliance at the MWGen stations at times when demand for electricity is high, an approach temperature of 7°F was used as the basis for this study.

An additional benefit of designing the towers with a 7°F approach is that it minimizes the temperature of the cooling tower blowdown flow to the relevant waterway. Decreasing the tower size and cost by selecting a larger approach temperature such as 9°F or 12°F would increase the temperature of the cooling tower blowdown flow. An approach temperature increase of even 2-3 degrees would likely lead to an end-of-pipe cooling tower blowdown flow temperature that is warmer than the Proposed UAA Thermal Standards maximum value during the summer months.

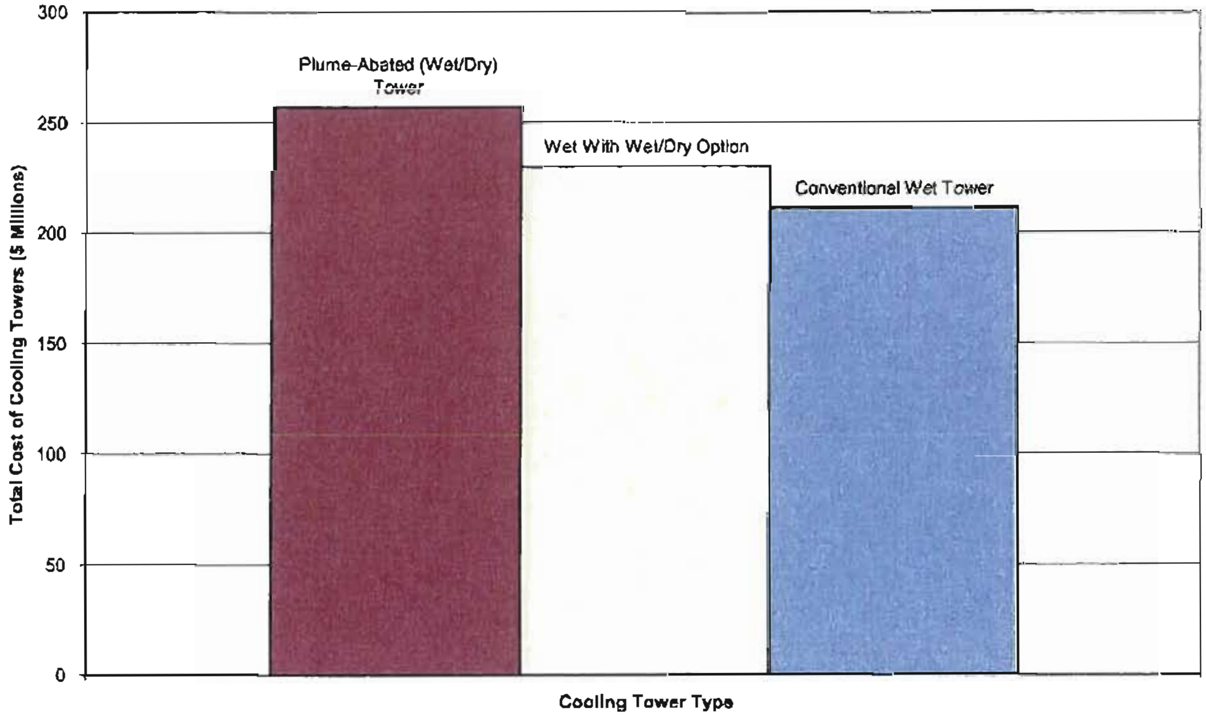
Figure 2-1
Total Installed Cost of Wet/Dry Cooling Towers and Power Generation Impact Vs. Approach Temperature at Joliet 7&8



A final design consideration is the treatment of the fog-like plume that normally rises from cooling towers. Towers with visible water vapor plumes are available at lower cost but can cause potential visibility problems and icing problems in freezing weather. Visibility and icing problems can create safety hazards on nearby streets and highways and for those who use them. Icing problems are particularly hazardous to power lines located in the vicinity of an electrical generating station because the icing can cause power lines to fail and interrupt power service to customers. Wet/dry or "plume-abated" towers minimize the risk of visibility and icing problems. Wet/dry towers have a dry reheating section above the wet section, which further warms the warm, moist air leaving the wet section of the tower. Such wet/dry towers make the plume essentially invisible and decreases the potential for visibility and icing problems. Hence, the reason they are called "plume-abated" towers. Plume-abated towers are designed so that the visible plume extends no farther than one tower height. It should be noted that there is still some icing concern with wet/dry towers, though the icing risk is lower than that associated with pure wet towers.

If it is uncertain whether plume abatement will ultimately be required for a given generating station, a wet-type tower can be designed with features which allow later conversion to plume-abated or wet/dry operation. The principal features required are design of the cooling tower basin and structural supports for the higher weight of the plume-abatement heat exchangers that are added to convert the tower to wet/dry operation. Although a wet-type tower that is not originally designed for conversion to plume abatement could subsequently be converted, the costs of doing so would be much higher than if provision for subsequent conversion were made in the original design. Figure 2-2 illustrates the relative costs of all three tower types based on the costs for Will County Station Units 3/4. As shown in more detail in Section 5, the cost relationship among the three types of towers at Will County is also typical for Joliet 6 and Joliet 7/8.

Figure 2-2
Installed Capital Cost of Will County Cooling Towers for
Three Different Types



Wet/dry towers were selected as the base design for Crawford and Fisk, owing to those stations' proximity to a nearby interstate highway, electric transmission lines, and commercial and residential areas. Wet-type towers are believed to be acceptable for Joliet 6, Joliet 7/8 and Will County 3/4, but installed costs for all three types are provided in Section 5.

All of the MWGen stations were designed for and operate as open-cycle cooling stations. Cooling tower costs for retrofit applications to convert from open-cycle to closed-cycle cooling, such as is the case here for the MWGen stations, are generally higher than those for a tower provided at a generating unit initially designed for closed-cycle operation – estimated to be approximately 10 to 20 percent higher. Units designed for once-through (open-cycle) cooling typically have a smaller condenser than units originally designed for closed-cycle operation. A retrofit tower will typically be made larger to compensate for the smaller condenser. Increasing the size of the condenser during retrofit is a potential design option, but the costs of condenser modifications are higher than the incremental costs of larger cooling towers.

The cost estimates provided here for all wet/dry cooling tower options are based on cooling tower quotes obtained from SPX/Marley, a cooling tower supplier, in response to a brief specification and sizing table provided by S&L. Low-clog film fill was selected by SPX/Marley as suitable for the MWGen applications, based on the Total Suspended Solids levels in the make-up water. Make-up water quality data is presented in Exhibit F.

Exhibit C contains preliminary design specifications for the cooling tower designs. This design basis information was provided to SPX/Marley by S&L to use as the basis for its estimates of cooling tower costs.

3) Alternative Cooling Tower Technologies

The following alternative cooling technologies were also considered at the start of the study, but were eliminated from further consideration for the reasons stated below:

- Radiator-type towers (with no water cooling): Eliminated because these towers have never been applied to units of the size or approach temperature applicable here and they would require a prohibitive amount of land that is not available at the MWGen stations.
- Air-cooled condensers: Eliminated because existing unit condensers at the MWGen stations would have to be replaced and low-pressure steam would need to be ducted to the new air-cooled condenser (ACC). This option would not likely be technically feasible due to large amount of land area required for such installations, and the difficulty routing the very large duct required from the turbine exhaust to the ACC inlet. An ACC would increase turbine backpressure, which would further reduce the station's generating capacity, and it also would be prohibitively expensive.
- Hyperbolic natural draft cooling towers: Eliminated due to the extremely high cost (4 to 8 times the cost of a conventional wet tower), concerns about a) interference with the glide paths for nearby airports, b) the land area required, and c) overall permitting owing to negative public perception of the aesthetics of such tall structures.

C. COOLING TOWER COST STUDY SCOPE

The scope of this study is as follows:

- Obtain capital and O&M costs in current dollars for cooling towers sized for closed-cycle operation under summer conditions. The cooling tower equipment arrangement drawings and closed-cooling cycle diagrams that form the basis of the cost estimating criteria are provided in Exhibits A and B, respectively. Major equipment was sized based on maximum boiler heat input, maximum exhaust flows, and original condenser and circulating water design conditions.

- Develop "order-of-magnitude" (-30%/+50%) cost estimates for the following scenarios in this study:
  - Wet cooling tower with plume abatement (wet/dry tower) for all five stations.
  - Wet cooling towers for Joliet (both stations) and Will County Stations without the option to add plume abatement.
  - Wet cooling towers for Joliet (both stations) and Will County Stations without plume abatement but designed with additional structure to allow addition of plume abatement at a later date.

  Budgetary cost estimates from SPX/Marley, a prominent power plant cooling tower supplier, were solicited to obtain current costs for all cooling tower options. S&L calculated balance-of-plant costs using previous plant designs and our in-house cost database.
- Estimate O&M costs, including auxiliary power for tower fans and additional circulating water pump head requirements, plus chemical costs and tower maintenance.
- Compare estimated cooling tower blowdown temperatures and volumes to proposed thermal standards to determine whether further temperature dispersion study is required.
- Estimate particulate emissions due to cooling tower "drift", and determine whether these emissions could trigger additional air permit or compliance requirements.
- Perform a qualitative assessment of possible tower noise emissions and any regulatory or ordinance requirements that may require measures for noise mitigation.
- Evaluate the impact of cooling tower addition on plant thermal cycle. The ability of a cooling tower to produce cold water is limited by the outdoor wet bulb temperature. Generally, the cooler the return water to the condenser, the higher the efficiency of the turbine generator, and the more electricity which is generated. In addition, lower return water temperatures result in lower condenser discharge temperatures.
- Determine preliminary permitting requirements for installation of cooling towers.
- Prepare a preliminary construction schedule based on typical cooling tower installation duration.

3. CONCEPTUAL DESIGN BASIS FOR CLOSED LOOP COOLING TOWER STUDY

In order to design the cooling towers required at each of the MWGen stations, the current unit rating (in gross MW), which represents the current generating capacity of each station, was used. Major equipment was sized based on maximum boiler heat input, maximum exhaust flows, and original condenser and circulating water design conditions. Preliminary design specifications were developed for the towers needed at each station.

The following paragraphs describe the parameters common to all units at the MWGen stations which set the design of the cooling towers for this study. Design bases for individual units at each of the stations are provided in Exhibit D.

A. DESIGN ELEMENTS COMMON TO ALL UNITS

The following design bases were applied to cooling tower cost estimates and layouts for all of the electrical generating units located at each of the MWGen stations:

1) Cost estimates are "order-of-magnitude" accuracy, -30%/+50%.

2) The cooling systems for all stations were sized for closed-cycle operation at summer conditions. Cost estimates include towers sized to handle 100% of heat rejection duty. To maintain the flexibility to operate in open-cycle mode, when river temperature and meteorological conditions permit, gates were included in the estimates. As discussed in Section 5 below, the incremental increase in capital cost for these open-cycle provisions of the design are a small percentage of overall project cost. As noted above, when this study was originally prepared in 2005, the design considerations were based on General Use thermal standards. Under the General Use thermal water quality standards, the probability of being able to operate in open-cycle mode during parts of the year is greater than under the stricter Proposed UAA Rules. Hence, the design basis of the 2005 study included the capability to switch between open-cycle and closed-cycle cooling operation. Given the incremental increase in capital cost associated with including open-cycle capability in the design is a small percentage of overall estimated costs, for the purposes of updating the study, it was decided to retain this open-cycle capability in the design basis.

3) Estimates of O&M costs, particulate emissions, and cooling tower blowdown discharge are based on continuous closed-cycle operation, for conservatism and because it is not known to what extent open-cycle operation will be compliant with applicable thermal standards.

4) Cost estimates for plume-abated (wet/dry) towers were developed for all stations. Consideration of wet only and wet/convertible to plume-abated was given to Joliet 6, Joliet 7/8 and Will County 3/4.

The following is a comparison of plume-abated (wet/dry) tower characteristics compared to conventional wet towers:

- Wet/dry towers use 7-13% less total makeup water than wet towers
- Extent of drift/level of particulate matter emissions will be the same for wet/dry and wet towers operations
- Icing still occurs with wet/dry towers, but will be less than with wet towers, due to the increased saturation temperature of the air. Moisture will still condense on cold surfaces, however.
- Visible plume will be negligible for wet/dry towers at the design point. A small amount of visible plume occurs at lower temperatures and/or at high relative humidity conditions.
- The wet/dry tower uses approximately 10-25% more electrical power than a wet tower.
- Noise emissions are similar for both types of towers.

5) The cooling tower site arrangement drawings (provided in Exhibit A) are based on the wet/dry tower layouts. SPX/Marley was consulted to determine the cooling tower arrangements that are technically feasible based on the type of cooling tower to be installed. SPX/Marley advised that back-to-back cooling towers are not available for wet/dry cooling tower types due to the need for the dry section to receive air from both sides. Therefore, the design for all of the wet/dry cooling towers consists of a single row of cells. Pure wet towers were not considered as the base design due to all of the previously mentioned reasons, including creation of poor visibility near the stations, icing of roads, and icing of overhead power lines. Cost estimates for both wet-only and wet/convertible to plume-abated were developed, however, and are provided in Section 5.

6) The cooling towers at all of the stations were designed for a summer season wet bulb temperature of 78°F. This is the 1% summer season wet bulb temperature for all of the stations.[1] This is a conservative approach used to avoid derating the units during the summer months when the demand for power is highest.

7) The cooling towers at all of the stations were designed for an 85°F cold water temperature, which is a reasonable choice based on the 1% summer wet bulb temperature in the Chicago area, and the choice of a 7°F approach temperature. This is a conservative approach selected to minimize the potential for unit derating (reduction in generating capacity) on hot, humid days.

[1] Departments of the Air Force (USAF), the Army, and the Navy, "Facility Design and Planning Engineering Weather Data", AFM 88-29, TM 5-785, NAVFAC P-89, Washington D.C., 1978.

8) All of the cooling towers were designed for a minimum achievable drift rate of 0.0005% (*i.e.*, with drift eliminators). This minimizes the water particulate emissions of the towers. Exhibit E contains the results of the particulate calculations. Exhibit F contains the water quality data input used.

9) Under closed-cycle operation, each station was assumed to operate at five cycles of concentration. The phrase "five cycles of concentration" means the cooling water is recirculated until the total dissolved solids (TDS) level reaches a value five times the TDS concentration in the make-up water. Further build-up is limited by cooling tower blowdown. A value of five cycles is most often chosen for design purposes because it minimizes the need for make-up water and limits TDS concentrations to levels which do not create corrosion problems for cooling system materials.

10) All of the towers are priced with fiberglass construction. Fire protection costs have not been incorporated into the cooling tower estimates but could increase the cost of the towers substantially dependent upon the requirements of the agency having jurisdiction and the extent to which they require installation of fire protection equipment.

11) Single speed non-reversing motors were assumed for all of the cooling towers.

12) Chlorination, sulfuric acid addition, and dechlorination equipment were included in the system design and cost estimates for closed-cycle operation at all of the stations.

13) From its professional experience, S&L estimates the annual water treatment chemical cost to be $1,000/MW for a station with closed-cycle cooling towers. This cost is based on the gross load of the station unit(s) in all cases, and is based on Sargent & Lundy's 120 years of power plant design experience.

14) Cooling tower blowdown from the closed-cycle mode of operation was assumed to be by a bleed stream from the cooling tower water supply pumps. No separate cooling tower blowdown pumps were included in the design or cost estimate, though a small (up to 12" diameter) pipe was included. The cooling tower blowdown, evaporation, and makeup water data are contained in Exhibit G.

15) The following methodology was used to estimate the potential impact on turbine MW output (*i.e.*, capacity loss) resulting from operation in a closed cooling configuration:

- The cold water temperatures of the towers corresponding to the 1% wet bulb during each month of the year were used as condenser circulating water input values. These cold water temperatures, which are identical to the cooling tower blowdown temperatures, are based on cooling tower industry (*i.e.*, Cooling Tower Institute) data.
- Condenser backpressures at 70% assumed cleanliness were estimated, and the percent heat rate adjustment was read from the original heat rate adjustment vs. backpressure curves at valves wide open flow.

- The variations in generator output between the design output value and the output during closed loop cooling operation at the maximum wet bulb temperature were calculated ("closed-cycle gain/loss"). Then the variations in generator output between the design output value and the output during open-cycle cooling operation with the Proposed UAA Thermal Standards Period Average temperature as the condenser circulating water inlet temperature were calculated ("open-cycle gain/loss"). The difference between the closed-cycle gain/loss and the open-cycle gain/loss is the MW output gain or loss for each time period during the year. Note that the Period Average values are tabulated on a partial month basis where so specified in the Proposed UAA Thermal Standards, while the closed-cycle 1% wet bulb values derive from the monthly ASHRAE[2] values. A separate partial month wet bulb distribution was not developed for this current study.

16) Isolating the stations' intake and discharge channels from the river typically involves a combination of fixed walls and moveable gates. Where the term "gate" alone is used in this report, the installation may also involve some fixed walls at that location. The actual configurations used in the design are documented in the capital cost estimates for each station that are presented in Exhibit I. It was assumed that the existing circulating water inlet channel would be partially left open to the river in closed-cycle operation so that makeup water to the cycle can be drawn in as needed. No separate makeup pumps or piping were included in the design or cost estimate.

17) No special noise abatement equipment was included in the base cost estimates. SPX/Marley indicates that the predicted noise level is about 90 dBA at 3 meters from the tower. Rough noise abatement options and costs were provided by SPX/Marley, but the predicted noise reduction is not guaranteed without a full noise study. A simple comparison of noise levels (inverse square method) was performed (see Section 4 of this report) by locating approximate distances of nearest residential and industrial/ commercial sites, using satellite photographs and the survey drawing for each site.

18) All electrical power costs are based on a price of electricity of $36.71/MWh, which is based on the weighted average price of peak and off-peak pricing over a five-year period beginning in 2011 as calculated by MWGen.

B. STATION OR UNIT-SPECIFIC ASSUMPTIONS

The design and layout of the cooling tower system must be customized at each station due to differences in plant size and layouts. The unit specific design inputs for cooling tower design provided to SPX/Marley are presented in Exhibit C. Exhibit D contains the detailed balance-of-project design inputs used for each station.

[2] American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), "The Handbook 2005 of Fundamentals", published by ASHRAE, Atlanta, Georgia, 2005.

4. REGULATORY AND PERMITTING ISSUES

The construction and operation of cooling towers at the five MWGen stations will be subject to a number of environmental and local construction permitting requirements. The S&L study included determining the expected permit requirements for the proposed closed-cycle cooling systems, which are presented in the discussion below, but further detailed review is recommended if any of the projects are slated to proceed. Regulatory and permitting standards potentially applicable to a cooling tower installation project include: (1) air permitting for particulate matter emissions; (2) modifications to the facility's National Pollutant Discharge Elimination System (NPDES) permit for changes associated with cooling water intake and wastewater treatment and discharge characteristics; (3) U.S. Army Corps of Engineer permits to allow construction activities within a waterway or activities that impact wetlands; (4) local building permit requirements; and (5) noise emission regulations. Due to the conceptual nature of the design basis included in this study, a cost estimate for preparing and obtaining the necessary permits for construction and operation of the closed-cycle cooling systems for each of the MWGen stations was beyond the scope of this study. Accordingly, costs associated with obtaining permits have not been included in the capital cost estimates presented in this report.

A. AIR PERMITTING

Particulate matter emissions occur from cooling towers as a result of cooling water being entrained in the air stream. Particulate matter in the drift water sent into the air by the tower is primarily composed of the same impurities as in the tower cooling water.[3] The magnitude of the drift loss is influenced by the number and size of droplets produced within the tower, which are a function of tower design, air and water flow patterns, and design of the drift eliminators. The most effective way to reduce drift from cooling towers is by installing drift eliminators. Drift eliminators, included in the design basis for all towers in this study, are designed to remove entrained droplets before the droplets leave the tower.

Particulate emissions from a new cooling tower can trigger the need for New Source Review (NSR) air quality review and permitting. NSR is a federal regulatory program (implemented in Illinois by the Illinois EPA) that applies to major new sources of air pollution and major modifications of existing major sources of air pollution. An existing major source of emissions (such as the Crawford, Fisk, Joliet, and Will County Generating Stations) can become subject to NSR if modifications are made to the existing source, and the modification results in a significant increase in the annual emissions of a regulated NSR pollutant.

Regulated NSR pollutants include total particulate matter (PM), PM with an aerodynamic diameter less than 10 microns (μm) or less (PM_{10}), and PM with an aerodynamic diameter of 2.5 μm or less ($PM_{2.5}$). With respect to particulate matter emissions, a significant emissions increase is defined as being above 25 tons per year (tpy) PM, 15 tpy PM_{10}, or 10 tpy PM2.5. (See 35 IAC §203.209).

[3] Cooling Tower Drift, it Measurement, Control and Environmental Effect. Cooling Tower Institute Paper No: TP73-01

Emission calculations were prepared for each MWGen cooling tower configuration to quantify potential particulate emissions. Total PM emissions were estimated based on: (1) the circulating water flow rate at full load; (2) projected drift eliminator efficiency; (3) total dissolved solids (TDS) in the circulating water; and (4) the assumption that 100% of the TDS in the drift would be emitted as PM, using the following equation:[4]

$$E_{PM} = Q * \rho_w * (60 \text{ min/hr}) * \%DL * (TDS/10^6)$$

Where:

E_{PM} = PM emission rate (lb/hr)
Q = circulating water flow rate (gpm)
ρ_w = density of water (8.34 lb/gal)
%DL = Drift Loss Efficiency (0.0005%)
TDS = Total Dissolved Solids in the liquid drift (ppmw)

The methodology given in EPA's AP-42 Chapter 13.4 calculates total PM emissions, but does not account for particle size distribution. Therefore, to determine PM10 and PM2.5 emissions, S&L used the methodology described by Reisman and Frisbie to calculate the particle size distribution of solids emitted after evaporation of the liquid drift.[5] Particle size is determined based on representative drift droplet size distribution data, TDS in the drift droplets, and the assumption that the total mass of dissolved solids in the drift condenses into a spherical particle after all the water evaporates. The percentage of drift droplets containing particles small enough to produce PM10 or PM2.5 emissions can be calculated using the following equation:

$$D_p = D_d\,[(TDS)(\rho_w / \rho_{TDS})]^{1/3}$$

Where:

D_p = diameter of the solid particle (μm)
D_d = diameter of the drift droplet (μm)
ρ_w = density of water (1.0 g/cm^3)
ρ_{TDS} = density of the solid particles (assumed to be equal to sodium chloride, 2.2 g/cm^3)
TDS = Total Dissolved Solids in the liquid drift (ppmw)

Using this approach, drift from cooling towers with higher TDS values tend to form larger solid particles as the liquid drift evaporates. In other words, PM10-to-PM and PM2.5-to-PM ratios are inversely related to circulating water TDS, as shown in Figure 4-1.

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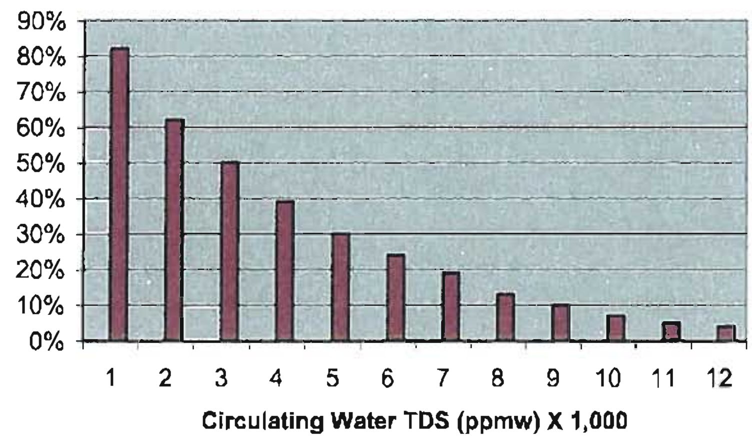
[4] The methodology described herein for calculating cooling tower particulate emissions is taken from EPA's *Compilation of Air Pollutant Emission Factors*, AP-42 Fifth Edition, Volume I: Stationary Point and Area Sources, Chapter 13.4 Wet Cooling Towers, available at: http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s04.pdf.

[5] Reisman, J., and Frisbie, G., *Calculating Realistic PM10 Emissions from Cooling Towers*, Greystone Environmental Consultants, Inc., Sacramento, CA. See also, Hennon, D., *Cooling Tower Emissions Quantification Using the Cooling Technology Institute Test Code ATC-140*, Cooling Tower Institute, Paper No. TP03-08.

FIGURE 4-1
Percentage of Drift PM That Evaporates to PM10



Taken from: Reisman, J., and Frisbie, G., "Calculating Realistic PM10 Emissions from Cooling Towers," Greystone Environmental Consultants, Inc., Sacramento, CA.

Particle size distribution was calculated for each MWGen generating station using the methodology described above and the circulating water TDS values summarized in Table 4-1. Cooling water TDS values were obtained from water quality data collected by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC).[6] Results of the particle size distribution calculations for three different maximum TDS concentrations (*i.e.*, 3,680 ppmw, 4,220 ppmw and 2,935 ppmw) are shown in Tables 4-2 through 4-4, respectively.

[6] Cooling water TDS values were obtained from the 2007 Annual Summary Report Water Quality within the Waterways System of the Metropolitan Water Reclamation District of Greater Chicago, September 2008.

Table 4-1
Generating Station TDS Values

CASE	Makeup Water TDS	Cycles of Concentration	Maximum TDS
	(ppm)	#	(ppm)
Fisk 19	736	5	3,680
Crawford 7&8	736	5	3,680
Will County 3&4	844	5	4,220
Joliet 6	587	5	2,935
Joliet 7&8	587	5	2,935

Table 4-2
Solid Particle Size Distribution (TDS = 3,680 ppmw)

TDS	3,680					
Liquid Droplet Diameter	**Liquid Droplet Volume**	**EPRI Droplet Size Distribution**	**Liquid Droplet Mass**	**Solid Particle Mass**	**Solid Particle Volume**	**Particle Size Diameter**
um	um^3	% smaller	ug	ug	um^3	um
10	524	0.000	5.24E-04	1.93E-06	0.9	1.187
20	4,189	0.196	4.19E-03	1.54E-05	7.0	2.374
30	14,137	0.226	1.41E-02	5.20E-05	23.7	3.561
40	33,510	0.514	3.35E-02	1.23E-04	56.1	4.748
50	65,450	1.816	6.55E-02	2.41E-04	109.5	5.935
60	113,097	5.702	1.13E-01	4.16E-04	189.2	7.122
70	179,594	21.348	1.80E-01	6.61E-04	300.4	8.309
90	381,704	49.812	3.82E-01	1.40E-03	638.5	10.684
110	696,910	70.509	6.97E-01	2.56E-03	1,165.7	13.058
130	1,150,347	82.023	1.15E+00	4.23E-03	1,924.2	15.432
150	1,767,146	88.012	1.77E+00	6.50E-03	2,956.0	17.806
180	3,053,628	91.032	3.05E+00	1.12E-02	5,107.9	21.367
210	4,849,048	92.468	4.85E+00	1.78E-02	8,111.1	24.928
240	7,238,229	94.091	7.24E+00	2.66E-02	12,107.6	28.490
270	10,305,995	94.689	1.03E+01	3.79E-02	17,239.1	32.051
300	14,137,167	96.288	1.41E+01	5.20E-02	23,647.6	35.612
350	22,449,298	97.011	2.24E+01	8.26E-02	37,551.6	41.547
400	33,510,322	98.340	3.35E+01	1.23E-01	56,053.6	47.483
450	47,712,938	99.071	4.77E+01	1.76E-01	79,810.7	53.418
500	65,449,847	99.071	6.54E+01	2.41E-01	109,479.7	59.353
600	113,097,336	100.0	1.13E+02	4.16E-01	189,181.0	71.224

Table 4-3
Solid Particle Size Distribution (TDS = 4,220 ppmw)

TDS	4,220					
Liquid Droplet Diameter	**Liquid Droplet Volume**	**EPRI Droplet Size Distribution**	**Liquid Droplet Mass**	**Solid Particle Mass**	**Solid Particle Volume**	**Particle Size Diameter**
um	**um^3**	**% smaller**	**ug**	**ug**	**um^3**	**um**
10	524	0.000	5.24E-04	2.21E-06	1.0	1.243
20	4,189	0.196	4.19E-03	1.77E-05	8.0	2.485
30	14,137	0.226	1.41E-02	5.97E-05	27.1	3.728
40	33,510	0.514	3.35E-02	1.41E-04	64.3	4.970
50	65,450	1.816	6.55E-02	2.76E-04	125.6	6.213
60	113,097	5.702	1.13E-01	4.77E-04	216.9	7.455
70	179,594	21.348	1.80E-01	7.58E-04	344.5	8.698
90	381,704	49.812	3.82E-01	1.61E-03	732.2	11.183
110	696,910	70.509	6.97E-01	2.94E-03	1,336.8	13.668
130	1,150,347	82.023	1.15E+00	4.85E-03	2,206.6	16.153
150	1,767,146	88.012	1.77E+00	7.46E-03	3,389.7	18.638
180	3,053,628	91.032	3.05E+00	1.29E-02	5,857.4	22.365
210	4,849,048	92.468	4.85E+00	2.05E-02	9,301.4	26.093
240	7,238,229	94.091	7.24E+00	3.05E-02	13,884.2	29.820
270	10,305,995	94.689	1.03E+01	4.35E-02	19,768.8	33.548
300	14,137,167	96.288	1.41E+01	5.97E-02	27,117.7	37.275
350	22,449,298	97.011	2.24E+01	9.47E-02	43,061.8	43.488
400	33,510,322	98.340	3.35E+01	1.41E-01	64,278.9	49.700
450	47,712,938	99.071	4.77E+01	2.01E-01	91,522.1	55.913
500	65,449,847	99.071	6.54E+01	2.76E-01	125,544.7	62.125
600	113,097,336	100.0	1.13E+02	4.77E-01	216,941.3	74.550

Table 4-4
Solid Particle Size Distribution (TDS = 2,935 ppmw)

TDS	2,935					
Liquid Droplet Diameter	**Liquid Droplet Volume**	**EPRI Droplet Size Distribution**	**Liquid Droplet Mass**	**Solid Particle Mass**	**Solid Particle Volume**	**Particle Size Diameter**
um	**um^3**	**% smaller**	**ug**	**ug**	**um^3**	**um**
10	524	0.000	5.24E-04	1.54E-06	0.7	1.101
20	4,189	0.196	4.19E-03	1.23E-05	5.6	2.202
30	14,137	0.226	1.41E-02	4.15E-05	18.9	3.303
40	33,510	0.514	3.35E-02	9.84E-05	44.7	4.403
50	65,450	1.816	6.55E-02	1.92E-04	87.3	5.504
60	113,097	5.702	1.13E-01	3.32E-04	150.9	6.605
70	179,594	21.348	1.80E-01	5.27E-04	239.6	7.706
90	381,704	49.812	3.82E-01	1.12E-03	509.2	9.908
110	696,910	70.509	6.97E-01	2.05E-03	929.7	12.109
130	1,150,347	82.023	1.15E+00	3.38E-03	1,534.7	14.311
150	1,767,146	88.012	1.77E+00	5.19E-03	2,357.5	16.513
180	3,053,628	91.032	3.05E+00	8.96E-03	4,073.8	19.815
210	4,849,048	92.468	4.85E+00	1.42E-02	6,469.1	23.118
240	7,238,229	94.091	7.24E+00	2.12E-02	9,656.5	26.420
270	10,305,995	94.689	1.03E+01	3.02E-02	13,749.1	29.723
300	14,137,167	96.288	1.41E+01	4.15E-02	18,860.3	33.026
350	22,449,298	97.011	2.24E+01	6.59E-02	29,949.4	38.530
400	33,510,322	98.340	3.35E+01	9.84E-02	44,705.8	44.034
450	47,712,938	99.071	4.77E+01	1.40E-01	63,653.4	49.538
500	65,449,847	99.071	6.54E+01	1.92E-01	87,316.1	55.043
600	113,097,336	100.0	1.13E+02	3.32E-01	150,882.1	66.051

Using straight-line interpolation for solid particle sizes of 2.5 and 10 μm diameter, the PM_{10}-to-PM and $PM_{2.5}$-to-PM ratios for each station are summarized in Table 4-5. Potential PM_{10} and $PM_{2.5}$ emissions for each cooling tower configuration are summarized in Table 4-6.

Table 4-5
PM_{10}-to-PM and $PM_{2.5}$-to-PM Ratios for Each Station

CASE	Maximum TDS	% of PM that Evaporates to PM10	% of PM that Evaporates to PM2.5
	(ppm)	(%)	(%)
Fisk 19	3,680	41.6	0.20
Crawford 7&8	3,680	41.6	0.20
Will County 3&4	4,220	36.3	0.20
Joliet 6	2,935	50.7	0.20
Joliet 7&8	2,935	50.7	0.20

Table 4-6
Potential PM/$PM_{2.5}$ Emission Calculation Summary

Station	Total Number of Cells	Circulating Water Flow per Cell	Calculated Total Drift Loss	Estimated Maximum TDS	Calculated Potential Total PM Emissions	Calculated Potential PM10 Emissions	Calculated Potential PM2.5 Emissions
	(#)	(gpm)	(gpm)	(ppm)	(tpy)	(tpy)	(tpy)
Fisk 19	16	13,125	1.0	3,680	8.5	3.53	0.017
Crawford 7&8	30	12,747	1.9	3,680	15.4	6.40	0.031
W/C 3&4	40	15,000	3.0	4,220	27.7	10.0	0.055
Joliet 6	18	14,500	1.3	2,935	8.5	4.29	0.017
Joliet 7&8	64	14,375	4.6	2,935	29.7	15.06	0.059

The following should be noted regarding interpretation of this calculation:

- Circulating water flows are the original station design values.
- Total Dissolved Solids (TDS) concentrations in the cooling water were obtained from water quality data collected by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC): 2007 Annual Summary Report, "Water Quality Within the Waterways System of the Metropolitan Water Reclamation District of Greater Chicago", September 2008. The 2007 data are given in Exhibit F. The 2009 Annual Summary Report No. 10-36, July 2010, was reviewed and the 2007 report data were found to be representative. Estimated maximum TDS values in Table 4-1 were based on the 90th percentile TDS values of water quality given in Exhibit F and on the assumption of 5 cycles of concentration. (See discussion in Section 3.A.9, above.)

- The calculations above are based on 100% capacity factor and operation in closed-cycle 100% of the time, which are both conservative assumptions.
- The NSR threshold for overall PM emissions is 25 tpy. Calculated total PM emissions from the Will County and Joliet 7&8 cooling towers exceed these thresholds, triggering NSR review for the control of PM emissions. Potential NSR considerations are discussed in more detail below.
- The NSR threshold for PM_{10} emissions is 15 tpy. Calculated PM_{10} emissions from cooling towers at Joliet 7&8 are slightly above this threshold, and could trigger NSR review for the control of PM_{10}. PM_{10} emissions from cooling towers at the other MWGen stations fall below this threshold and should not trigger NSR permitting. Annual PM_{10} emissions were calculated using the PM_{10}-to-PM ratios calculated in Tables 4-2 thru 4-4, and the conservative assumption regarding capacity factors. The methodology used to calculate the PM_{10}-to-PM ratio has been accepted by Illinois EPA in the past for permitting of new units, but acceptance is not guaranteed for all future cases. If this calculated ratio method is not accepted and a higher PM_{10}:PM ratio is required. Joliet 7&8, Will County 3&4 and Crawford 7&8 could be at some risk of exceeding the PM_{10} NSR threshold, triggering NSR review and permitting.
- The NSR threshold for $PM_{2.5}$ emissions is 10 tpy. Calculated $PM_{2.5}$ emissions from cooling towers at all MWGen stations fall below this threshold and should not trigger NSR permitting. Annual $PM_{2.5}$ emissions were calculated using the $PM_{2.5}$-to-PM ratios calculated in Tables 4-2 thru 4-4, and the conservative assumption regarding capacity factors. The methodology used to calculate the $PM_{2.5}$-to-PM ratio results in very low $PM_{2.5}$ emissions because of the diameter of the drift droplets and the cooling water TDS. Using the methodology described above, a large majority of PM emitted from the cooling towers will have an aerodynamic diameter greater than 2.5 μm. If this methodology is not accepted by Illinois EPA, $PM_{2.5}$ emissions would need to be calculated using an alternative methodology, and, depending on the $PM_{2.5}$-to-PM ratio used, could result in higher annual $PM_{2.5}$ emissions. However, a significant change in the ratio would be needed to result in $PM_{2.5}$ emissions above the NSR significance level.

More detail on potential NSR considerations is provided below to give an idea of the upper bounds of this risk for Joliet and Will County Stations.

Project specific NSR permitting requirements depend upon the location of the emission source. Sources located in an area meeting the National Ambient Air Quality Standards (NAAQS) are subject to the Prevention of Significant Deterioration (PSD) regulations, while sources located in areas that do not meet the NAAQS are subject to the nonattainment area (NAA) regulations in 35 IAC Part 203. A summary of the current PM NAAQS is provided in Table 4-7.

Table 4-7
Current Particulate Matter National Ambient Air Quality Standards

Pollutant	Primary Standards		Secondary Standards	
	Level	Averaging Time	Level	Averaging Time
PM_{10}	150 $\mu g/m^3$	24-hour	Same as Primary	
$PM_{2.5}$	15.0 $\mu g/m^3$	Annual (Arithmetic Average)	Same as Primary	
	35 $\mu g/m^3$	24-hour	Same as Primary	

All areas in Illinois are currently designated as attainment/unclassifiable with respect to the PM_{10} NAAQS. Thus, cooling tower projects that result in a significant net increase in annual emissions of PM or PM_{10} would be subject to the PSD preconstruction permitting and review regulations. Among other things, the PSD regulations require air pollutants to be controlled using best available control technology (BACT).

BACT is defined as an emission limitation based on the maximum degree of reduction which, on a case-by-case basis, is determined to be achievable taking into account energy, environmental, and economic impacts and other costs. U.S. EPA maintains a database of recently issued NSR permits, including a description of the control technology required to meet the LAER or BACT (the "RBLC Database"). The RBLC Database lists several BACT determinations for industrial process cooling towers (process code 99.009). All recently permitted industrial process cooling towers have been permitted with "drift eliminators" as BACT for PM_{10} control. For example an NSR permit recently issued to the City Utilities of Springfield – Southwest Power Station in Missouri identified "high efficiency drift eliminator – 0.001% drift" as BACT to control particulate emissions from the facility's cooling tower.

Based on a review of BACT determinations listed in the RBLC Database, high efficiency drift eliminators should represent BACT for large industrial process cooling towers, and would likely represent LAER. Based on information from Marley, drift eliminators can be designed to reduce drift to 0.0005% of the circulating water flow. There are no other technically feasible drift control technologies available for wet cooling towers. Emission calculations in Table 4-6 are based on a drift eliminator efficiency of 0.0005%, and all of the cooling tower capital costs in this study include drift eliminators.

Crawford, Fisk, Will County, and Joliet generating stations are located in Cook and Will Counties, respectively. U.S.EPA has designated both Cook and Will Counties as nonattainment areas with respect to annual $PM_{2.5}$ NAAQS. Because all of the generating stations are located within areas designated as nonattainment for $PM_{2.5}$, the cooling tower projects will be subject to the NAA permitting regulations in 35 IAC Part 203 if their emissions exceed the NSR significant emissions threshold. Under the Part 203 air regulations, a construction permit is required prior to actual construction of a major new source or major modification (35 IAC 203.203). In addition, the owner or operator of a major modification must demonstrate that the control equipment and process measures applied to the modification will produce the lowest achievable emission rate (LAER). This requirement applies to each emissions unit at which a net increase in emissions of the pollutant will occur as a result of the modification (e.g., the cooling towers). LAER is defined as the more stringent rate of emissions based on the following:

a. The most stringent emission limitation which is contained in the implementation plan of any state for such class or category of stationary source, unless it is demonstrated that such limitation is not achievable; or

b. The most stringent emission limitation which is achieved in practice by such a class or category of stationary sources.

As discussed above, EPA's RBLC Database lists several BACT determinations for industrial process cooling towers (process code 99.009), but does not include any recent projects that required LAER. Based on a review of the RBLC Database, and a review of cooling tower particulate control technologies, high efficiency drift eliminators should represent BACT for large industrial process cooling towers, and would likely represent LAER.

High efficiency drift eliminators would likely represent LAER for large industrial process cooling towers. However, because LAER does not include an evaluation of economic impacts, and because the Illinois NAA regulations require an evaluation of alternative environmental control techniques, it is possible that Illinois EPA would require MWGen to evaluate the feasibility of dry cooling tower configurations (*e.g.*, air cooled condensers) to minimize particulate matter emissions in the $PM_{2.5}$ nonattainment areas. As noted previously, dry cooling towers were not investigated in the study since this technology is generally more expensive and requires significantly more land than the equivalent wet cooling tower. If dry cooling towers were required to be installed in order to meet LAER requirements, the estimated costs of compliance presented in this study would significantly increase, and overall feasibility issues would need to be considered.

In addition to the requirement to achieve LAER, 35 IAC Section 203.302 requires the owner or operator of a new major modification to provide emission offsets equal to or greater than the net increase in emissions from the modification. Offsets must be sufficient to allow Illinois EPA to determine that the modification will not interfere with reasonable further progress toward meeting the applicable NAAQS. Owners/operators of a new major modification are also required to demonstrate that benefits of the modification significantly outweigh the environmental and social costs based upon an analysis of alternative sites, sizes, production processes, and environmental control techniques for such proposed source. (35 IAC Section 203.306).

Because LAER may require an evaluation of dry cooling, and because Illinois NAA regulations require emissions off-sets, MWGen may need to investigate options to reduce further particulate emissions to provide internal emission offsets and "net-out" of NSR review. NSR significant thresholds are based on the "net" emissions increase at an existing source. Net emissions increase is defined as the amount by which the sum of any increase in actual emissions from a particular modification and any other increases or decreases in actual emissions at the source that are contemporaneous with the particular change and are otherwise creditable, exceeds zero.

(See, 35 IAC 203.208: Net Emission Determination). In other words, if a generating station can reduce existing actual particulate matter emissions by a quantity equal to or greater than the increase from the cooling tower project, the station should net-out of NSR review and eliminate the need for a LAER evaluation and emission offsets.

B. NPDES PERMITTING

Modifications to the cooling water systems that alter the characteristics of the cooling water discharge or the location of the cooling water discharge are subject to NPDES permitting requirements. NPDES permitting procedures require any person proposing modifications to an existing discharge to submit an application to the appropriate agency at least 180 days before the date on which the discharge is to begin.

1. Wastewater Discharges

All facilities that discharge pollutants from any point source into waters of the United States are required to obtain a NPDES permit. The term "pollutant" is defined very broadly by the NPDES regulations and includes any type of industrial waste discharged into water, including cooling tower blowdown. Depending on the design of the cooling tower, including any water recycling/reuse systems, operating a cooling tower could result in a new wastewater stream requiring treatment and discharge. MWGen would be required to modify its existing NPDES permits to allow treatment and discharge of any wastewater streams associated with the cooling towers investigated in this study.

The cooling tower blowdown flows to the river in closed-cycle operation were calculated using the evaporation flow rates provided by Marley and the assumed five cycles of concentration. The temperature of cooling tower blowdown was assumed to be the same as the cold water temperature of the tower. The 1% wet bulb temperature at O'Hare, according to the ASHRAE 2005 handbook, was used as the wet bulb temperature during each month of the year.

The maximum temperatures of the cooling tower blowdown from each station were calculated month-by-month, and the results were compared with the Proposed UAA Thermal Standards. The results are presented in Exhibit H. Average monthly blowdown temperatures are much more difficult to predict, as those estimates require a detailed study of the meteorological data as a function of time of day for each day of the month. Such a detailed evaluation was beyond the scope of this study.

In general, the maximum monthly end-of-pipe cooling tower blowdown temperatures exceed the corresponding Proposed UAA Thermal Standards' monthly allowable discharge temperature. However, in closed-cycle operation, the cooling tower blowdown would be routed to the existing station discharge canal at a point just beyond the barrier walls/gates which would isolate the circulating water systems from the river. (Refer to Exhibits A and B.) Some mixing will occur in the discharge canal, and, as mentioned previously, the cooling tower blowdown flow rates are negligible compared to the overall volumetric flow of the waterways, therefore any temperature rise in the receiving water would be expected to be negligible.

If compliance is to be determined based on end-of-pipe temperature and the Proposed UAA Thermal Standards would be exceeded at times, the cooling tower blowdown can be routed through a chiller package to cool it prior to discharge. The installed cost of a chiller package is estimated to be about $3,000,000 for Joliet 7/8, the station which has the highest cooling tower blowdown flow rate and therefore, the highest likelihood and frequency of exceeding the Proposed UAA Thermal Standards if a mixing zone is not allowed for the cooling tower blowdown discharge. The costs of chiller packages for the other stations are expected to be proportionally lower.

2. Wastewater Treatment Facility Construction Permits

In Illinois, a water pollution control construction permit is required for industrial activities with the potential to cause water pollution. This construction permit is required prior to constructing or modifying any wastewater treatment facility as specified in the Illinois water pollution regulations.

A construction permit is required prior to commencing construction of a regulated wastewater management system. The treatment of cooling tower blowdown prior to discharge from any MWGen generating station would require a construction permit. The construction permit application can be submitted concurrently with the NPDES permit modification, if required. Cost estimates for obtaining permits were not included in this analysis.

C. U.S. ARMY CORPS OF ENGINEERS PERMITTING

Section 404 of the CWA requires a permit before discharging or placing any dredged or fill material into navigable waters of the United States. The CWA delegates dredged or fill material discharge permit approval authority to the U.S. Army Corps of Engineers. The definition of "navigable water" for a section 404 permit is very broad, and includes waters that are, or could be, used for interstate commerce, as well as lakes, impoundments, and wetlands. The subject CSSC and UDIP surface waters meet the definition of a "navigable water" under CWA Section 404.

Activities, including modifications to the cooling water intake/discharge structures and construction activities impacting existing wetlands, will require a permit from the U.S. Army Corps of Engineers. In general, if a wetland is located on a site proposed for development, the developer must apply for a Corp of Engineers permit to place fill into the wetland. For projects that impact over 0.25 acre of wetlands, the applicant will be required to provide compensatory wetland mitigation. It is important to note that the Corp of Engineers will require the applicant to avoid and/or minimize wetland destruction before compensatory wetland mitigation will be considered.[7]

[7] None of the cooling tower arrangements studies here for the MWGen generating stations are believed to impact existing wetland areas.

The construction of the cooling towers at each of the MWGen stations may require the issuance of a CWA section 404 permit due to excavation and fill activities adjacent to or in the waterway necessary to complete their construction. In order to expedite the permitting and review process, the Corps of Engineers has developed a limited number of nationwide permits (NWPs) for activities the Corps has identified as being substantially similar in nature and causing only minimal environmental impacts. Construction activities within a waterway that are not covered by a NWP require the Corps to issue an individual permit for the activity. Issuance of an individual construction permit may also trigger the need for a formal Environmental Impact Statement (EIS).

The Corps of Engineers cannot issue a permit for any activity that may result in a discharge into navigable waters unless the State of Illinois, through the Illinois EPA, first provides a CWA Section 401 Certification. The Section 401 Certification includes a statement that the State has reasonable assurance that the activity will be conducted in a manner which will not violate applicable water quality standards. For purposes of this study, it was assumed that both the CWA section 401 Certification and a section 404 permit would be issued for the proposed cooling towers construction projects necessary to attain compliance with the Proposed UAA Thermal Standards. Cost estimates for obtaining permits were not included in this analysis.

D. NOISE REGULATIONS

Generally speaking, the falling water within a cooling tower results in locally high noise levels. To meet county noise regulations, the sound levels must be reduced approximately to that of a normal conversation at nearby site boundaries. Under current regulations, only Joliet 7&8 appears to have the potential to violate noise limits.

Table 4-8 below shows approximate costs and abatement reduction options for Joliet Units 7 and 8 that were proposed by SPX/Marley. The most expensive option, on the order of $12.5 million, would most likely be necessary to achieve the required sound level reduction.

Table 4-8
Joliet 7&8 Noise Abatement Cost Options

Attenuation Method	dBA Reduction	Approximate Cost For 80 Cells
SA	-2.4	$3,000,000
GBW	-3.7	$4,450,000
SA + GBW	-4.8	$7,450,000
FDBW	-0.7	$5,110,000
SA + FDBW	-3.6	$8,110,000
GBW+FDBW	-5.4	$9,560,000
SA+GBW+FDBW	-7.1	$12,560,000

SA = Splash Attenuation
GBW = Grade Barrier Wall
FDBW = Fan Deck Barrier Wall

Splash attenuation (SA) consists of installing a thin layer of film at the bottom of the air inlet to the tower to help break up the noise generated by the falling water.

A grade barrier wall (GBW) is a wall installed at the ground elevation along the side of the tower which is more noise-sensitive to further attenuate the noise of falling water. It is as high as the tower air inlet, and is three air inlet heights away from the tower structure.

A fan deck barrier wall (FDBW) is a wall installed along the tower fan deck along the more noise-sensitive side to screen the noise from the fans, motors and gearboxes. The barrier wall extends to a height about one foot above the tops of the fan stacks.

5. STUDY RESULTS

There are three primary elements of cost associated with conversion of an existing electrical generating station from open-cycle operation to closed-cycle operation. These are:

- The engineering, material and equipment purchase, and construction of modifications to the plant's circulating water system, including
  - Cooling towers,
  - Pumps and piping,
  - Electrical and control equipment,
  - Barrier walls and/or gates (to isolate the open-cycle intake and discharge).
- Operating and maintenance costs, including
  - Electricity to run the new pumps and cooling tower fans,
  - Costs of chemicals needed to control water quality in closed-cycle operation, and
  - Mechanical and electrical maintenance of the new equipment.
- Loss of plant generating capacity. As discussed in Section 2, the circulating water inlet temperature to the condenser is higher in closed-cycle mode than in open-cycle mode, because it is not possible to reduce (with cooling towers) the cold-water temperature of the circulating water system to the temperature of the body of water previously used for open-cycle cooling. This higher condenser inlet temperature reduces turbine-generator efficiency and results in a loss of plant generating capacity, and a corresponding loss of revenue from electricity sales.

All three elements of the costs of closed-cycle conversion and operation are discussed individually for each station in the paragraphs below. The methodologies that were used to develop the costs in this section were discussed in Section 3 above. All O&M and lost capacity costs are based on a 75 percent capacity factor.

A. FISK STATION TECHNOLOGY OPTIONS AND COST ESTIMATE RESULTS

A1. FISK COOLING TOWER ARRANGEMENT

Exhibit A1 shows the arrangement of the cooling tower proposed for Fisk. The "tower" actually consists of two physically separate sections – two groups of cells – as there is not enough room at the station property for one long tower section. Installation of the northern tower would require the demolition of existing old Switch House No. 1 to make room for the cooling tower. The cost estimate includes this demolition and replacement of active electrical equipment in this switch house in the electrical costs. The demolition costs do not include asbestos removal or lead paint abatement which may be necessary given the age of the Switch House.

The northern tower is not ideally oriented to the prevailing winds and may be subject to increased recirculation which would lower the cooling ability of the towers, leading to increased risk of violating the thermal discharge limits, as well as requiring derates to the unit. The adjacent building to the east may interfere with air flow into that side of the tower which could also decrease tower cooling ability. A ComEd switchyard is located immediately to the west of the tower and would be subject to icing risk, although it is generally upwind of the tower. Wet/dry (plume-abated) cooling towers reduce the potential for icing downwind of the tower but do not eliminate it. Any such buildup of ice would lead to extra weight loading the live power lines, potentially resulting in line collapse. The consequences of this would be power outages and the risk of injury to persons in the immediate area. The southern tower section is more suitably oriented but would require demolition of the existing metal cleaning tank and demolition/ replacement of the plant makeup water treatment facility. The existing boiler building to the north of this tower may interfere with air flow into that side of the tower, adversely impacting tower performance.

Exhibit B1 shows the closed loop cooling tower flow diagram for the Fisk Station. A gate would be installed in the existing discharge flume in order to allow for the option of switching between open and closed-cycle cooling modes. Under closed-cycle operation, this gate would be closed and two 50% cooling tower supply pumps would pump the water from the flume upstream of the gate to the cooling towers. The cooled water would be pumped by four 25% cooling tower discharge pumps (two per tower) through above ground steel-lined concrete piping to the existing circulating water (CW) intake, and discharged there between the existing trash rakes and traveling screens to re-enter the existing CW pumps and condenser.

A2. FISK COOLING TOWER CAPITAL COST ESTIMATES

The capital costs (including the quoted pricing from Marley) for the wet/dry tower are shown in Exhibit I1. Below in Table 5-1, the cost for the 100% closed loop tower is broken into the key components. For the wet/dry tower option, the total estimated capital cost is approximately $137 million, which translates to a normalized capital cost of $394 per kilowatt of generating capacity. This value is derived by dividing the total installed cost of closed-cycle conversion in dollars by the plant's gross electrical capacity in kilowatts. Normalizing capital costs on a "per kW" basis is common practice in the power industry, similar to comparing costs on a "per square foot" basis in the construction industry.

Table 5-1
Fisk Capital Costs

Unit	Marley Wet/Dry CT Cost ($)	BOP Equipment and Material Cost ($)	Installation Cost ($)	Indirect Costs ($)	Contingency ($)	Total Cost ($)	Total Cost ($/kW)
Fisk 19	$13,300,000	$23,600,000	$60,500,000	$18,500,000	$21,400,000	$137,100,000	$394

A3. FISK COOLING TOWER O&M COST ESTIMATES

The operation and maintenance cost for a wet/dry (plume-abated) cooling tower at Fisk includes cooling tower fan and pump power (46,831 MWh at $36.71/MWh), tower maintenance costs such as gear oil replacement, and chemical costs for chlorination and anti-scaling additives. The total annual O&M cost is approximately $2,127,000. A detailed breakdown of these O&M costs is shown in Exhibit J. The breakdown of the costs is shown in Table 5-2.

Table 5-2
Fisk O&M Costs

Unit	Annual CT Fan Power Cost ($)	Annual Pump Power Cost ($)	Annual Maintenance Cost ($)	Annual Chemical Cost ($)	Total Annual O&M Cost ($)
Fisk 19	$781,000	$938,000	$60,000	$348,000	$2,127,000

A4. FISK DERATING IMPACTS WITH CLOSED-CYCLE COOLING TOWER

Table 5-3 below summarizes the month-by-month loss of plant capacity in closed-cycle operation compared to open-cycle operation weather and water temperature conditions.

Table 5-3
Fisk 19 Megawatt Loss Due to Closed v. Open-Cycle Operation

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
January	-1.37	0.26	-1.63
February	-1.75	0.35	-2.11
March 1-15	-3.70	-0.15	-3.55
March 16-31	-3.70	-0.15	-3.55
April 1-15	-4.98	-0.75	-4.23
April 16-30	-4.98	-1.00	-3.98
May 1-15	-7.18	-2.68	-4.50
May 16-31	-7.18	-3.34	-3.84
June 1-15	-8.75	-4.29	-4.46
June 16-30	-8.75	-10.56	1.81
July 1-15	-10.10	-10.56	0.46
July 16-31	-10.10	-10.56	0.46
August 1-15	-9.78	-10.56	0.78
August 16-31	-9.78	-10.56	0.78
Sep. 1-15	-8.02	-10.56	2.54
Sep. 16-30	-8.02	-5.39	-2.64
October 1-15	-5.18	-3.94	-1.24
Oct. 16-31	-5.18	-2.80	-2.38

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
November	-3.70	-1.90	-1.80
December	-2.77	-0.59	-2.18
		Annual Average	-1.79

Nominal plant output: 348 MW gross
Annual-average capacity loss: 1.79 MW
Annual revenue loss: $432,000 (75% capacity, $36.71/MWh)

B. CRAWFORD STATION TECHNOLOGY OPTIONS AND COST ESTIMATE RESULTS

B1. CRAWFORD COOLING TOWER ARRANGEMENT

Exhibit A2 shows the layout for the two Crawford cooling tower sections. A ComEd switchyard is located to the east of the southern tower, with potential icing concerns. 138 kV transmission line crosses the tower location, and would need to be relocated, and a 345 kV line would need to be raised and more insulators added. Costs for relocation and insulation of ComEd transmission lines are included in the estimate, but because the lines are not owned by MWGen, it is not known whether permission will be granted to relocate these lines. If permission to relocate the ComEd transmission lines is not granted, an alternate location may not be available or feasible. The northern tower is not ideally oriented to the prevailing winds and may be subject to increased recirculation. The northern tower location requires routing of 10 ft diameter circulating water lines across the site.

See Exhibit B2 for the closed loop cycle diagram at Crawford. A wall with a gate would be constructed across the existing CW discharge channel. In closed-cycle operation, this gate would be closed and four 25% cooling tower supply pumps would pump the water from the discharge channel upstream of the wall to the cooling towers. The cooled water would be pumped by two 25% cooling tower discharge pumps from the northern tower and would flow by gravity from the southern tower to the existing CW intake channel, and would be discharged there to re-enter the existing crib house and condenser.

B2. CRAWFORD COOLING TOWER CAPITAL COST ESTIMATES

The capital costs (including the quoted pricing from Marley) for the wet/dry towers are shown in Exhibit I2. Below in Table 5-4, the cost for the 100% closed loop tower is broken into the key components. For the wet/dry tower option, the total estimated capital cost is approximately $165 million. This translates to a normalized capital cost of about $282 per kilowatt of generating capacity.

Table 5-4
Crawford Capital Costs

Unit	Marley Wet/Dry CT Cost w/Delivery ($)	BOP Equipment Material Cost ($)	Labor ($)	Indirect Costs ($)	Contingency ($)	Total Cost ($)	Total Cost ($/ kW)
Crawford 7&8	$24,900,000	$28,400,000	$61,300,000	$24,800,000	$25,800,000	$165,200,000	$282

B3. CRAWFORD COOLING TOWER O&M COST ESTIMATES

The operation and maintenance cost for the Crawford plume-abated (wet/dry) cooling tower consists of cooling tower fan and pump power (88,872 MWh at $36.71/MWh), tower maintenance costs such as gear oil replacement, and chemical costs for chlorination and anti-scaling additives. The total annual O&M cost is approximately $3,960,000. A detailed breakdown of these O&M costs is shown in Exhibit J. The breakdown of the costs is shown in Table 5-5.

Table 5-5
Crawford O&M Costs

Unit	Annual CT Fan Power Cost ($)	Annual Pump Power Cost ($)	Annual Maintenance Cost ($)	Annual Chemical Cost ($)	Total Annual O&M Cost ($)
Crawford 7&8	$1,460,000	$1,800,000	$112,500	$585,000	$3,957,500

B4. CRAWFORD DERATING IMPACTS WITH CLOSED-CYCLE COOLING TOWER

Tables 5-6 and 5-7 below summarize the month-by-month loss of plant capacity in closed-cycle operation for Crawford 7 and Crawford 8, respectively, compared to open-cycle operation weather and water temperature conditions.

Table 5-6
Crawford 7 Megawatt Loss Due to Closed v. Open-Cycle Operation

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
January	-1.33	-0.24	-1.10
February	-1.60	-0 18	-1.43
March 1-15	-3.09	-0.51	-2.58
March 16-31	-3.09	-0.51	-2.58
April 1-15	-3.92	-0.92	-3.00
April 16-30	-3.92	-1.09	-2.83
May 1-15	-5.54	-2.28	-3.26
May 16-31	-5.54	-2.75	-2.78
June 1-15	-6.71	-3.45	-3.26
June 16-30	-6.71	-8.11	1.40
July 1-15	-7.81	-8.11	0.30
July 16-31	-7.81	-8.11	0.30
August 1-15	-7.52	-8.11	0.58
August 16-31	-7.52	-8.11	0.58
Sep. 1-15	-6.12	-8.11	1.98
Sep. 16-30	-6.12	-4.25	-1.88
October 1-15	-3.98	-3.19	-0.79
Oct. 16-31	-3.98	-2.36	-1.61
November	-3.09	-1.72	-1.37
December	-2.40	-0.81	-1.60
		Annual Average	**-1.27**

Nominal unit output: 237 MW gross
Annual-average capacity loss: 1.27 MW
Annual revenue loss: $306,000 (75% capacity, $36.71/MWh)

Table 5-7
Crawford 8 Megawatt Loss Due to Closed v. Open-Cycle Operation

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
January	-2.08	0.71	-2.79
February	-2.66	0.89	-3.55
March 1-15	-5.44	-0.07	-5.37
March 16-31	-5.44	-0.07	-5.37
April 1-15	-6.78	-1.13	-5.66
April 16-30	-6.78	-1.53	-5.25
May 1-15	-9.11	-4.01	-5.10
May 16-31	-9.11	-4.87	-4.24
June 1-15	-10.61	-6.04	-4.58
June 16-30	-10.61	-12.27	1.66
July 1-15	-11.93	-12.27	0.34
July 16-31	-11.93	-12.27	0.34
August 1-15	-11.60	-12.27	0.68
August 16-31	-11.60	-12.27	0.68
Sep. 1-15	-9.87	-12.27	2.40
Sep. 16-30	-9.87	-7.28	-2.59
October 1-15	-6.87	-5.61	-1.26
Oct. 16-31	-6.87	-4.16	-2.71
November	-5.44	-2.91	-2.54
December	-4.24	-0.85	-3.39
		Annual Average	-2.50

Nominal unit output: 348 MW gross
Annual-average capacity loss: 2.5 MW
Annual revenue loss: $603,000 (75% capacity, $36.71/MWh)

C. WILL COUNTY STATION TECHNOLOGY OPTIONS AND COST ESTIMATE RESULTS

C1. WILL COUNTY COOLING TOWER ARRANGEMENT

Exhibit A3 represents the arrangement drawing for the Will County towers. Two transmission lines (including two river crossings) run parallel with the towers and would need to be relocated to prevent icing problems. As at Crawford and Fisk, denial of a request to ComEd to relocate these transmission lines may not leave any other feasible locations open. One pond would need to be partially filled under the area where towers would be installed. Costs for these site modifications are included in the estimate. Some interference between the towers is likely under prevailing wind conditions. It proved necessary to separate the tower into three tower sections in order to provide the number of cells required to accommodate the combined cooling water flow for both Unit 3 and Unit 4. There is not enough space for one long tower due to the roads and railroad tracks that cross the tower location.

See Exhibit B3 for the closed loop diagram at Will County. A wall with a gate would be installed in the existing discharge channel. Under closed-cycle operation, this gate would be closed and four 25% cooling tower supply pumps would pump the water from the channel upstream of the wall to the cooling towers. The cooled water would be pumped by two 20% and four 15% cooling tower discharge pumps through above ground steel-lined concrete piping to the existing screen houses, to re-enter the CW pumps and condensers.

C2. WILL COUNTY COOLING TOWER CAPITAL COST ESTIMATES

The capital costs (including the quoted pricing from Marley) for the wet/dry tower are shown in Exhibit I3. Below in Table 5-8, the cost for the 100% closed loop tower is broken into the key components. For the wet/dry tower option, the total estimated capital cost is approximately $257 million. This translates to a normalized capital cost of $307 per kilowatt.

Table 5-8
Will County Capital Costs

Unit	Marley Wet/Dry CT Cost w/Delivery ($)	BOP Equipment Material Cost ($)	Labor ($)	Indirect Costs ($)	Contingency ($)	Total Cost ($)	Total Cost ($/kW)
Will County 3&4	$33,200,000	$47,300,000	$108,300,000	$28,200,000	$40,100,000	$257,100,000	$309

Below in Table 5-9, the cost of plume-abated (wet/dry) towers is compared to the cost for a wet tower with and without the provisions for later conversion to a wet/dry configuration. (See Section 2 for a discussion of the provisions required for a wet convertible to wet/dry tower.)

Table 5-9
Will County Capital Costs for Three Tower Styles

Unit	Wet/Dry Total Installed Cost ($)	Wet With Dry Option Total Installed Cost ($)	Wet Without Dry Option Total Installed Cost ($)
Will County 3&4	$257,100,000	$230,200,000	$210,700,000

C3. WILL COUNTY COOLING TOWER O&M COST ESTIMATES

The operation and maintenance cost for the Will County plume-abated (wet/dry) cooling tower consists of cooling tower fan and pump power (137,832 MWh at $36,71/MWh), tower maintenance costs such as gear oil replacement, and chemical costs for chlorination and anti-scaling additives. The total annual O&M cost is approximately $5,750,000. A detailed breakdown of these O&M costs is shown in Exhibit J. The breakdown of the costs is shown in Table 5-10.

Table 5-10
Will County O&M Costs

Unit	Annual CT Fan Power Cost ($)	Annual Pump Power Cost ($)	Annual Maintenance Cost ($)	Annual Chemical Cost ($)	Total Annual O&M Cost ($)
Will County 3&4	$1,950,000	$2,820,000	$150,000	$832,000	$5,752,000

C4. WILL COUNTY DERATING IMPACTS WITH CLOSED-CYCLE COOLING TOWER

Tables 5-11 and 5-12 below summarize the month-by-month loss of plant capacity in closed-cycle operation for Will County 3 and Will County 4, respectively, compared to open-cycle operation weather and water temperature conditions.

Table 5-11
Will County 3 Megawatt Loss Due to Closed v. Open-Cycle Operation

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
January	-1.37	0.41	-1.77
February	-1.67	0.50	-2.17
March 1-15	-4.64	-0.03	-4.61
March 16-31	-4.64	-0.03	-4.61
April 1-15	-6.26	-0.72	-5.54
April 16-30	-6.26	-1.02	-5.24
May 1-15	-9.49	-3.19	-6.30
May 16-31	-9.49	-4.10	-5.39
June 1-15	-11.95	-5.44	-6.51
June 16-30	-11.95	-14.93	2.98
July 1-15	-14.32	-14.93	0.62
July 16-31	-14.32	-14.93	0.62
August 1-15	-13.72	-14.93	1.21
August 16-31	-13.72	-14.93	1.21
Sep. 1-15	-11.00	-14.93	3.93
Sep. 16-30	-11.0	-7.03	-3.97
October 1-15	-6.67	-4.93	-1.73
Oct. 16-31	-6.67	-3.35	-3.32
November	-4.60	-2.15	-2.45
December	-1.93	-0.53	-1.40
		Annual Average	**-2.18**

Nominal unit output: 281 MW gross
Annual-average capacity loss: 2.18 MW
Annual revenue loss: $526,000 (75% capacity, $36.71/MWh)

Table 5-12
Will County 4 Megawatt Loss Due to Closed v. Open-Cycle Operation

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
January	-0.57	1.06	-1.63
February	-0.85	1.14	-1.99
March 1-15	-3.63	0.66	-4.29
March 16-31	-3.63	0.66	-4.29
April 1-15	-5.16	0.03	-5.19
April 16-30	-5.16	-0.25	-4.91
May 1-15	-8.25	-2.27	-5.98
May 16-31	-8.25	-3.12	-5.14
June 1-15	-10.64	-4.38	-6.25
June 16-30	-10.64	-13.57	2.93
July 1-15	-12.96	-13.57	0.61
July 16-31	-12.96	-13.57	0.61
August 1-15	-12.37	-13.57	1.19
August 16-31	-12.37	-13.57	1.19
Sep. 1-15	-9.71	-13.57	3.85
Sep. 16-30	-9.71	-5.89	-3.82
October 1-15	-5.55	-3.91	-1.64
Oct. 16-31	-5.55	-2.41	-3.13
November	-3.59	-1.29	-2.29
December	-1.09	0.20	-1.29
		Annual Average	**-2.03**

Nominal unit output: 551 MW gross
Annual-average capacity loss: 2.03
Annual revenue loss: $490,000 (75% capacity, $36.71/MWh)

D. JOLIET 6 STATION TECHNOLOGY OPTIONS AND COST ESTIMATE RESULTS

D1. JOLIET 6 COOLING TOWER ARRANGEMENT

Exhibit A4 represents the arrangement drawing developed for the Joliet 6 cooling tower sections. The arrangement of the cooling towers is favorable, considering the space constraints. The towers are oriented to minimize recirculation and interference under prevailing wind conditions. The site would need to be filled to raise the elevation suitably above the canal. There is a microwave easement that crosses the tower location. It is assumed for purposes of this analysis that this easement is sufficiently elevated that the towers do not interfere with it.

Exhibit B4 is the closed loop cycle diagram for at Joliet 6. A wall with a gate would be installed across the existing discharge channel. Under closed-cycle operation, this gate would be closed and four 25% cooling tower supply pumps would pump the water from the channel upstream of the wall to the cooling towers. The cooled water would be pumped by four 25% cooling tower discharge pumps (two per tower section) through steel-lined concrete piping to the intake of the existing crib house, to re-enter the CW pumps and condensers. The crib house intake would be enclosed with gates on the north and west sides to prevent the circulating water from entering the canal.

D2. JOLIET 6 COOLING TOWER CAPITAL COST ESTIMATES

The capital costs (including the quoted pricing from Marley) for the wet/dry tower are shown in Exhibit I4. Below in Table 5-13, the cost for the 100% closed loop tower is broken into the key components. For the wet/dry tower option, the total estimated capital cost is approximately $116 million. This translates to a normalized capital cost of $339 per kilowatt.

Table 5-13
Joliet 6 Capital Cost

Joliet 6 Capital Costs Unit	Marley Wet/Dry CT Cost w/Delivery ($)	BOP Equipment Material Cost ($)	Labor ($)	Indirect Costs ($)	Contingency ($)	Total Cost ($)	Total Cost ($/kW)
Joliet 6	$14,900,000	$21,000,000	$42,600,000	$19,100,000	$18,100,000	$115,700,000	$339

Below in Table 5-14, the cost of plume-abated (wet/dry) towers is compared to the cost for a wet tower with and without provisions to convert to wet/dry. (See Section 2 for a discussion of the provisions required for a wet convertible to wet/dry tower.)

Table 5-14
Joliet 6 Capital Costs for Three Tower Styles

Unit	Wet/Dry Total Installed Cost ($)	Wet With Dry Option Total Installed Cost ($)	Wet Without Dry Option Total Installed Cost ($)
Joliet 6	$115,700,000	$103,600,000	$93,400,000

D3. JOLIET 6 COOLING TOWER O&M COST ESTIMATES

Operation and maintenance costs for plume-abated (wet/dry) cooling towers at Joliet 6 wet/dry consists of cooling tower fan and pump power (65,350 MWh at $36.71/MWh), tower maintenance costs such as gear oil replacement, and chemical costs for chlorination and anti-scaling additives. The total annual O&M cost is approximately $2,660,000. A detailed breakdown of these O&M costs is shown in Exhibit J. The breakdown of the costs is shown in Table 5-15.

Table 5-15
Joliet 6 O&M Costs

Unit	Annual CT Fan Power Cost ($)	Annual Pump Power Cost ($)	Annual Maintenance Cost ($)	Annual Chemical Cost ($)	Total Annual O&M Cost ($)
Joliet 6	$880,000	$1,370,000	$67,500	$341,000	$2,660,000

D4. JOLIET 6 DERATING IMPACTS WITH CLOSED-CYCLE COOLING TOWER

Table 5-16
Joliet 6 Megawatt Loss Due to Closed v. Open-Cycle Operation

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
January	-1.26	0.47	-1.73
February	-1.71	0.58	-2.29
March 1-15	-3.85	-0.04	-3.81
March 16-31	-3.85	-0.04	-3.81
April 1-15	-5.14	-0.76	-4.38
April 16-30	-5.14	-1.05	-4.09
May 1-15	-7.35	-2.94	-4.41
May 16-31	-7.35	-3.64	-3.71
June 1-15	-9.08	-4.64	-4.43
June 16-30	-9.08	-9.82	0.75
July 1-15	-10.36	-9.82	-0.54
July 16-31	-10.36	-9.82	-0.54
August 1-15	-10.06	-9.82	-0.24

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
August 16-31	-10.06	-9.82	-0.24
Sep. 1-15	-8.26	-9.82	1.56
Sep. 16-30	-8.26	-5.76	-2.50
October 1-15	-5.39	-4.27	-1.11
Oct. 16-31	-5.39	-3.06	-2.32
November	-3.85	-2.07	-1.77
December	-2.88	-0.57	-2.30
		Annual Average	**-2.08**

Nominal plant output:	341 MW gross
Annual-average capacity loss:	2.08
Annual revenue loss:	$502,000 (75% capacity, $36.71/MWh)

E. JOLIET 7&8 STATION TECHNOLOGY OPTIONS AND COST ESTIMATE RESULTS

E1. JOLIET 7&8 COOLING TOWER ARRANGEMENT

Exhibit A4 represents the arrangement drawing developed for the Joliet 7&8 towers. Interference between the towers is likely under prevailing wind conditions, as the spacing between the towers is less than desired. Recirculation may also be a problem with westerly winds.

See Exhibit B5 for the closed loop diagram corresponding to Joliet 7&8 case. A dividing wall would be installed down the center of the existing discharge channel, and a wall with a gate would be installed at the southwestern end of the channel formed north of this wall. Under closed-cycle operation, this gate would be closed and six 17% cooling tower supply pumps would pump the water from this channel to the cooling towers. The cooled water would be pumped by six cooling tower discharge pumps (two per tower) through buried steel-lined concrete piping to the channel south of the dividing wall. This channel would be isolated from the canal by a new wall and gate. The flow in the southern section of the divided discharge channel would be reversed and a new flume with a gate would connect this channel with the existing inlet channel. From the inlet channel, the circulating water would re-enter the CW pumps and condensers.

E2. JOLIET 7&8 COOLING TOWER CAPITAL COST ESTIMATES

The capital costs (including the quoted pricing from Marley) for the wet/dry tower are shown in Exhibit I5. Below in Table 5-17, the cost for the closed loop tower is broken into the key components. For the wet/dry tower option, the total estimated capital cost is approximately $301 million. This translates to a normalized capital cost of $264 per kilowatt.

Table 5-17
Joliet 7&8 Capital Costs

Unit	Marley Wet/Dry CT Cost w/Delivery ($)	BOP Equipment Material Cost ($)	Labor ($)	Indirect Costs ($)	Contingency ($)	Total Cost ($)	Total Cost ($/kW)
Joliet 7&8	$53,100,000	$58,800,000	$115,400,000	$26,600,000	$47,000,000	$300,900,000	$264

Table 5-18 presents a comparison of the cost of plume-abated (wet/dry) towers is compared to the cost for a wet tower with or without the option to convert to wet/dry.

Table 5-18
Joliet 7&8 Tower Capital Cost for Three Tower Styles

Unit	Wet/Dry Total Installed Cost ($)	Wet With Dry Option Total Installed Cost ($)	Wet Without Dry Option Total Installed Cost ($)
Joliet 7&8 100%	$300,900,000	$257,900,000	$223,800,000

E3. JOLIET 7&8 COOLING TOWER O&M COST ESTIMATES

The operation and maintenance cost for the Joliet 7&8 plums-abated (wet/dry) cooling tower consists of cooling tower fan and pump power (230,962 MWh at $36.71/MWh), tower maintenance costs such as gear oil replacement, and chemical costs for chlorination and anti-scaling additives. The total annual O&M cost is approximately $9,080,000. A detailed breakdown of these O&M costs is shown in Exhibit J. The breakdown of the costs is shown in Table 5-19.

Table 5-19
Joliet 7&8 O&M Costs

Unit	Annual CT Fan Power Cost ($)	Annual Pump Power Cost ($)	Annual Maintenance Cost ($)	Annual Chemical Cost ($)	Total Annual O&M Cost ($)
Joliet 7&8	$3,100,000	$4,570,000	$240,000	$1,138,000	$9,050,000

Total O&M costs for Joliet 7&8 are markedly higher than the O&M costs for other MWGen station units for two reasons: 1) Most O&M costs are related to plant generating capacity, and Joliet 7&8 is the largest station of the five stations considered in this study, and 2) Joliet 7&8 have three cooling tower sections, which requires one additional set of large pumps than is required for the other stations.

E4. JOLIET 7&8 DERATING IMPACTS WITH CLOSED-CYCLE COOLING TOWER

Table 5-20
Joliet 7&8 Megawatt Loss Due to Closed v. Open-Cycle Operation

Period	Closed-Cycle MW Loss	Open-Cycle MW Gain/Loss	Total MW Gain/Loss Running Closed vs. Open-Cycle
January	-2.19	-0.71	-1.48
February	-2.91	-0.71	-2.20
March 1-15	-7.31	-0.28	-7.02
March 16-31	-7.31	-0.28	-7.02
April 1-15	-9.53	-0.64	-8.89
April 16-30	-9.53	-1.30	-8.23
May 1-15	-13.36	-5.32	-8.04
May 16-31	-13.36	-6.71	-6.64
June 1-15	-16.13	-8.61	-7.53
June 16-30	-16.13	-17.29	1.15
July 1-15	-18.20	-17.29	-0.91
July 16-31	-18.20	-17.29	-0.91
August 1-15	-17.65	-17.29	-0.36
August 16-31	-17.65	-17.29	-0.36
Sep. 1-15	-15.02	-17.29	2.27
Sep. 16-30	-15.02	-10.63	-4.38
October 1-15	-10.26	-7.92	-2.34
Oct. 16-31	-10.26	-5.56	-4.70
November	-7.24	-3.53	-3.71
December	-5.50	-0.20	-5.30
		Annual Average	**-3.72**

Nominal plant output: 569 MW gross (each unit)
Annual-average capacity loss: 3.72
Annual revenue loss: $897,000 (75% capacity, $36.71/MWh)

F. **CAPITAL COSTS ASSOCIATED WITH OPEN-CYCLE CAPABILITY**

Conversion of Crawford 7/8, Fisk, Joliet 6, Joliet 7/8 and Will County 3/4 to closed-cycle cooling requires isolation of the existing cooling water intake and discharge canals from the river. For cost estimating purposes, S&L assumed this isolation would be accomplished by installing a combination of fixed barrier walls with moveable gates at the points of isolation from the river. Although there are many other systems and structures required to convert these stations to closed-cycle cooling, conversion does not require any changes to existing plant equipment which would prevent the plant from operating in open-cycle mode if access to the river were maintained. Thus, the only additional equipment included in the capital cost estimates to allow the stations to maintain their current open-cycle capability is the inclusion of moveable gates as part of the fixed barrier walls.

Table 5-21 provides a comparison of the capital costs of conversion from open-cycle to closed-cycle cooling with and without moveable gates. For the estimates without gates, S&L substituted continuous fixed barrier walls for walls with moveable gates.

Table 5-21
Capital Costs With and Without Moveable Gates (2007 $)

	Crawford	Fisk	Joliet 6	Joliet 7/8	Will County
Open-Cycle Capability Costs	$144,652,125	$119,952,645	$109,045,489	$296,100,668	$225,485,626
Closed-Cycle Costs	$141,995,107	$118,832,840	$107,185,075	$292,252,428	$224,095,727
Difference	$2,657,018	$1,119,805	$1,860,414	$3,846,240	$1,389,899
Percentage Difference	1.9	0.9	1.7	1.3	0.6

6. TYPICAL COOLING TOWER PROJECT SCHEDULE

A typical schedule for the design, procurement, fabrication and erection of a cooling tower and other closed-cycle conversion activities for a single station is shown in Figure 6-1. If all of the towers at each of the MWGen stations had to be installed to meet a single compliance deadline and therefore, schedules for the work to install the cooling towers would need to overlap, the overall schedule duration would be considerably longer than that shown for a single station.

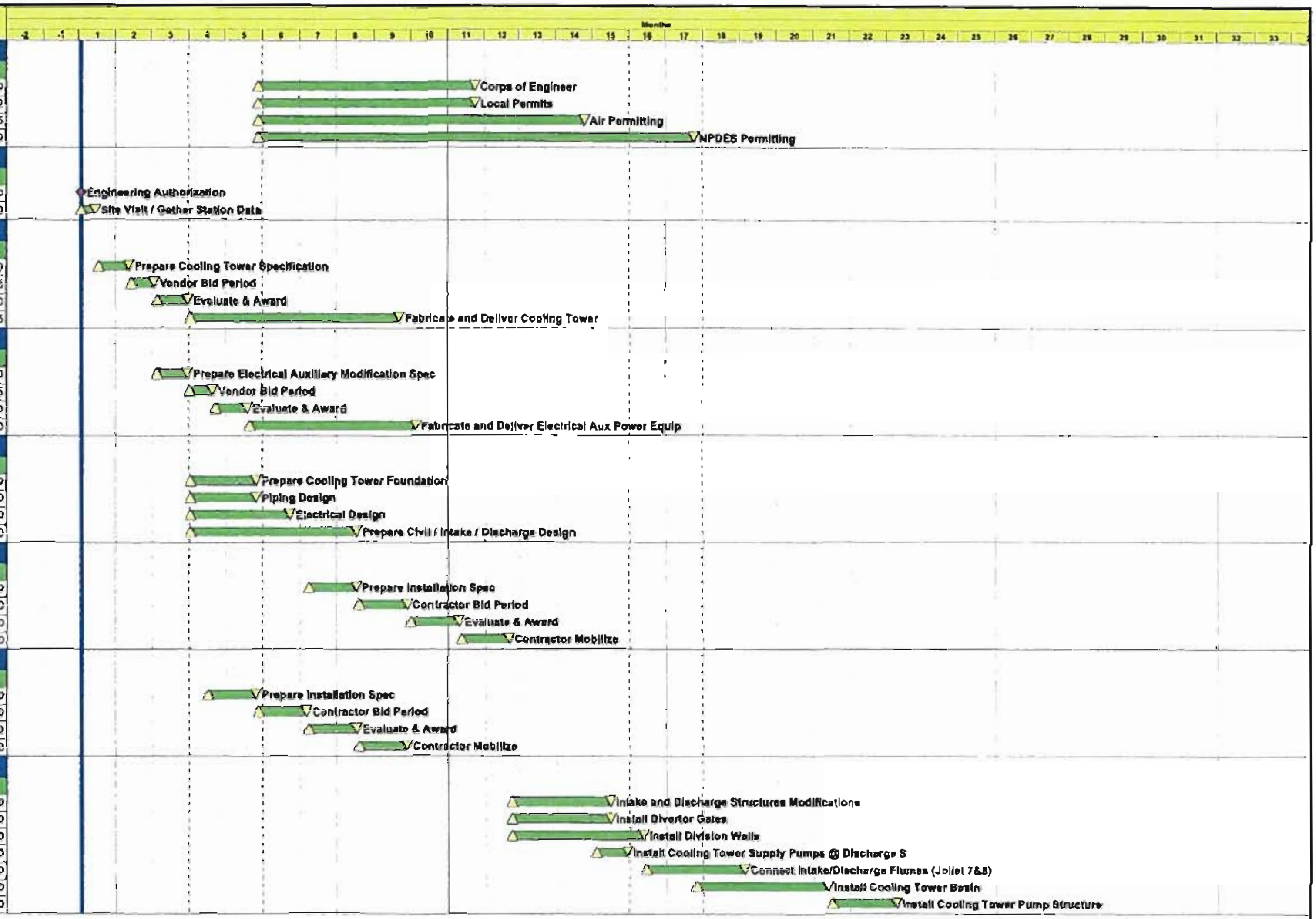
As shown on Figure 6-1, S&L estimates that a typical single-station installation will require about 29 months to complete, not including the time needed both to conduct necessary design studies and to complete critical design criteria. The 29-month duration is applicable to Fisk, Crawford and Joliet 6; the overall durations for closed-cycle conversion at Will County 3/4 and Joliet 7/8 are estimated to be 31 months and 33 months, respectively.

The overall duration for a multiple station cooling tower installation will require over twice as much time as a single-station installation. From a design standpoint, much of the required effort will be largely repetitive. For example, once a cooling tower specification is prepared for one station, it will take considerably less time to prepare a comparable specification for another station. However, it is likely that MWGen's ability to pursue multiple cooling tower projects in parallel will be limited by the time required to fabricate and deliver the cooling tower material and equipment and/or by the time required to construct the tower and other structures. At present, there are few utility-size cooling tower projects underway nationally and the construction labor market is favorable. With such conditions, and assuming the necessary funds are available, one might be able to execute projects at Fisk and Crawford stations in parallel, and to start projects at the next stations in sequence with a 12- to 15-month lag. Assuming such "best case" scenario circumstances, after the time required to complete the final design criteria, the overall time required to implement closed-cycle cooling at the five MWGen stations is estimated to be a minimum of 60 months. However, as the economy improves, lead times will lengthen and construction labor will become less available. Therefore it is not possible to predict accurately the overall time required to design, fabricate and install cooling towers at five power stations. Again, assuming that funding can be obtained when needed, for planning purposes, S&L recommends that at least 72 months should be allowed for that process.

There are several permits required to install cooling towers at the MWGen stations. S&L believes the time frames we have indicated in Figure 6-1 for acquisition of those permits for a single tower installation is reasonable, but any delay in preparation, agency review or agency issue of those permits will result in a commensurate delay in the overall project schedule. If all of the towers at each of the MWGen stations had to be installed to meet a single compliance deadline and therefore, multiple permit applications were submitted to the Agency simultaneously or close in time, it is expected that the time frames indicated in Figure 6-1 for agency review and issuance of permits for a single cooling tower installation would increase significantly due to the additional permit applications review burden this would place on the Agency.

The extent of transmission line relocation was not examined in any detail during this study. The time required to obtain permission for line relocation and to actually relocate the lines has not been considered in the schedule discussion above.

Activity ID	Activity Description	Days
Permitting		
30	Corps of Engineer	130
40	Local Permits	130
10	Air Permitting	185
20	NPDES Permitting	260
Engineering Study		
100	Engineering Authorization	0
110	Site Visit / Gather Station Data	10
Cooling Tower Procurement		
160	Prepare Cooling Tower Specification	20
170	Vendor Bid Period	15
180	Evaluate & Award	20
190	Fabricate and Deliver Cooling Tower	125
Electical Aux. Power Modification Procurement		
240	Prepare Electrical Auxiliary Modification Spec	20
250	Vendor Bid Period	15
260	Evaluate & Award	20
270	Fabricate and Deliver Electrical Aux Power Equip	100
Engineering / Design		
280	Prepare Cooling Tower Foundation	40
300	Piping Design	40
310	Electrical Design	60
290	Prepare Civil / Intake / Discharge Design	100
Civil Contractor Procurement		
312	Prepare Installation Spec	30
313	Contractor Bid Period	30
314	Evaluate & Award	30
315	Contractor Mobilize	30
Construction Contractor Procurement		
320	Prepare Installation Spec	30
330	Contractor Bid Period	30
340	Evaluate & Award	30
350	Contractor Mobilize	30
Construction / Startup		
Structural		
365	Intake and Discharge Structures Modifications	60
375	Install Divertor Gates	60
385	Install Division Walls	80
387	Install Cooling Tower Supply Pumps @ Discharge S	20
410	Connect Intake/Discharge Flumes (Joliet 7&8)	60
360	Install Cooling Tower Basin	60
395	Install Cooling Tower Pump Structure	40



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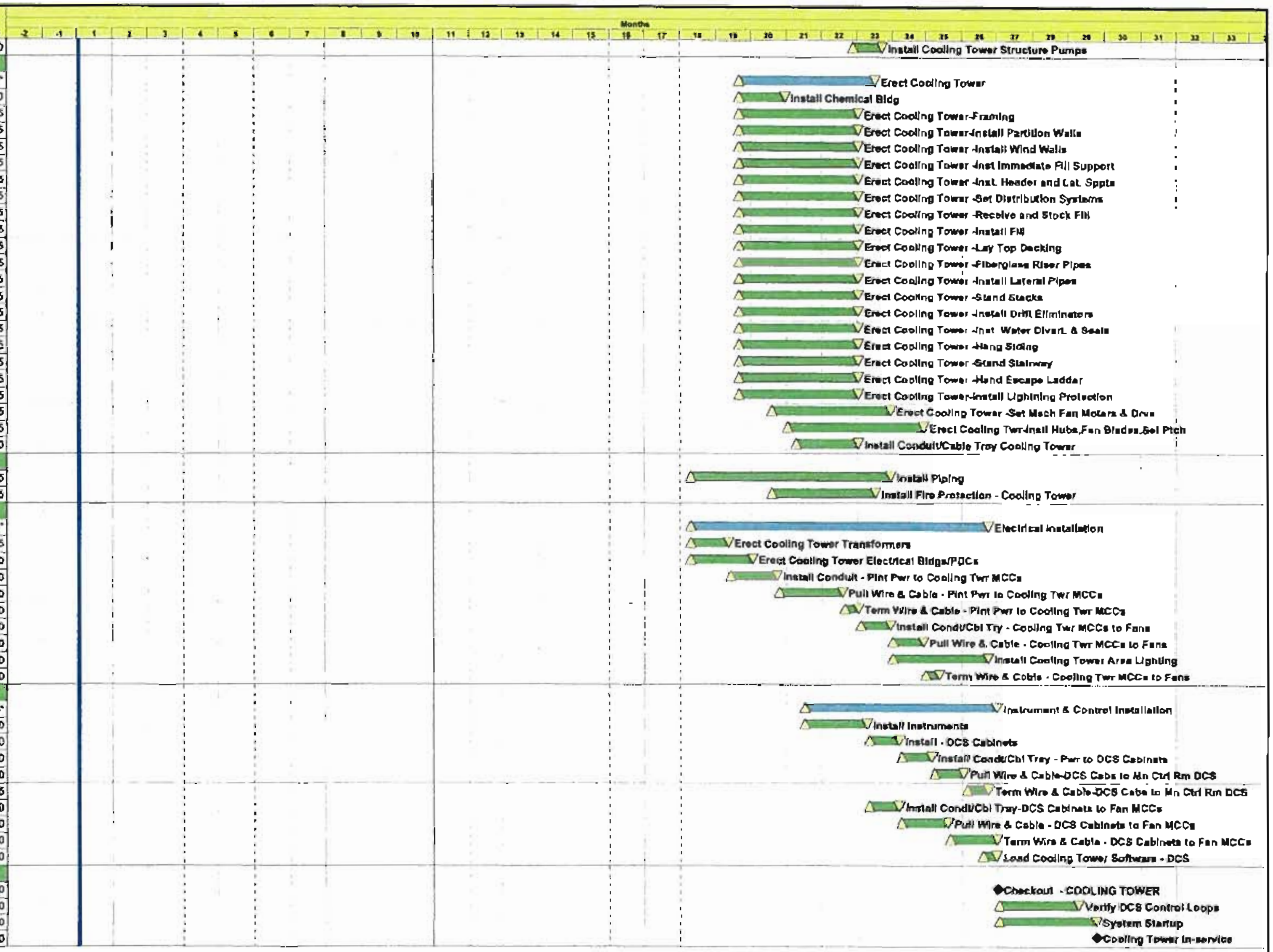
Typical Single Station
Project Schedule
Cooling Tower Addition
Design-Fabrication-Installation

Sheet 1 of 2

Sargent & Lundy LLC

Activity ID	Activity Description	Days
400	Install Cooling Tower Structure Pumps	20
Cooling Tower/Mechanical		
C5CWGVC000	Erect Cooling Tower	85*
405	Install Chemical Bldg	30
C5CWGVC016	Erect Cooling Tower-Framing	75
C5CWGVC017	Erect Cooling Tower-Install Partition Walls	75
C5CWGVC018	Erect Cooling Tower -Install Wind Walls	75
C5CWGVC019	Erect Cooling Tower -Inst Immediate Fill Support	75
C5CWGVC020	Erect Cooling Tower -Inst. Header and Lat. Sppts	75
C5CWGVC022	Erect Cooling Tower -Set Distribution Systems	75
C5CWGVC023	Erect Cooling Tower -Receive and Stock Fill	75
C5CWGVC024	Erect Cooling Tower -Install Fill	75
C5CWGVC025	Erect Cooling Tower -Lay Top Decking	75
C5CWGVC026	Erect Cooling Tower -Fiberglass Riser Pipes	75
C5CWGVC027	Erect Cooling Tower -Install Lateral Pipes	75
C5CWGVC030	Erect Cooling Tower -Stand Stacks	75
C5CWGVC031	Erect Cooling Tower -Install Drift Eliminators	75
C5CWGVC032	Erect Cooling Tower -Inst. Water Divert. & Seals	75
C5CWGVC033	Erect Cooling Tower -Hang Siding	75
C5CWGVC034	Erect Cooling Tower -Stand Stairway	75
C5CWGVC035	Erect Cooling Tower -Hand Escape Ladder	75
C5CWGVC036	Erect Cooling Tower-Install Lightning Protection	75
C5CWGVC028	Erect Cooling Tower -Set Mech Fan Motors & Drvs	75
C5CWGVC029	Erect Cooling Twr-Instl Hubs,Fan Blades,Set Ptch	85
C5CWPEW000	Install Conduit/Cable Tray Cooling Tower	40
Piping/Fire Protection		
380	Install Piping	125
C5FPGVF010	Install Fire Protection - Cooling Tower	65
Electrical		
420	Electrical Installation	185*
455	Erect Cooling Tower Transformers	25
450	Erect Cooling Tower Electrical Bldgs/PDCs	40
460	Install Conduit - Plnt Pwr to Cooling Twr MCCs	30
465	Pull Wire & Cable - Plnt Pwr to Cooling Twr MCCs	40
470	Term Wire & Cable - Plnt Pwr to Cooling Twr MCCs	10
475	Install Cond/Cbl Try - Cooling Twr MCCs to Fans	20
480	Pull Wire & Cable - Cooling Twr MCCs to Fans	20
490	Install Cooling Tower Area Lighting	60
485	Term Wire & Cable - Cooling Twr MCCs to Fans	10
I&C		
495	Instrument & Control Installation	120*
C5CWPND010	Install Instruments	40
500	Install - DCS Cabinets	20
505	Install Cond/Cbl Tray - Pwr to DCS Cabinets	20
510	Pull Wire & Cable-DCS Cabs to Mn Ctrl Rm DCS	20
C5CWPEW020	Term Wire & Cable-DCS Cabs to Mn Ctrl Rm DCS	15
545	Install Cond/Cbl Tray-DCS Cabinets to Fan MCCs	20
550	Pull Wire & Cable - DCS Cabinets to Fan MCCs	30
555	Term Wire & Cable - DCS Cabinets to Fan MCCs	30
580	Load Cooling Tower Software - DCS	10
Start-Up & Commissioning		
C514-820	Checkout - COOLING TOWER	0
565	Verify DCS Control Loops	50
430	System Startup	60
440	Cooling Tower In-service	0



EXHIBITS

EXHIBIT A

Cooling Tower Equipment Arrangements

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S)) PERFORMING THE WORK.

FILENAME: msk-fis-1.dgn

DRAWING RELEASE RECORD					
REV.	DATE REL'D.	PREPARED	REVIEWED	APPROVED	PURPOSE

DRAWING RELEASE RECORD					
REV.	DATE REL'D.	PREPARED	REVIEWED	APPROVED	PURPOSE

SCALE	1"=60'
PROJECT NUMBER	01683-068

GENERAL ARRANGEMENT
SCR/DRY FGD/COOLING TOWER
UNIT 19
FISK STATION
MIDWEST GENERATION
CHICAGO, ILLINOIS

Sargent & Lundy

DRAWING NO.	REV.
MSK-FIS-1	1

SHEET OF

12/20/2010 1:42:18 PM

LEGEND:
1. SDA
2. BAGHOUSE
3. 10 BOOSTER FANS
■ 4. RECYCLE ASH SILO
■ 5. FGD WASTE SILO
■ 6. SLURRY HOUSE
7. CARBON SILOS
■ 8. LIME SILO
■ 9. AMMONIA STORAGE
■ 10. COOLING TOWER
■ 11. BARRIER WALL
■ 12. INTAKE STRUCTURE

■ - COMMON WITH UNIT 3&4

GRAPHIC SCALE

1" = 100'

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S)) PERFORMING THE WORK.

FILENAME: msk-wil-1.dgn

DRAWING RELEASE RECORD					
REV.	DATE REL'D.	PREPARED	REVIEWED	APPROVED	PURPOSE

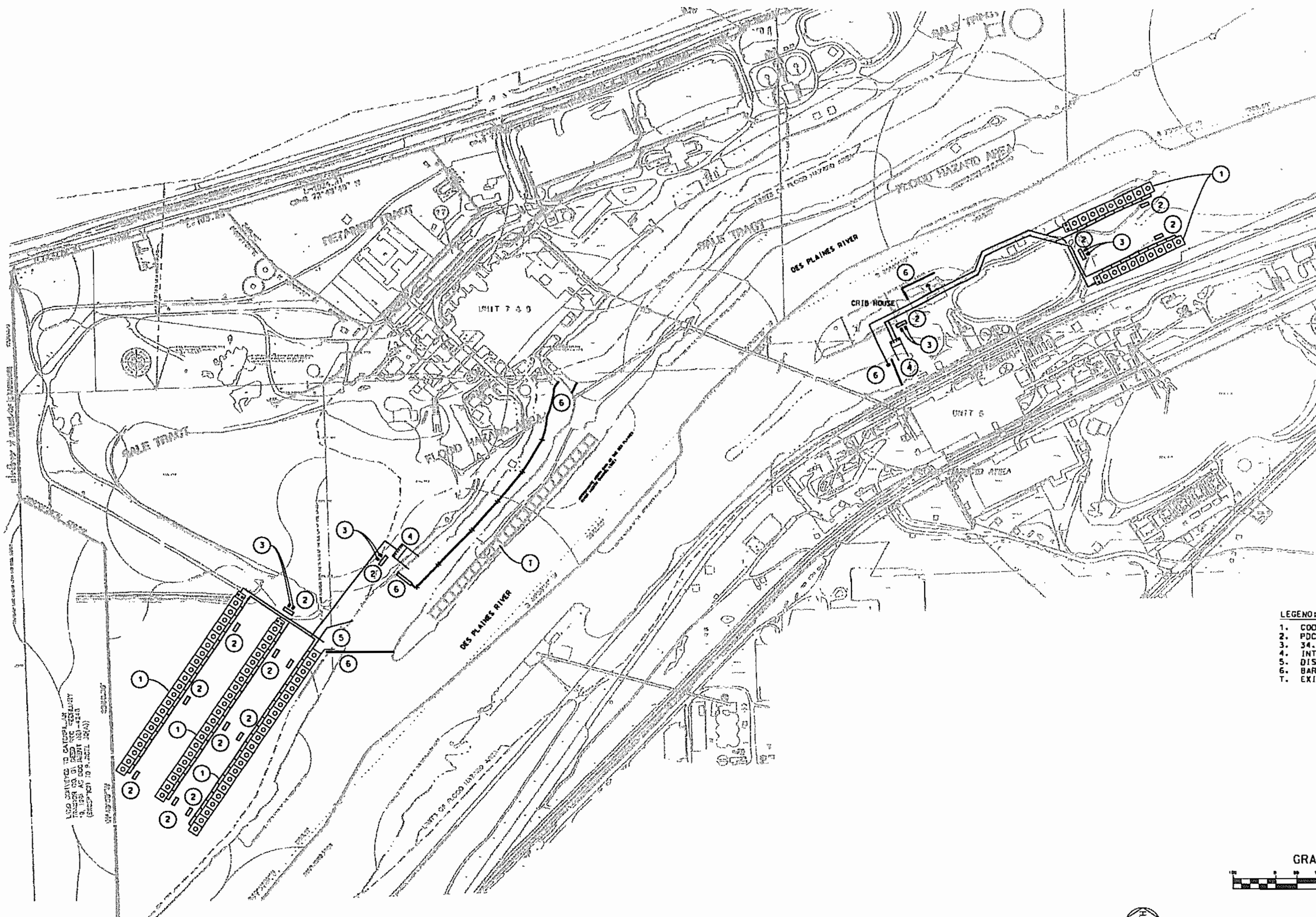
DRAWING RELEASE RECORD					
REV.	DATE REL'D.	PREPARED	REVIEWED	APPROVED	PURPOSE

SCALE 1"=100'
PROJECT NUMBER

GENERAL ARRANGEMENT
DRY FGD COOLING TOWER
STATION 8 - UNIT 3&4
WILL COUNTY STATION
MIDWEST GENERATION
CHICAGO, ILLINOIS

Sargent & Lundy

DRAWING NO. MSK-WIL-1
REV. 3
SHEET OF



LEGEND:
1. COOLING TOWER
2. PDC
3. 34.5 - 4.16 KV TRANSFORMER
4. INTAKE STRUCTURE
5. DISCHARGE STRUCTURE
6. BARRIER WALL
T. EXISTING PSI HELPER TOWER

GRAPHIC SCALE

1" = 200'

NORTH

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S)) PERFORMING THE WORK.

FILENAME: msk-jol-8.dgn

DRAWING RELEASE RECORD					
REV.	DATE REL'D.	PREPARED	REVIEWED	APPROVED	PURPOSE

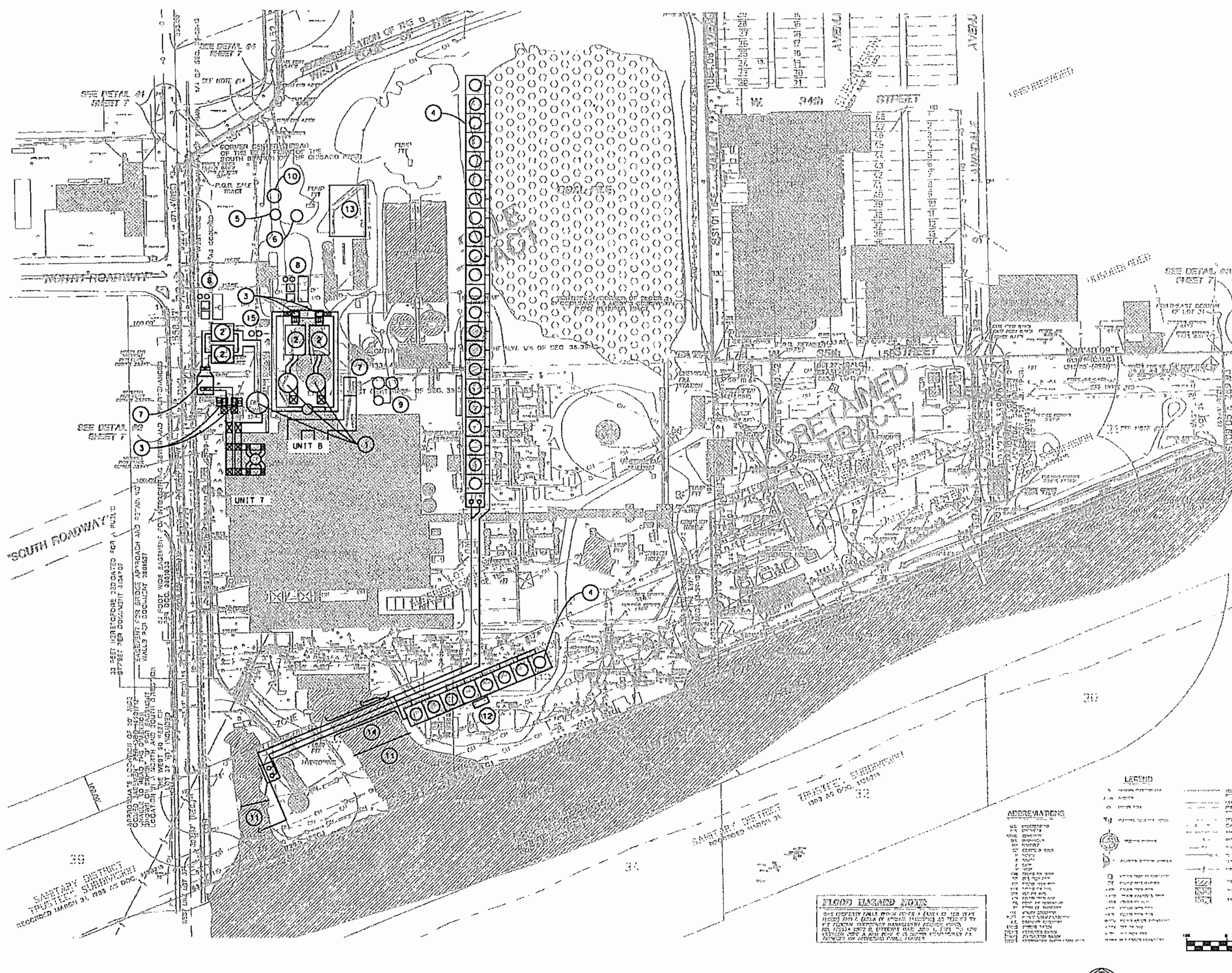
DRAWING RELEASE RECORD					
REV.	DATE REL'D.	PREPARED	REVIEWED	APPROVED	PURPOSE

SCALE: 1"=200'
PROJECT NUMBER: 01683-068

GENERAL ARRANGEMENT
COOLING TOWERS
STATION 9 & 29
JOLIET STATION
MIDWEST GENERATION
CHICAGO, ILLINOIS

Sargent & Lundy

DRAWING NO.: MSK-JOL-8
REV.: 2
SHEET OF



LEGEND:

1. SDA (TYP.)
2. BAGHOUSE (TYP.)
3. ID BOOSTER FAN (TYP.)
* 4. COOLING TOWER (TYP.)
* 5. FGD WASTE SILO
* 6. LIME SILO/UNLOADING
7. SCR
8. SCR/FGD ELECTRICAL EQUIPMENT BUILDINGS
* 9. SLURRY HOUSE
* 10. RECYCLED ASH SILO
* 11. BARRIER WALLS
* 12. COOLING TOWER ELECTRICAL BUILDING (TYP.)
* 13. UREA BLDG.
* 14. PIPE BRIDGE
* 15. CARBON SILO

* - COMMON WITH UNIT 7&8

GRAPHIC SCALE

1" = 100'

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUBCONTRACTOR(S)) PERFORMING THE WORK.

FILENAME: msk-cra-1.dgn

DRAWING RELEASE RECORD					
REV.	DATE REL'D.	PREPARED	REVIEWED	APPROVED	PURPOSE

DRAWING RELEASE RECORD					
REV.	DATE REL'D.	PREPARED	REVIEWED	APPROVED	PURPOSE

SCALE	1"=100'
PROJECT NUMBER	01683-068

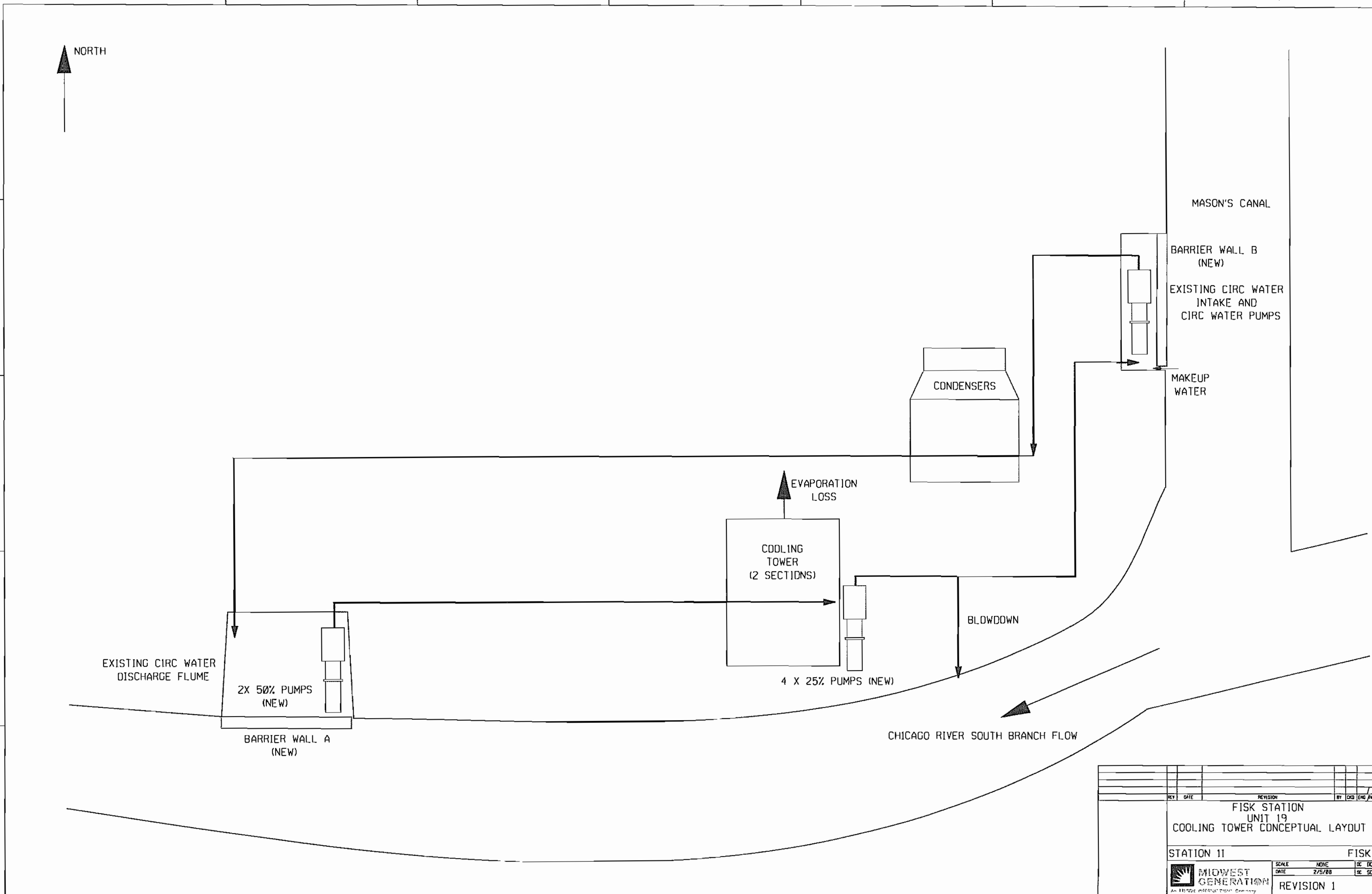
GENERAL ARRANGEMENT
SCR/DRY FGD/COOLING TOWER
UNIT 7&8
CRAWFORD STATION
MIDWEST GENERATION
CHICAGO, ILLINOIS

Sargent & Lundy

DRAWING NO.	REV.
MSK-CRA-1	1
SHEET OF	

EXHIBIT B

Closed-Cycle Cooling Tower Flow Diagrams



REV	DATE	REVISION	BY	CKD	ENG	APPS

FISK STATION
UNIT 19
COOLING TOWER CONCEPTUAL LAYOUT

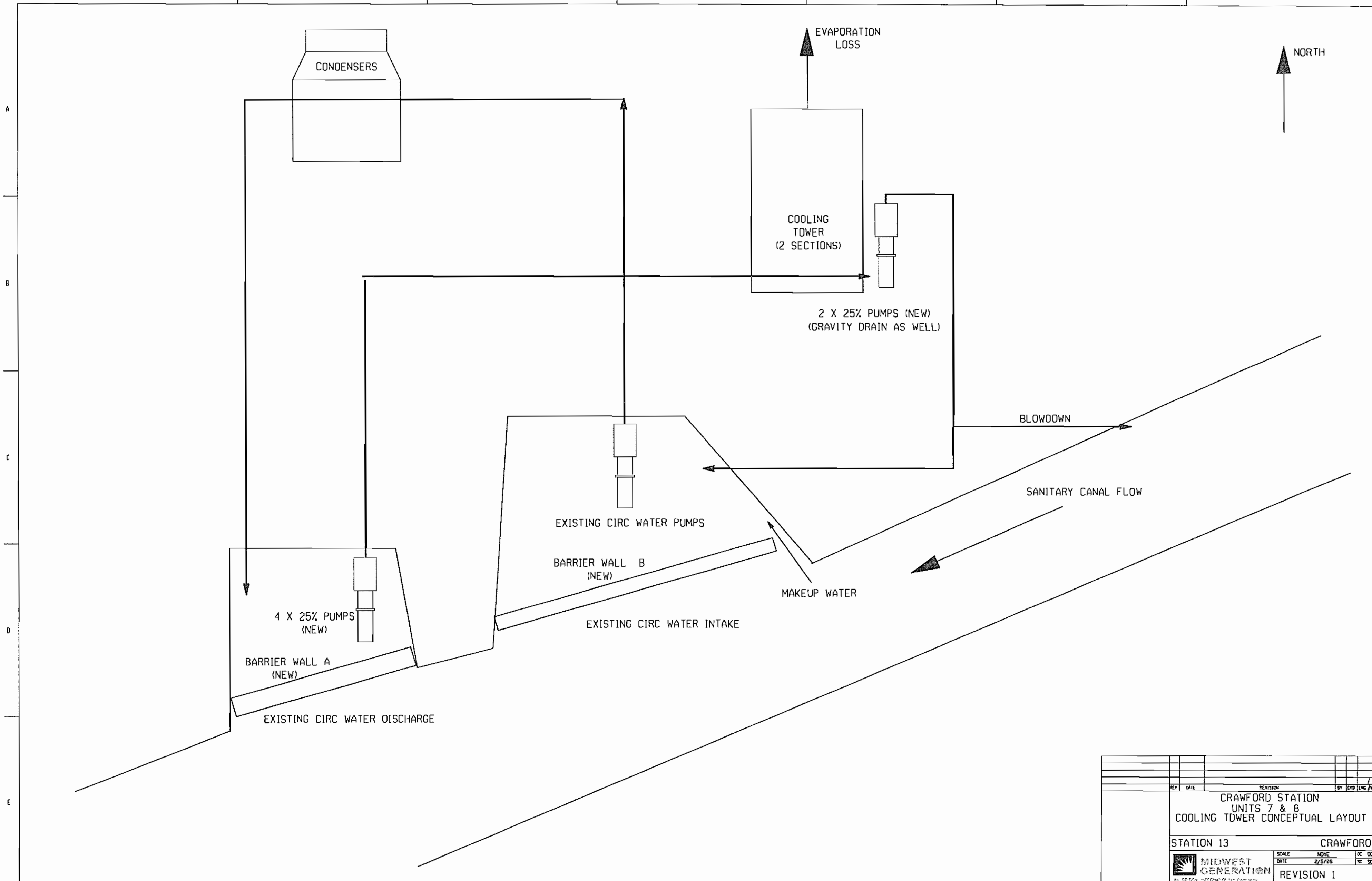
STATION 11 FISK

MIDWEST GENERATION

SCALE NONE
DATE 2/5/08

REVISION 1

CADME JDH-2/5/08



CRAWFORD STATION
UNITS 7 & 8
COOLING TOWER CONCEPTUAL LAYOUT

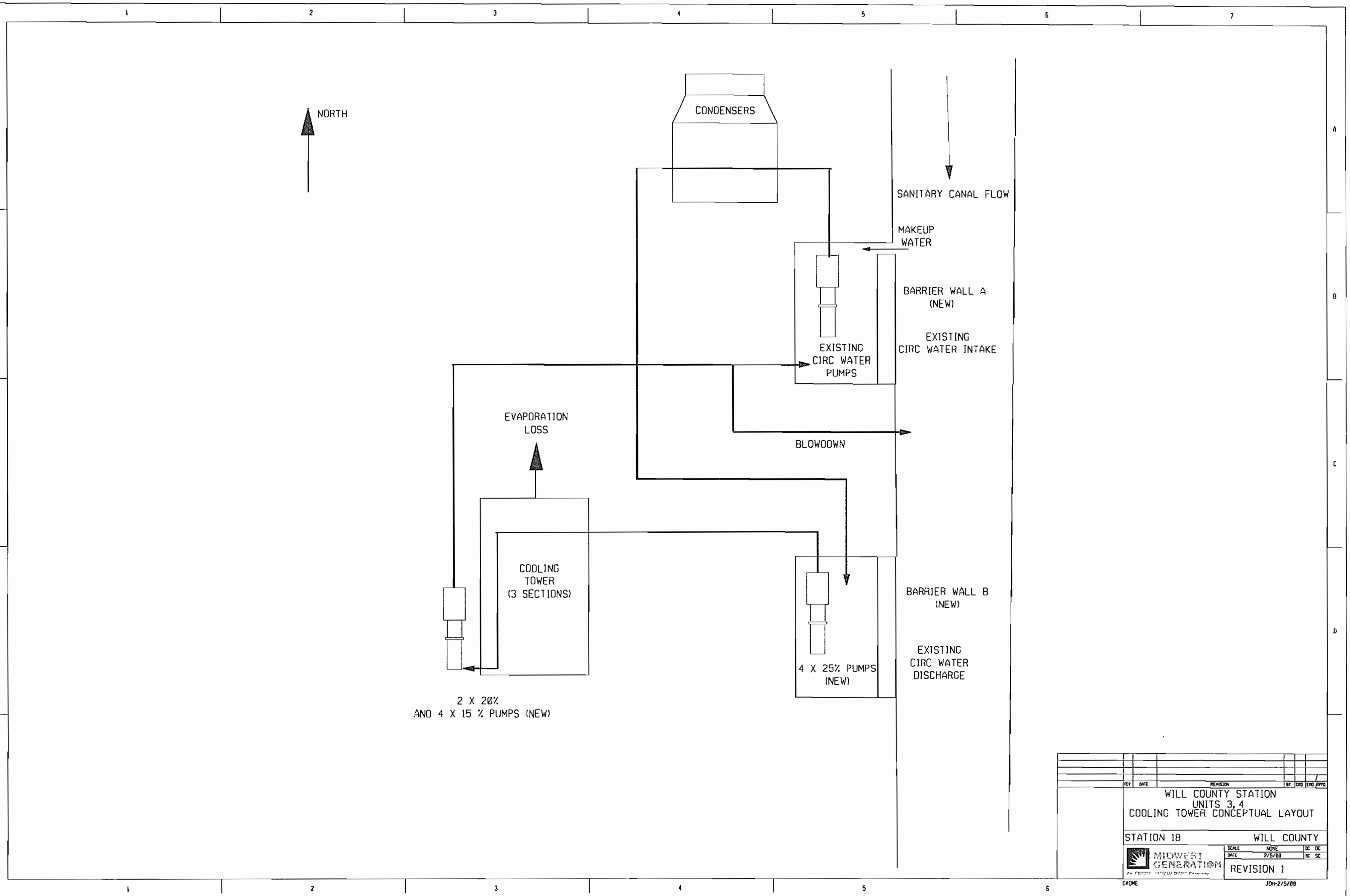
STATION 13 CRAWFORD

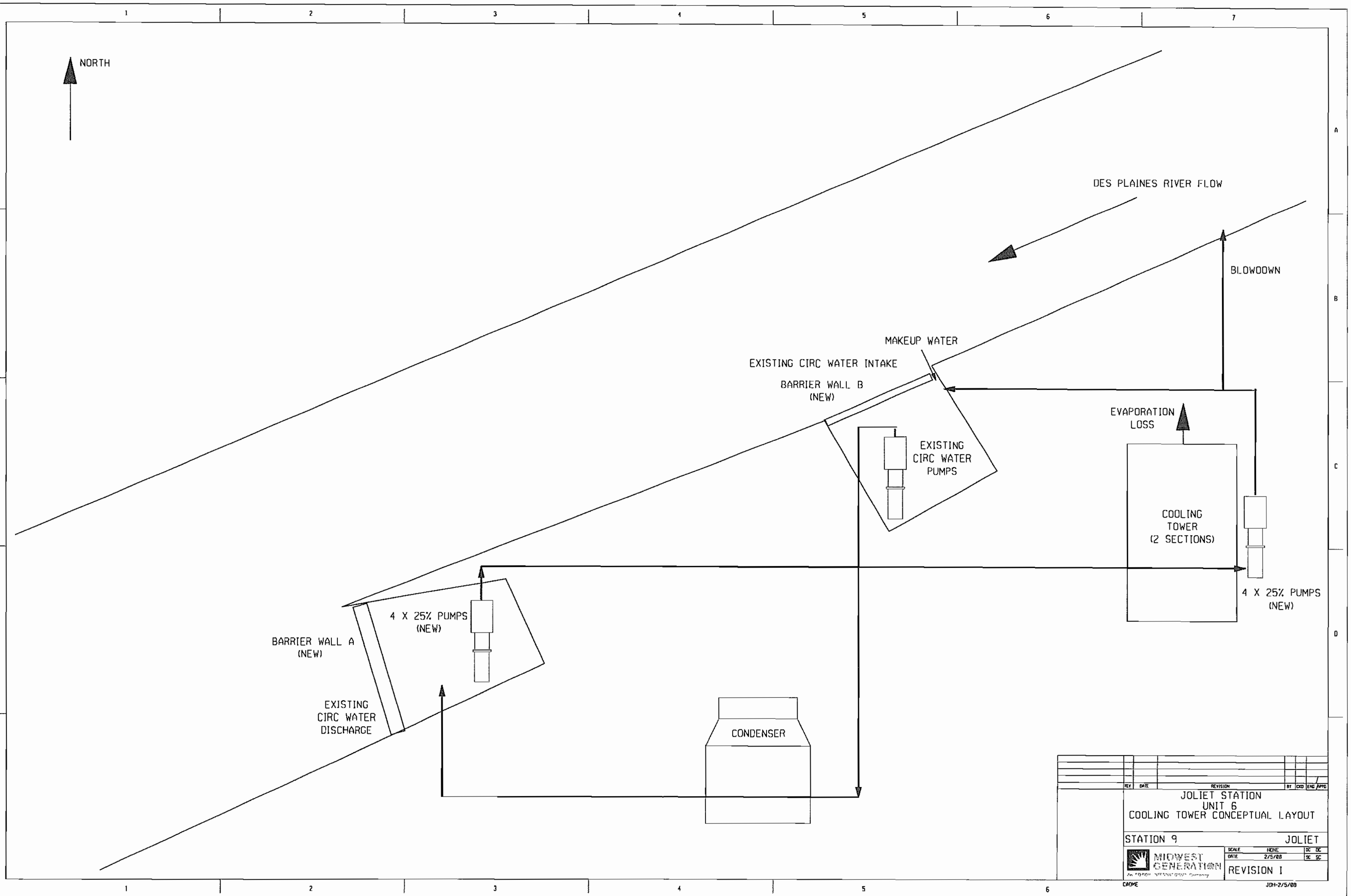
MIDWEST GENERATION

SCALE NONE
DATE 2/5/08

REVISION 1

JDH-2/5/08


NORTH
CONDENSERS
SANITARY CANAL FLOW
MAKEUP WATER
BARRIER WALL A (NEW)
EXISTING CIRC WATER INTAKE
EXISTING CIRC WATER PUMPS
EVAPORATION LOSS
BLOWDOWN
COOLING TOWER (3 SECTIONS)
BARRIER WALL B (NEW)
EXISTING CIRC WATER DISCHARGE
4 X 25% PUMPS (NEW)
2 X 20% AND 4 X 15 % PUMPS (NEW)
REV DATE REVISION BY CKD ENG APPD
WILL COUNTY STATION
UNITS 3, 4
COOLING TOWER CONCEPTUAL LAYOUT
STATION 18
WILL COUNTY
MIDWEST GENERATION
SCALE NONE
DATE 2/5/08
REVISION 1
CADME
JDH-2/5/08


NORTH
DES PLAINES RIVER FLOW
BLOWDOWN
MAKEUP WATER
EXISTING CIRC WATER INTAKE
BARRIER WALL B
(NEW)
EVAPORATION
LOSS
EXISTING
CIRC WATER
PUMPS
COOLING
TOWER
(2 SECTIONS)
4 X 25% PUMPS
(NEW)
BARRIER WALL A
(NEW)
EXISTING
CIRC WATER
DISCHARGE
CONDENSER
REV
DATE
REVISION
BY
CKD
ENG
APPD
JOLIET STATION
UNIT 6
COOLING TOWER CONCEPTUAL LAYOUT
STATION 9
JOLIET
MIDWEST
GENERATION
SCALE
NONE
DATE
2/5/08
REVISION I

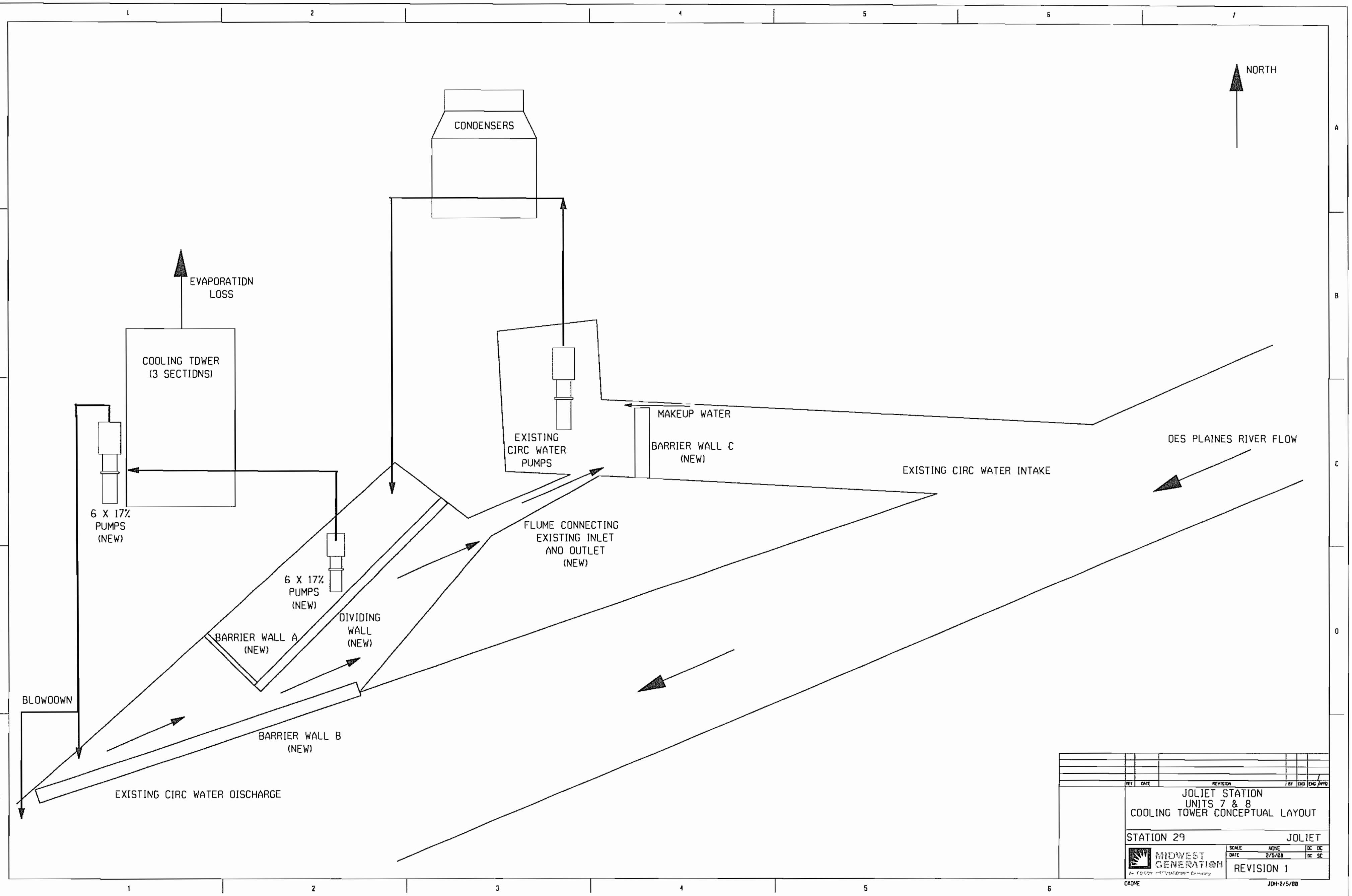

NORTH
CONDENSERS
EVAPORATION LOSS
COOLING TOWER (3 SECTIONS)
6 X 17% PUMPS (NEW)
EXISTING CIRC WATER PUMPS
MAKEUP WATER
BARRIER WALL C (NEW)
DES PLAINES RIVER FLOW
EXISTING CIRC WATER INTAKE
FLUME CONNECTING EXISTING INLET AND OUTLET (NEW)
6 X 17% PUMPS (NEW)
DIVIDING WALL (NEW)
BARRIER WALL A (NEW)
BLOWDOWN
BARRIER WALL B (NEW)
EXISTING CIRC WATER DISCHARGE
JOLIET STATION
UNITS 7 & 8
COOLING TOWER CONCEPTUAL LAYOUT
STATION 29
JOLIET
MIDWEST GENERATION
SCALE NONE
DATE 2/5/08
REVISION 1
CADME
JDH-2/5/08

EXHIBIT C

Cooling Tower Sizing and Specification Data

Cooling Tower Design Data - Fisk Unit 19
Cooling Tower Design Data

Case	Units	Wet/Dry
Total Number of Tower Sections		2
Water Flow to be Cooled	gpm	210,000 total
Ambient Wet Bulb Temperature	°F	78
Ambient Dry Bulb Temperature	°F	94
Cooling Tower Approach	°F	7
Cooling Tower Range	°F	12.72
Cooling Tower Drift	%	0.0005
Cycles of Concentration		5
Makeup Source		South Branch of Chicago River
Makeup Total Suspended Solids*	mg/l	17.1
Makeup Total Dissolved Solids*	mg/l	736
Makeup BOD*	mg/l	6
Cooling Tower Cell Arrangement		Single Row

Cooling Tower Design Data - Crawford Units 7&8
Cooling Tower Design Data

Case	Units	Wet/Dry
Total Number of Tower Sections		2
Water Flow to be Cooled	gpm	382,400 total
Ambient Wet Bulb Temperature	°F	78
Ambient Dry Bulb Temperature	°F	94
Cooling Tower Approach	°F	7
Cooling Tower Range	°F	12.61
Cooling Tower Drift	%	0.0005
Cycles of Concentration		5
Makeup Source		Chicago Sanitary and Ship Canal
Makeup Total Suspended Solids*	mg/l	17.1
Makeup Total Dissolved Solids*	mg/l	736
Makeup BOD*	mg/l	6
Cooling Tower Cell Arrangement		Single Row

Cooling Tower Design Data - Will County Units 3&4
Cooling Tower Design Data

Case	Units	Wet/Dry
Total Number of Tower Sections		3
Water Flow to be Cooled	gpm	600,000 total
Ambient Wet Bulb Temperature	°F	78
Ambient Dry Bulb Temperature	°F	94
Cooling Tower Approach	°F	7
Cooling Tower Range	°F	11.12
Cooling Tower Drift	%	0.0005
Cycles of Concentration		5
Makeup Source		Chicago Sanitary and Ship Canal
Makeup Total Suspended Solids*	mg/l	18.7
Makeup Total Dissolved Solids*	mg/l	844
Makeup BOD*	mg/l	6.4
Cooling Tower Cell Arrangement		Single Row

Cooling Tower Design Data - Joliet Unit 6
Cooling Tower Design Data

Case	Units	Wet/Dry
Total Number of Tower Sections		2
Water Flow to be Cooled	gpm	261,000 total
Ambient Wet Bulb Temperature	°F	78
Ambient Dry Bulb Temperature	°F	94
Cooling Tower Approach	°F	7
Cooling Tower Range	°F	10.69
Cooling Tower Drift	%	0.0005
Cycles of Concentration		5
Makeup Source		Lower Des Plaines River
Makeup Total Suspended Solids*	mg/l	21.7
Makeup Total Dissolved Solids*	mg/l	587
Makeup BOD*	mg/l	3
Cooling Tower Cell Arrangement		Single Row

Cooling Tower Design Data - Joliet Units 7&8
Cooling Tower Design Data

Case	Units	Wet/Dry
Total Number of Tower Sections		3
Water Flow to be Cooled	gpm	920,000 total
Ambient Wet Bulb Temperature	°F	78
Ambient Dry Bulb Temperature	°F	94
Cooling Tower Approach	°F	7
Cooling Tower Range	°F	12.44
Cooling Tower Drift	%	0.0005
Cycles of Concentration		5
Makeup Source		Lower Des Plaines River
Makeup Total Suspended Solids*	mg/l	21.7
Makeup Total Dissolved Solids*	mg/l	587
Makeup BOD*	mg/l	3
Cooling Tower Cell Arrangement		Single Row

* Total Suspended Solids, Total Dissolved Solids and BOD data are 90th percentile values for locations adjacent to each station. Water quality information was obtained from the Metropolitan Water Reclamation District. Refer to Exhibit F.

EXHIBIT D

Design Basis for Cooling Tower Selection

The following are unit specific design criteria that were used for developing the cooling tower options for each station. All O&M and lost capacity costs were developed using an annual-average plant capacity factor of 75 percent.

A. Design Features for Fisk Station:

1) The cooling system design and cost estimate are for cooling towers for Fisk Unit 19. Tower design data is shown in Exhibit C.
2) The heat rejection at the current unit gross rating of 348 MW was calculated to be 1,335 mmBtu/hr based on condenser heat balance calculations using the original heat balance diagrams.
3) The CW flow rate through the condenser was assumed to be 210,000 gpm, the original design value. This results in a calculated condenser temperature rise of 12.72°F. However, plant personnel indicate that the temperature rise can be as high as 20°F. It is not known if this is due to deteriorated CW pump performance or operation with a CW pump offline. The calculated rise and original flow rate were used in the tower design and cost estimate, resulting in a larger tower and higher cost estimate.
4) At the summer design wet bulb temperature, an 85°F condenser inlet temperature would occur under closed-cycle operation. This is calculated to result in a turbine backpressure of 2.29 in HgA at a 70% cleanliness factor.
5) Based on station data and Metropolitan Water Reclamation District data provided by Midwest Generation, the cooling tower was designed for river water makeup with a total suspended solids level of 17.1 ppm, a total dissolved solids level of 736 ppm, and a BOD of 6 ppm. Based on the relatively low total suspended solids levels in the make-up, Marley designed the cooling towers to use anti-clog film fill.
6) The cooling system design includes two cooling towers of 8 cells each. Each cell is 48 ft x 48 ft and has a 250 hp fan that is 30 ft in diameter.

B. Design Features for Crawford Station:

1) The cooling system design and cost estimate are for cooling towers shared by Crawford Units 7&8. Tower design data is shown in Exhibit C.
2) The heat rejection for the cooling towers at the current unit gross rating was calculated based on condenser heat balance calculations using the original heat balance diagrams. For Unit 7 the heat rejection was calculated to be 992 mmBtu/hr at 237 MW. For Unit 8 the heat rejection was calculated to be 1,417 mmBtu/hr at 348 MW.
3) The combined CW flow rate through the Units 7 and 8 condensers was assumed to be 382,400 gpm, the original design value. This results in a calculated combined Unit 7 and 8 CW temperature rise of 12.61°F. However, plant personnel indicate that the temperature rise can be as high as 16°F for Unit 7 and 15°F for Unit 8. It is not known if this is due to deteriorated CW pump performance or operation with a CW pump offline. The calculated rise and original flow rate were used in the tower design and cost estimate, resulting in a larger tower and higher cost estimate.

4) At the summer design wet bulb temperature, an 85°F condenser inlet temperature would occur under closed-cycle operation. This is calculated to result in turbine backpressure of 2.94 and 2.41 in HgA the Units 7 and 8, respectively, at a 70% cleanliness factor.

5) Based on station data and Metropolitan Water Reclamation District data provided by Midwest Generation, the cooling tower was designed for river water makeup with a total suspended solids level of 17.1 ppm, a total dissolved solids level of 736 ppm, and a BOD of 6 ppm. Based on this data, Marley designed the cooling towers to use anti-clog film fill.

6) The cooling system design includes two cooling tower sections with a total of 30 cells. Each cell is 48 ft x 48 ft and has a 250 hp fan that is 28 ft in diameter.

C. Design Features for Will County Station:

1) The cooling system design and cost estimate are for cooling towers shared by Will County Units 3 and 4. Tower design data is shown in Exhibit C.

2) The heat rejection for the cooling towers at the current unit gross rating was calculated based on condenser heat balance calculations using the original heat balance diagrams. For Unit 3 the heat rejection was calculated to be 1,099 mmBtu/hr at 281 MW. For Unit 4 the heat rejection was calculated to be 2,235 mmBtu/hr at 551 MW.

3) The combined CW flow rate through the Units 3 and 4 condensers was assumed to be 600,000 gpm, the original design value. This results in a calculated combined Unit 3 and 4 CW temperature rise of 11.12°F.

4) At the summer design wet bulb temperature, an 85°F condenser inlet temperature would occur under closed-cycle operation. This is calculated to result in turbine backpressures of 2.34 for Unit 3, and 2.17 HgA for Unit 4, at a 70% cleanliness factor.

5) Based on station data and Metropolitan Water Reclamation District data provided by Midwest Generation, the cooling tower was designed for river water makeup with a total suspended solids level of 18.7 ppm, a total dissolved solids level of 844 ppm, and a BOD of 6.4 ppm. Based on this data, Marley designed the cooling towers to use anti-clog film fill.

6) The cooling system design includes three cooling tower sections with a total of 40 cells. Each cell is 48 ft long x 48 ft wide and has a 250 hp fan that is 28 ft in diameter.

D. Design features for Joliet Unit 6:

1) The cooling system design for the Joliet 6 cooling towers are shown in Exhibit C.

2) The heat rejection at the current unit gross rating of 341 MW was calculated to be 1,395 mmBtu/hr based on condenser heat balance calculations using the original heat balance diagrams.

3) The CW flow rate through the Unit 6 condenser was assumed to be 261,000 gpm, the original design value. This results in a calculated CW temperature rise of 10.69°F.

4) At the summer design wet bulb temperature, an 85°F condenser inlet temperature would occur under closed-cycle operation. This results in a turbine backpressure of 2.30 in HgA at a 70% cleanliness factor.

5) Based on station data and Metropolitan Water Reclamation District data provided by Midwest Generation, the cooling tower was designed for river water makeup with a total suspended solids level of 21.7 ppm, a total dissolved solids level of 587 ppm, and a BOD of 3 ppm. Based on this data, Marley designed the cooling towers to use anti-clog film fill.

6) The cooling system design includes two cooling towers with a total of 18 cells. Each cell is 48 ft long x 48 ft wide and has a 240 hp fan that is 30 ft in diameter.

E. Design Features for Joliet Unit 7&8:

1) The cooling system design and cost estimate are for cooling towers shared by Joliet Units 7&8. This is shown in Exhibit C.

2) The heat rejection at the current unit gross rating of 569 MW was calculated to be 2,861 mmBtu/hr based on condenser heat balance calculations using the original heat balance diagrams.

3) The CW flow rate through the Units 7&8 condensers was assumed to be 920,000 gpm, the original design value. This results in a calculated CW temperature rise of 12.44°F.

4) At the summer design wet bulb temperature, an 85°F condenser inlet temperature would occur under closed-cycle operation. This results in a calculated turbine backpressure of 2.32 in HgA for Unit 7 or 8.

5) Based on station data and Metropolitan Water Reclamation District data provided by Midwest Generation, the cooling tower was designed for river water makeup with a total suspended solids level of 21.7 ppm, a total dissolved solids level of 587 ppm, and a BOD of 3 ppm. Based on this data, Marley designed the cooling towers to use anti-clog film fill.

6) The cooling system design includes three cooling tower sections with a total of 64 cells. Each cell is 48 ft long x 48 ft wide and has a 250 hp fan that is 30 ft in diameter.

7) The existing Psychometric System Inc (PSI) helper cooling tower was assumed to be abandoned in place. The high drift rate of this tower would make permitting more difficult, and the tower would be difficult to incorporate into a closed-cycle operating scenario.

EXHIBIT E

Particulate Emissions Calculations

PROJECT: MidWest Gen Cooling Tower Evaluation

		Wet Cooling Towers				
Case Description		Fisk 19	Crawford 7&8	W/C 3&4	Joliet 6	Joliet 7&8
Number of Total Cells		16	30	40	18	64
Number of Cooling Towers (Marley info is all in terms of 2 towers)		2	2	2	2	2
Water						
Makeup Water TDS	ppm	736	736	844	587	587
Maximum Cycles of Concentration		5	5	5	5	5
TDS of Circ. Water	ppm (mg/L)	3,680	3,680	4,220	2,935	2,935
Cooling Tower						
Hours of Operation per Year	hours/year	8,760	8,760	8,760	8,760	8,760
Total Circulating Water Flow per Cell	gpm	**13,125**	**12,747**	**15,000**	**14,500**	**14,375**
Total Circulating Water Flow per Cell	gal/hr	787,500	764,800	900,000	870,000	862,500
Total Circulating Water Flow per Cell	lb/hr	6,567,750	6,378,432	7,506,000	7,255,800	7,193,250
Total Circulating Water Flow per Cell	L/hr	2,981,003	2,895,074	3,406,860	3,293,298	3,264,908
Approximate Cooling Water Make-up Flow	%	1.575%	1.575%	1.575%	1.575%	1.575%
Approximate Cooling Water Make-up Flow per Cell	gpm	207	201	236	228	226
Approximate Cooling Water Make-up Flow per Cell	MGD	0.30	0.29	0.34	0.33	0.33
Approximate Cooling Water Make-up Flow (Total)	MGD	4.80	8.70	13.60	5.94	21.12
Mist Eliminator/Drift Rate	%	0.0005%	0.0005%	0.0005%	0.0005%	0.0005%
Calculated Drift Loss per Cell	lb/hr	32.8	31.9	37.5	36.3	36.0
Calculated Drift Loss per Cell	gpm	0.066	0.064	0.075	0.073	0.072
Calculated Drift Loss (Total)	gpm	1.0	1.9	3.0	1.3	4.6
PM10:PM Ratio	ratio	41.6%	41.6%	36.3%	50.7%	50.7%
PM2.5:PM Ratio	ratio	0.20%	0.20%	0.20%	0.20%	0.20%
EMISSIONS						
PER CELL						
PM Emissions per Cell (TDS x Drift Loss)	lb/hr	0.121	0.117	0.158	0.107	0.106
PM Emission per Cell	tons/year	0.53	0.51	0.69	0.47	0.46
PM-10 Emissions per Cell	lb/hr	0.05	0.05	0.06	0.05	0.05
PM-10 Emissions per Cell	tons/year	0.22	0.21	0.25	0.24	0.23
PM2.5 Emissions per Cell	lb/hr	0.00024	0.00023	0.00032	0.00021	0.00021
PM2.5 Emissions per Cell	tons/year	0.0011	0.0010	0.0014	0.0009	0.0009
COOLING TOWER EMISSIONS RESULTS						
Total PM Emissions (Total emissions per cell x # of cells)	lb/hr	1.94	3.51	6.32	1.93	6.78
Total PM Emissions (Total emissions per cell x # of cells)	tons/year	8.5	15.4	27.7	8.5	29.7
PM10 Emissions (Total Cooling Tower)	lb/hr	0.81	1.46	2.29	0.98	3.44
PM10 Emissions (Total Cooling Tower)	tons/year	3.53	6.40	10.05	4.29	15.06
PM2.5 Emissions (Total Cooling Tower)	lb/hr	0.0039	0.0070	0.0126	0.0039	0.0136
PM2.5 Emissions (Total Cooling Tower)	tons/year	0.017	0.031	0.055	0.017	0.059

Conversion Factors

Typical density of water	lb/gal	8.34
Conversion from gallons to liters	L/gal	3.7854
conversion from lbs. to grams	grams/lb	453.59

EXHIBIT F

Metropolitan Water Reclamation District Water Quality Data

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

WATER QUALITY DATA FOR SELECTED PARAMETERS AND LOCATIONS
AT THE CHICAGO RIVER SYSTEM IN 2004

Location Code	Location	Date	BOD_5 (mg/L)[1]	TSS (mg/L)[2]	TDS (mg/L)[3]
	Fisk/Crawford Input:				
40	Damen Avenue, Chicago Sanitary & Ship Canal	01/20/04	3.000	11.0	658
40	Damen Avenue, Chicago Sanitary & Ship Canal	02/17/04	3.000	24.0	756
40	Damen Avenue, Chicago Sanitary & Ship Canal	03/15/04	6.000	14.0	644
40	Damen Avenue, Chicago Sanitary & Ship Canal	04/19/04	7.000	13.0	620
40	Damen Avenue, Chicago Sanitary & Ship Canal	05/17/04	3.000	11.0	414
40	Damen Avenue, Chicago Sanitary & Ship Canal	06/21/04	0.000	18.0	340
40	Damen Avenue, Chicago Sanitary & Ship Canal	07/19/04	3.000	11.0	296
40	Damen Avenue, Chicago Sanitary & Ship Canal	08/16/04	0.000	9.0	262
40	Damen Avenue, Chicago Sanitary & Ship Canal	09/20/04	0.000	11.0	342
40	Damen Avenue, Chicago Sanitary & Ship Canal	10/18/04	0.000	23.0	344
40	Damen Avenue, Chicago Sanitary & Ship Canal	11/15/04	0.000	15.0	424
40	Damen Avenue, Chicago Sanitary & Ship Canal	12/20/04	4.000	15.0	566
41	Harlem Avenue, Chicago Sanitary & Ship Canal	01/20/04	5.000	6.0	776
41	Harlem Avenue, Chicago Sanitary & Ship Canal	02/17/04	6.000	9.0	750
41	Harlem Avenue, Chicago Sanitary & Ship Canal	03/15/04	4.000	8.0	704
41	Harlem Avenue, Chicago Sanitary & Ship Canal	04/19/04	9.000	12.0	662
41	Harlem Avenue, Chicago Sanitary & Ship Canal	05/17/04	3.000	5.0	512
41	Harlem Avenue, Chicago Sanitary & Ship Canal	06/21/04	0.000	12.0	442
41	Harlem Avenue, Chicago Sanitary & Ship Canal	07/19/04	3.000	7.0	404
41	Harlem Avenue, Chicago Sanitary & Ship Canal	08/16/04	5.000	12.0	360
41	Harlem Avenue, Chicago Sanitary & Ship Canal	09/20/04	0.000	8.0	420
41	Harlem Avenue, Chicago Sanitary & Ship Canal	10/18/04	0.000	13.0	418
41	Harlem Avenue, Chicago Sanitary & Ship Canal	11/15/04	0.000	10.0	434
41	Harlem Avenue, Chicago Sanitary & Ship Canal	12/20/04	3.000	0.0	610
	Average Fisk/Crawford Values		2.792	11.5	507
	Max Fisk/Crawford Values		9.000	24.0	776
	Min Fisk/Crawford Values		0.000	0.0	262
	90% value		6.000	17.1	736
	95% value		6.850	22.3	755
	Will County Input:				
42	Route 83, Chicago Sanitary & Ship Canal	01/20/04	4.000	7.0	1124
42	Route 83, Chicago Sanitary & Ship Canal	02/17/04	3.000	7.0	866
42	Route 83, Chicago Sanitary & Ship Canal	03/15/04	3.000	6.0	520
42	Route 83, Chicago Sanitary & Ship Canal	04/19/04	8.000	9.0	728
42	Route 83, Chicago Sanitary & Ship Canal	05/17/04	7.000	5.0	504
42	Route 83, Chicago Sanitary & Ship Canal	06/21/04	0.000	10.0	498
42	Route 83, Chicago Sanitary & Ship Canal	07/19/04	5.000	9.0	476
42	Route 83, Chicago Sanitary & Ship Canal	08/16/04	0.000	10.0	364
42	Route 83, Chicago Sanitary & Ship Canal	09/20/04	4.000	10.0	460
42	Route 83, Chicago Sanitary & Ship Canal	10/18/04	0.000	21.0	430
42	Route 83, Chicago Sanitary & Ship Canal	11/15/04	0.000	14.0	466
42	Route 83, Chicago Sanitary & Ship Canal	12/20/04	0.000	0.0	622

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

WATER QUALITY DATA FOR SELECTED PARAMETERS AND LOCATIONS AT THE CHICAGO RIVER SYSTEM IN 2004

Location Code	Location	Date	BOD_5 (mg/L)[1]	TSS (mg/L)[2]	TDS (mg/L)[3]
48	Stephen Street, Chicago Sanitary & Ship Canal	01/20/04	3.000	10.0	794
48	Stephen Street, Chicago Sanitary & Ship Canal	02/17/04	3.000	9.0	1094
48	Stephen Street, Chicago Sanitary & Ship Canal	03/15/04	3.000	16.0	754
48	Stephen Street, Chicago Sanitary & Ship Canal	04/19/04	10.000	12.0	758
48	Stephen Street, Chicago Sanitary & Ship Canal	05/17/04	0.000	15.0	508
48	Stephen Street, Chicago Sanitary & Ship Canal	06/21/04	0.000	14.0	516
48	Stephen Street, Chicago Sanitary & Ship Canal	07/19/04	0.000	10.0	492
48	Stephen Street, Chicago Sanitary & Ship Canal	08/16/04	0.000	18.0	386
48	Stephen Street, Chicago Sanitary & Ship Canal	09/20/04	0.000	10.0	384
48	Stephen Street, Chicago Sanitary & Ship Canal	10/18/04	0.000	19.0	450
48	Stephen Street, Chicago Sanitary & Ship Canal	11/15/04	0.000	41.0	530
48	Stephen Street, Chicago Sanitary & Ship Canal	12/20/04	3.000	15.0	428
	Average Will County Values		2.333	12.4	590
	Max Will County Values		10.000	41.0	1124
	Min Will County Values		0.000	0.0	364
	90% value		6.400	18.7	844
	95% value		7.850	20.7	1060
	Joliet Input:				
92	Lockport Forebay, Chicago Sanitary & Ship Canal	01/05/04	0.000	11.0	590
92	Lockport Forebay, Chicago Sanitary & Ship Canal	01/12/04	3.000	10.0	1320
92	Lockport Forebay, Chicago Sanitary & Ship Canal	01/20/04	0.000	11.0	840
92	Lockport Forebay, Chicago Sanitary & Ship Canal	01/26/04	6.000	7.0	684
92	Lockport Forebay, Chicago Sanitary & Ship Canal	02/02/04	0.000	7.0	1150
92	Lockport Forebay, Chicago Sanitary & Ship Canal	02/09/04	3.000	9.0	1458
92	Lockport Forebay, Chicago Sanitary & Ship Canal	02/17/04	4.000	10.0	1060
92	Lockport Forebay, Chicago Sanitary & Ship Canal	02/23/04	3.000	13.0	908
92	Lockport Forebay, Chicago Sanitary & Ship Canal	03/01/04	3.000	13.0	964
92	Lockport Forebay, Chicago Sanitary & Ship Canal	03/08/04	4.000	26.0	752
92	Lockport Forebay, Chicago Sanitary & Ship Canal	03/15/04	0.000	29.0	750
92	Lockport Forebay, Chicago Sanitary & Ship Canal	03/22/04	0.000	7.0	802
92	Lockport Forebay, Chicago Sanitary & Ship Canal	03/29/04	5.000	12.0	706
92	Lockport Forebay, Chicago Sanitary & Ship Canal	04/05/04	0.000	8.0	690
92	Lockport Forebay, Chicago Sanitary & Ship Canal	04/12/04	3.000	8.0	736
92	Lockport Forebay, Chicago Sanitary & Ship Canal	04/19/04	5.000	13.0	740
92	Lockport Forebay, Chicago Sanitary & Ship Canal	04/26/04	0.000	16.0	666
92	Lockport Forebay, Chicago Sanitary & Ship Canal	05/03/04	6.000	14.0	532
92	Lockport Forebay, Chicago Sanitary & Ship Canal	05/10/04	0.000	18.0	501
92	Lockport Forebay, Chicago Sanitary & Ship Canal	05/17/04	4.000	11.0	452
92	Lockport Forebay, Chicago Sanitary & Ship Canal	05/24/04	3.000	23.0	560
92	Lockport Forebay, Chicago Sanitary & Ship Canal	06/01/04	ND	24.0	419
92	Lockport Forebay, Chicago Sanitary & Ship Canal	06/07/04	0.000	30.0	654
92	Lockport Forebay, Chicago Sanitary & Ship Canal	06/14/04	4.000	30.0	377
92	Lockport Forebay, Chicago Sanitary & Ship Canal	06/21/04	0.000	13.0	518

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

WATER QUALITY DATA FOR SELECTED PARAMETERS AND LOCATIONS AT THE CHICAGO RIVER SYSTEM IN 2004

Location Code	Location	Date	BOD_5 (mg/L)[1]	TSS (mg/L)[2]	TDS (mg/L)[3]
92	Lockport Forebay, Chicago Sanitary & Ship Canal	06/28/04	0.000	5.0	476
92	Lockport Forebay, Chicago Sanitary & Ship Canal	07/06/04	ND	ND	348
92	Lockport Forebay, Chicago Sanitary & Ship Canal	07/12/04	0.000	13.0	416
92	Lockport Forebay, Chicago Sanitary & Ship Canal	07/19/04	0.000	5.0	504
92	Lockport Forebay, Chicago Sanitary & Ship Canal	07/26/04	3.000	17.0	382
92	Lockport Forebay, Chicago Sanitary & Ship Canal	08/02/04	0.000	18.0	442
92	Lockport Forebay, Chicago Sanitary & Ship Canal	08/09/04	3.000	13.0	418
92	Lockport Forebay, Chicago Sanitary & Ship Canal	08/16/04	0.000	22.0	370
92	Lockport Forebay, Chicago Sanitary & Ship Canal	08/23/04	0.000	10.0	458
92	Lockport Forebay, Chicago Sanitary & Ship Canal	08/30/04	3.000	18.0	308
92	Lockport Forebay, Chicago Sanitary & Ship Canal	09/07/04	0.000	10.0	496
92	Lockport Forebay, Chicago Sanitary & Ship Canal	09/13/04	0.000	14.0	480
92	Lockport Forebay, Chicago Sanitary & Ship Canal	09/20/04	0.000	10.0	376
92	Lockport Forebay, Chicago Sanitary & Ship Canal	09/27/04	0.000	13.0	446
92	Lockport Forebay, Chicago Sanitary & Ship Canal	10/04/04	0.000	19.0	472
92	Lockport Forebay, Chicago Sanitary & Ship Canal	10/11/04	0.000	21.0	517
92	Lockport Forebay, Chicago Sanitary & Ship Canal	10/18/04	0.000	22.0	466
92	Lockport Forebay, Chicago Sanitary & Ship Canal	10/25/04	0.000	23.0	468
92	Lockport Forebay, Chicago Sanitary & Ship Canal	11/01/04	0.000	15.0	496
92	Lockport Forebay, Chicago Sanitary & Ship Canal	11/08/04	3.000	12.0	399
92	Lockport Forebay, Chicago Sanitary & Ship Canal	11/15/04	0.000	16.0	526
92	Lockport Forebay, Chicago Sanitary & Ship Canal	11/22/04	0.000	9.0	610
92	Lockport Forebay, Chicago Sanitary & Ship Canal	11/29/04	0.000	10.0	603
92	Lockport Forebay, Chicago Sanitary & Ship Canal	12/06/04	0.000	15.0	442
92	Lockport Forebay, Chicago Sanitary & Ship Canal	12/13/04	4.000	14.0	552
92	Lockport Forebay, Chicago Sanitary & Ship Canal	12/20/04	3.000	7.0	404
92	Lockport Forebay, Chicago Sanitary & Ship Canal	12/27/04	0.000	20.0	602
	Average Joliet Values		1.500	14.6	602
	Max Joliet Values (Max TSS Used from USGS data. Not Available		6.000	30.0	1458
	Min Joliet Values		0.000	5.0	308
	90% value		3.000	21.7	587
	95% value		3.000	22.0	603

[1]Biochemical Oxygen Demand

[2]Total Suspended Solids

[3]Total Dissolved Solids

ND = No Data

EXHIBIT G

Cooling Tower Blowdown, Evaporation and Make-Up Water Data

Average Summer Water Usage – Closed-Cycle

Station	Evaporation (gpm)	Makeup (gpm)	Blowdown (gpm)
Fisk 19	2608	3261	652
Crawford 7&8	4776	5972	1194
Will County 3&4	6834	8546	1709
Joliet 6	3006	3759	752
Joliet 7&8	11888	14865	2972

Average Winter Water Usage – Closed-Cycle

Station	Evaporation (gpm)	Makeup (gpm)	Blowdown (gpm)
Fisk 19	1708	2136	427
Crawford 7&8	3082	3855	771
Will County 3&4	4430	5541	1108
Joliet 6	1914	2394	479
Joliet 7&8	7788	9740	1947

Station	Average Annual Makeup (Mgal/yr) – Closed-Cycle
Fisk 19	1418
Crawford 7&8	2582
Will County 3&4	3702
Joliet 6	1617
Joliet 7&8	6466

Note: The total annual fresh water makeup (Mgal/yr) is bounded by the winter and summer values. Averaging the winter and summer values is a reasonable approximation for annual average.

EXHIBIT H

Cooling Tower Blowdown Temperature Data

Fisk:

Based on the SPX/Marley wet/dry cooling tower design data tabulated in Exhibit C, the temperature of the cooling tower blowdown from the Fisk 19 cooling system under summer design conditions would be as shown in Table H-1:

Table H-1
Fisk 19 Cooling Tower Blowdown Temperatures at B/D Flowrate = 652 gpm
Towers Designed for 7 F Approach at 78 F Wet Bulb

Month	1% WB Temp (F)	Blowdown Temperature (F)	UAA Proposed Average ALU B Temp Limits (F)
January	47.5	63.9	54.3
February	50.1	65.6	53.6
March	60.9	72.5	57.2
April	65.3	76	60.8/62.1
May	72.1	80.9	69.2/71.4
June	76.2	83.8	74.2/86.7
July	79.5	86	86.7
August	78.5	85.5	86.7
September	74.6	82.5	86.7/77
October	66.3	76.5	73.2/69.6
November	60.7	72.5	66.2
December	56.3	69.5	59.9
Maximum Temperature, Any Month			90.3

Crawford:

Based on the SPX/Marley wet/dry cooling tower design data tabulated in Exhibit C, the temperature of the cooling tower blowdown from the Crawford 7&8 cooling system under summer design conditions would be as shown in Table H-2:

Table H-2
Crawford 7&8 Cooling Tower Blowdown Temperatures at B/D Flowrate = 1194 gpm
Towers Designed for 7 F Approach at 78 F Wet Bulb

Month	1% WB Temp (F)	Cooling Tower Blowdown Temperature (F)	UAA Proposed Average ALU B Temp Limits (F)
January	47.5	63.8	54.3
February	50.1	65.5	53.6
March	60.9	72.8	57.2
April	65.3	75.9	60.8/62.1
May	72.1	80.8	69.2/71.4
June	76.2	83.7	74.2/86.7
July	79.5	86.1	86.7
August	78.5	85.5	86.7
September	74.6	82.3	86.7/77
October	66.3	76.1	73.2/69.6
November	60.7	72.8	66.2
December	56.3	69.8	59.9
Maximum Temperature, Any Month			90.3

Will County:

Based on the SPX/Marley wet/dry cooling tower design data tabulated in Exhibit C, the temperature of the cooling tower blowdown from the Will County 3&4 cooling system under summer design conditions would be as shown in Table H-3:

Table H-3
Will County 3&4 Cooling Tower Blowdown Temperatures at B/D Flowrate = 1709 gpm
Towers Designed for 7 F Approach at 78 F Wet Bulb

Month	1% WB Temp (F)	Cooling Tower Blowdown Temperature (F)	UAA Proposed Average ALU B Temp Limits (F)
January	47.5	63.5	54.3
February	50.1	64.6	53.6
March	60.9	72.6	57.2
April	65.3	75.7	60.8/62.1
May	72.1	80.6	69.2/71.4
June	76.2	83.6	74.2/86.7
July	79.5	86.1	86.7
August	78.5	85.5	86.7
September	74.6	82.5	86.7/77
October	66.3	76.4	73.2/69.6
November	60.7	72.5	66.2
December	56.3	65.5	59.9
Maximum Temperature, Any Month			90.3

Joliet 6:

Based on the SPX/Marley wet/dry cooling tower design data tabulated in Exhibit C, the temperature of the cooling tower blowdown from the Joliet 6 cooling system under summer design conditions would be as shown in Table H-4:

Table H-4
Joliet 6 Cooling Tower Blowdown Temperatures at B/D Flowrate = 752 gpm
Towers Designed for 7 F Approach at 78 F Wet Bulb

Month	1% WB Temp (F)	Cooling Tower Blowdown Temperature (F)	UAA Proposed UDIP Temp Limits (F)
January	47.5	63	54.3
February	50.1	64.8	53.6
March	60.9	72	57.2
April	65.3	75.5	60.8/62.1
May	72.1	80.5	69.2/71.4
June	76.2	83.8	74.2/86.7
July	79.5	86	85.1
August	78.5	85.5	85.1
September	74.6	82.3	85.1/77
October	66.3	76.1	73.2/69.6
November	60.7	72	66.2
December	56.3	69	59.9
Maximum Temperature, Any Month			88.7

Joliet 7&8:

Based on the SPX/Marley wet/dry cooling tower design data tabulated in Exhibit C, the temperature of the cooling tower blowdown from the Joliet 7&8 cooling system under summer design conditions would be as shown in Table H-5:

Table H-5
Joliet 7&8 Cooling Tower Blowdown Temperatures at B/D Flowrate = 2972 gpm
Towers Designed for 7 F Approach at 78 F Wet Bulb

Month	1% WB Temp (F)	Cooling Tower Blowdown Temperature (F)	IEPA UDIP Temp Limits (F)
January	47.5	63.8	54.3
February	50.1	65.1	53.6
March	60.9	72.3	57.2
April	65.3	75.5	60.8/62.1
May	72.1	80.5	69.2/71.4
June	76.2	83.8	74.2/86.7
July	79.5	86.1	85.1
August	78.5	85.5	85.1
September	74.6	82.5	85.1/77
October	66.3	76.5	73.2/69.6
November	60.7	72.2	66.2
December	56.3	69.5	59.9
Maximum Temperature, Any Month			90.3

EXHIBIT I

Capital Cost Estimates

Estimate No.: 21870D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Sargent Lundy

Exhibit I1
Fisk 19
Wet/Dry Cooling Towers
Conceptual Cost Estimate

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
1	COOLING TOWER - WET / DRY	13,271,040	6,082,560	19,353,600
2	COOLING TOWER SUPPLY PUMPS	1,613,520	541,200	2,154,720
3	COOLING TOWER DISCHARGE PUMPS	909,060	204,180	1,113,240
4	YARD PIPING	2,166,000	2,642,640	4,808,640
5		0	0	0
6	BLOWDOWN PUMPS	0	0	NOT REQUIRED
7	BLOWDOWN PIPING	35,090	37,510	72,600
8	MAKEUP PUMPS	0	0	NOT REQUIRED
9	MAKEUP PIPING	0	0	NOT REQUIRED
10	WATER TREATMENT	1,614,600	2,127,840	3,742,440
11	OPEN	0	0	0
20	SITEWORK	0	764,750	764,750
21	CONSTRUCTABILITY ACTIVITIES	0	1,529,500	1,529,500
22	COOLING TOWER BASINS	750,070	1,965,540	2,715,610
23	CT SUPPLY PUMP STRUCTURE AND BASIN	797,040	2,122,130	2,919,170
24	CT DISCHARGE PUMP STRUCTURE AND BASIN	791,640	2,166,600	2,958,240
25	NEW GATE IN EXISTING CW DISCHARGE PIPE	663,000	774,700	1,437,700
26	TIE-IN CT DISCHARGE PIPING	19,720	103,600	123,320
27	MODIFY CRIBHOUSE FOR CT DISCHARGE PIPING	111,360	424,200	535,560
28	FOUNDATIONS FOR NEW CLARIFIERS AND MU WT PLANT	80,040	348,600	428,640
29	NEW MU WT BUILDING	1,173,920	973,000	2,146,920
30	CW PIPE SLEEPERS	419,920	2,072,000	2,491,920
31	MISCELLANEOUS STRUCTURES AND FOUNDATIONS	208,800	715,400	924,200
32	DEMOLISH OLD OIL/WATER SEPARATOR BLDG	0	89,600	89,600
33	DEMOLISH OLD METAL CLEANING TANK	0	89,600	89,600
34	DEMOLISH EXISTING MUW FACILITY	0	361,200	361,200
41	AUXILIARY POWER SYSTEM FOR CT	3,417,120	3,408,790	6,825,910
42	DCS INTEGRATON	186,840	27,930	214,770
43	REPLACE ACTIVE EQUIPMENT IN DEMOLISHED OLD SWITCH-HOUSE NO. 1	2,484,000	11,910,090	14,394,090
44	BOP INSTRUMENTATION	37,800	14,630	52,430
51	CLEANUP ALLOWANCE	0	305,900	305,900
52	WASTE DISPOSAL	0	152,950	152,950
53	MOBILIZE / DEMOBILIZE	524,458	2,097,832	2,622,290

Estimate No.: 21870D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Sargent Lundy

Exhibit I1
Fisk 19
Wet/Dry Cooling Towers
Conceptual Cost Estimate

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
54	EQUIPMENT RENTAL SUPPLEMENT, LARGE CRANES	0	1,101,362	1,101,362
	Total Equipment, Material and Labor Costs	**31,275,038**	**45,155,834**	**76,430,872**
	Consumables	156,375	0	156,375
	Freight-ExWorks To Site	720,160	0	720,160
	Taxes - Sales	**0**	**0**	0
	Contractor's General and Administration Expense	1,563,752	2,257,792	3,821,544
	Contractor's Profit	3,127,504	4,515,583	7,643,087
	Total Direct Project Costs	**36,842,829**	**51,929,209**	**88,772,038**
	Indirect Project Costs			
	Engineering			16,310,528
	Construction Management/Field Engineering			INCL. IN ENGR.
	Permitting			0
	Startup, testing			467,943
	Owner's cost			0
	Spare parts			1,529,000
	Subtotal			**107,079,509**
	EPC Differential			8,566,000
	Project Contingency			21,415,902
	Total Construction Cost			**137,061,411**

Estimate No.: 21871D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Exhibit I2
Crawford 7 & 8
Wet/Dry Cooling Towers
Conceptual Cost Estimate

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
1	COOLING TOWER - WET / DRY	24,883,200	11,404,800	36,288,000
2	COOLING TOWER SUPPLY PUMPS	3,040,200	859,770	3,899,970
3	COOLING TOWER DISCHARGE PUMPS	674,710	157,440	832,150
4	YARD PIPING	4,652,400	5,740,240	10,392,640
5		0	0	0
6	BLOWDOWN PUMPS	0	0	NOT REQUIRED
7	BLOWDOWN PIPING	35,090	37,510	72,600
8	MAKEUP PUMPS	0	0	NOT REQUIRED
9	MAKEUP PIPING	0	0	NOT REQUIRED
10	WATER TREATMENT	322,920	303,800	626,720
11	WASTE WATER TREATMENT	0	0	NOT REQUIRED
19	SITEWORK	0	917,700	917,700
20	CONSTRUCTABILITY ACTIVITIES	0	1,529,500	1,529,500
21	OPEN	0	0	0
22	COOLING TOWER BASINS	1,647,800	4,575,450	6,223,250
23	CT SUPPLY PUMP STRUCTURE AND BASIN	221,400	1,075,450	1,296,850
24	CT DISCHARGE PUMP STRUCTURE AND BASIN	478,440	2,517,120	2,995,560
25	DISCHARGE STRUCTURE TO EXISTING CW DISCHARGE CHANNEL	32,860	105,820	138,680
26	NEW WALL AND GATE IN EXISTING CW DISCHARGE CHANNEL	614,900	419,100	1,034,000
27	DISCHARGE STRUCTURE TO EXISTING CW INLET CHANNEL	38,280	109,200	147,480
28	NEW WALL AND GATE ACROSS MOUTH OF EXISTING INTAKE CHANNEL	768,200	610,560	1,378,760
29	CW PIPE BRIDGE AND SLEEPERS	1,086,920	2,770,600	3,857,520
31	MISCELLANEOUS STRUCTURES AND FOUNDATIONS	208,800	715,400	924,200
32	DEMOLISH OLD SWITCHYARD STRUCTURE	0	180,600	180,600
33	DEMOLISH PEAKER UNITS	0	0	0
34	DEMOLISH LOCOMOTIVE MAINTENANCE BLDG	0	193,200	193,200
35	RELOCATE PART OF THE COAL PILE	0	89,600	89,600
36	TRANSMISSION LINE MODIFICATIONS	248,400	611,800	860,200
41	AUXILIARY POWER SYSTEM FOR CT	5,762,880	5,764,220	11,527,100
42	DCS INTEGRATON	185,760	29,260	215,020
44	BOP INSTRUMENTATION	49,680	22,610	72,290
51	CLEANUP ALLOWANCE	0	305,900	305,900
52	WASTE DISPOSAL	0	152,950	152,950

Estimate No.: 21871D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Exhibit I2

Crawford 7 & 8

Wet/Dry Cooling Towers

Conceptual Cost Estimate

Sargent & Lundy

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
53	MOBILIZE / DEMOBILIZE	514,995	2,059,980	2,574,975
54	EQUIPMENT RENTAL SUPPLEMENT, LARGE CRANES	0	1,081,490	1,081,490
	Total Equipment, Material and Labor Costs	**45,467,835**	**44,341,070**	**89,808,905**
	Consumables	227,339	0	227,339
	Freight-ExWorks To Site	823,385	0	823,385
	Taxes - Sales	0	0	0
	Contractor's General and Administration Expense	2,273,392	2,217,053	4,490,445
	Contractor's Profit	4,546,784	4,434,107	8,980,890
	Total Direct Project Costs	**53,338,735**	**50,992,230**	**104,330,965**
	Indirect Project Costs			
	Engineering			22,497,280
	Construction Management/Field Engineering			INCL. IN ENGR.
	Permitting			0
	Startup, testing			467,943
	Owner's cost			0
	Spare parts			1,796,000
	Subtotal			**129,092,188**
	EPC Differential			10,327,000
	Project Contingency			25,818,438
	Total Construction Cost			**165,237,626**

Estimate No.: 21873D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Exhibit I3
Will County 3 & 4
Wet/Dry Cooling Towers

Sargent & Lundy

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
1	COOLING TOWER - WET / DRY	33,177,600	15,206,400	48,384,000
2	COOLING TOWER SUPPLY PUMPS	3,942,000	947,100	4,889,100
3	COOLING TOWER DISCHARGE PUMPS	2,027,400	319,800	2,347,200
4	YARD PIPING	9,240,000	11,253,000	20,493,000
5		0	0	0
6	BLOWDOWN PUMPS	0	0	NOT REQUIRED
7	BLOWDOWN PIPING	35,090	37,510	72,600
8	MAKEUP PUMPS	0	0	NOT REQUIRED
9	MAKEUP PIPING	0	0	NOT REQUIRED
10	WATER TREATMENT	216,000	198,400	414,400
11	WASTE WATER TREATMENT	0	0	NOT REQUIRED
20	SITEWORK	0	3,059,000	3,059,000
21	CONSTRUCTABILITY ACTIVITIES	0	764,750	764,750
22	COOLING TOWER BASINS	3,413,300	6,316,800	9,730,100
23	CT SUPPLY PUMP STRUCTURE AND BASIN	259,200	1,109,700	1,368,900
24	CT DISCHARGE PUMP STRUCTURE AND BASIN	1,032,480	4,927,980	5,960,460
25	DISCHARGE STRUCTURE TO EXISTING CW DISCHARGE CHANNEL	165,360	391,820	557,180
26	NEW WALL AND GATE IN EXISTING CW DISCHARGE CHANNEL	614,900	628,650	1,243,550
27	MODIFY CRIB HOUSES	133,400	338,800	472,200
28	FILL ABANDONED POND	0	292,600	292,600
29	BRIDGE SYSTEM FOR CW PIPING	1,708,680	3,936,800	5,645,480
30	CW PIPE SLEEPERS	1,202,920	5,924,800	7,127,720
31	MISCELLANEOUS STRUCTURES AND FOUNDATIONS	605,520	2,489,200	3,094,720
32	RELOCATE TRANSMISSION LINES	496,800	1,529,500	2,026,300
33	OPEN	0	0	0
34	OPEN	0	0	0
41	AUXILIARY POWER SYSTEM FOR CT	9,007,200	14,310,800	23,318,000
42	DCS INTEGRATON	185,760	29,260	215,020
44	BOP INSTRUMENTATION	37,800	14,630	52,430
51	CLEANUP ALLOWANCE	0	305,900	305,900
52	WASTE DISPOSAL	0	152,950	152,950
53	MOBILIZE / DEMOBILIZE	931,077	3,724,308	4,655,384
54	EQUIPMENT RENTAL SUPPLEMENT, LARGE CRANES	0	1,955,261	1,955,261

Estimate No.: 21873D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Exhibit I3
Will County 3 & 4
Wet/Dry Cooling Towers

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
	Total Equipment, Material and Labor Costs	**68,432,487**	**80,165,719**	**148,598,206**
	Consumables	342,162	0	342,162
	Freight-ExWorks To Site	1,410,195	0	1,410,195
	Taxes - Sales	0	0	0
	Contractor's General and Administration Expense	3,421,624	4,008,286	7,429,910
	Contractor's Profit	6,843,249	8,016,572	14,859,821
	Total Direct Project Costs	**80,449,718**	**92,190,577**	**172,640,295**
	Indirect Project Costs			
	Engineering			24,747,008
	Construction Management/Field Engineering			INCL. IN ENGR.
	Permitting			0
	Startup, testing			467,943
	Owner's cost			0
	Spare parts			2,972,000
	Subtotal			**200,827,246**
	EPC Differential			16,066,000
	Project Contingency			40,165,449
	Total Construction Cost			**257,058,695**

Estimate No.: 21874D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Exhibit I4
Joliet 6
Wet/Dry Cooling Towers
Conceptual Cost Estimate

Sargent & Lundy

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
1	COOLING TOWER- WET / DRY	14,929,920	6,842,880	21,772,800
2	COOLING TOWER SUPPLY PUMPS	2,705,400	751,530	3,456,930
3	COOLING TOWER DISCHARGE PUMPS	1,014,790	205,410	1,220,200
4	YARD PIPING	3,258,000	3,798,190	7,056,190
5		0	0	0
6	BLOWDOWN PUMPS	0	0	NOT REQUIRED
7	BLOWDOWN PIPING	35,090	35,090	70,180
8	MAKEUP PUMPS	0	0	NOT REQUIRED
9	MAKEUP PIPING	0	0	NOT REQUIRED
10	WATER TREATMENT	0	0	NOT REQUIRED
11	WASTE WATER TREATMENT	0	0	NOT REQUIRED
20	SITEWORK INCL FLOOD PLAIN WORK	919,080	1,098,580	2,017,660
21	CONSTRUCTABILITY ACTIVITIES	0	764,750	764,750
22	COOLING TOWER BASINS	1,178,070	2,487,240	3,665,310
23	CT SUPPLY PUMP STRUCTURE AND BASIN	157,680	790,490	948,170
24	CT DISCHARGE PUMP STRUCTURE AND BASIN	333,720	1,489,020	1,822,740
25	DISCHARGE STRUCTURE TO EXISTING CW DISCHARGE CHANNEL	72,080	188,760	260,840
26	NEW WALL AND GATE IN EXISTING CW DISCHARGE CHANNEL	612,300	541,020	1,153,320
27	NEW WALL IN SANITARY CANAL AROUND EXISTING CRIBHOUSE WITH GATES	550,450	689,110	1,239,560
28	BRIDGE SYSTEM FOR CW PIPE	40,600	226,800	267,400
29	CW PIPE SLEEPERS	440,800	1,050,000	1,490,800
31	MISCELLANEOUS STRUCTURES AND FOUNDATIONS	393,240	1,365,000	1,758,240
32	DEMOLISH	0	0	0
33	OPEN	0	0	0
41	AUXILIARY POWER SYSTEM FOR CT	3,321,000	5,724,320	9,045,320
42	DCS INTEGRATON	186,840	29,260	216,100
44	BOP INSTRUMENTATION	37,800	14,630	52,430
51	CLEANUP ALLOWANCE	0	305,900	305,900
52	WASTE DISPOSAL	0	152,950	152,950
53	MOBILIZE / DEMOBILIZE	356,887	1,427,547	1,784,433
54	EQUIPMENT RENTAL SUPPLEMENT, LARGE CRANES	0	749,462	749,462

Estimate No.: 21874D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Exhibit I4

Joliet 6

Wet/Dry Cooling Towers

Conceptual Cost Estimate

Sargent & Lundy

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
	Total Equipment, Material and Labor Costs	**30,543,747**	**30,727,938**	**61,271,685**
	Consumables	152,719	0	152,719
	Freight-ExWorks To Site	624,553	0	624,553
	Taxes - Sales	0	0	0
	Contractor's General and Administration Expense	1,527,187	1,536,397	3,063,584
	Contractor's Profit	3,054,375	3,072,794	6,127,169
	Total Direct Project Costs	**35,902,580**	**35,337,129**	**71,239,710**
	Indirect Project Costs			
	Engineering			17,435,392
	Construction Management/Field Engineering			INCL. IN ENGR.
	Permitting			0
	Startup, testing			467,943
	Owner's cost			0
	Spare parts			1,225,000
	Subtotal			**90,368,045**
	EPC Differential			7,229,000
	Project Contingency			18,073,609
	Total Construction Cost			**115,670,654**

Estimate No.: 21875D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Exhibit I5
Joliet 7 & 8
Wet/Dry Cooling Towers
Conceptual Cost Estimate

Sargent & Lundy

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
1	COOLING TOWER - WET / DRY	53,084,160	24,330,240	77,414,400
2	COOLING TOWER SUPPLY PUMPS	6,046,000	1,293,000	7,339,000
3	COOLING TOWER DISCHARGE PUMPS	2,391,000	326,000	2,717,000
4	YARD PIPING	9,855,000	6,464,000	16,319,000
5		0	0	0
6	BLOWDOWN PUMPS	0	0	NOT REQUIRED
7	BLOWDOWN PIPING	35,000	35,000	70,000
8	MAKEUP PUMPS	0	0	NOT REQUIRED
9	MAKEUP PIPING	0	0	NOT REQUIRED
10	WATER TREATMENT	323,000	283,000	606,000
11	WASTE WATER TREATMENT	0	0	NOT REQUIRED
20	SITEWORK	0	3,059,000	3,059,000
21	CONSTRUCTABILITY ACTIVITIES	0	1,529,500	1,529,500
22	COOLING TOWER BASINS	4,292,000	9,019,000	13,311,000
23	CT SUPPLY PUMP STRUCTURE AND BASIN	357,000	1,341,000	1,698,000
24	CT DISCHARGE PUMP STRUCTURE AND BASIN	414,000	1,857,000	2,271,000
25	DISCHARGE STRUCTURE TO EXISTING DISCHARGE TUNNEL	220,000	392,000	612,000
26	NEW WALL AND GATE IN EXISTING DISCHARGE CHANNEL	1,344,000	1,738,000	3,082,000
27	NEW CHANNEL AND GATE ACROSS MOUTH OF EXISTING INLET AND DISCHARGE CHANNEL	849,000	1,629,000	2,478,000
28	NEW 2ND CHANNEL AND GATE ACROSS MOUTH OF EXISTING INLET AND DISCHARGE CHANNEL	802,000	756,000	1,558,000
29	CW PIPE EARTHWORK	0	492,100	492,100
31	MISCELLANEOUS STRUCTURES AND FOUNDATIONS	737,000	2,584,000	3,321,000
32	OPEN	0	0	0
33	OPEN	0	0	0
41	AUXILIARY POWER SYSTEM FOR CT	13,460,040	20,418,160	33,878,200
42	DCS INTEGRATON	185,760	29,260	215,020
44	BOP INSTRUMENTATION	37,800	14,630	52,430
51	CLEANUP ALLOWANCE	0	305,900	305,900
52	WASTE DISPOSAL		152,950	152,950
53	MOBILIZE / DEMOBILIZE	975,609	3,902,437	4,878,046
54	EQUIPMENT RENTAL SUPPLEMENT, LARGE CRANES	0	2,048,779	2,048,779

Estimate No.: 21875D
Project No.: 10683-130
Issue Date: 1/14/11
Preparer: JMK
Reviewer: RK

Exhibit I5

Joliet 7 & 8

Wet/Dry Cooling Towers

Conceptual Cost Estimate

Item No.	Description	Equipment & Material Cost	Labor Cost	Total Cost
	Total Equipment, Material and Labor Costs	**95,408,369**	**83,999,956**	**179,408,326**
	Consumables	477,042	0	477,042
	Freight-ExWorks To Site	1,692,968	0	1,692,968
	Taxes - Sales	0	0	0
	Contractor's General and Administration Expense	4,770,418	4,199,998	8,970,416
	Contractor's Profit	9,540,837	8,399,996	17,940,833
	Total Direct Project Costs	**111,889,635**	**96,599,950**	**208,489,585**
	Indirect Project Costs			
	Engineering			22,497,280
	Construction Management/Field Engineering			INCL. IN ENGR.
	Permitting			0
	Startup, testing			467,943
	Owner's cost			0
	Spare parts			3,588,000
	Subtotal			**235,042,808**
	EPC Differential			18,803,000
	Project Contingency			47,009,000
	Total Construction Cost			**300,854,808**

EXHIBIT J

Operation and Maintenance Cost Estimates

Cooling Tower Operations & Maintenance Costs

	Fisk 19	Crawford 7&8	Will County 3&4 Plume Abated	Will County 3&4 Wet Tower	Joliet 6 Plume Abated	Joliet 6 Wet Tower	Joliet 7&8 Plume Abated	Joliet 7&8 Wet Tower
Total Gross MW of Site	348	585	832	832	341	341	1,138	1,138
Approach, F	7	7	7	7	7	7	7	7
Capacity Factor	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Aux Power Cost $/MWh	$37	$37	$37	$37	$37	$37	$37	$37
No of CT Cells	16	30	40	40	18	16	64	60
Fan BHP	250	250	250	250	250	250	250	250
CT MWh/yr	21,287	39,913	53,217	53,217	23,948	21,287	85,147	79,826
CT Power Cost	$781,438	$1,465,197	$1,953,596	$1,953,596	$879,118	$781,438	$3,125,754	$2,930,394
No of Supply Pumps	2	4	4	4	4	4	6	6
Supply Pump BHP	2,000	2,000	3,000	3,000	1,500	1,250	3,500	3,000
Supply Pump MWh/yr	21,287	42,574	63,860	63,860	31,930	26,609	111,756	95,791
Supply Pump Power Cost	$781,438	$1,562,877	$2,344,315	$2,344,315	$1,172,158	$976,798	$4,102,552	$3,516,473
No of Discharge Pumps	4	4	2	2	4	4	6	6
Discharge Pump BHP	200	300	500	500	250	250	400	400
Discharge Pump MWh/yr	4,257	6,386	5,322	5,322	5,322	5,322	12,772	12,772
Discharge Pump Power Cost	$156,288	$234,432	$195,360	$195,360	$195,360	$195,360	$468,863	$468,863
No of Discharge Pumps			4	4				
Discharge Pump BHP			350	300				
Discharge Pump MWh/yr			7,450	6,386				
Discharge Pump Power Cost			$273,503	$234,432				
Total MWh/yr	46,831	88,872	129,849	128,785	61,200	53,217	209,675	188,388
Total Pump Power Cost per year	$937,726	$1,797,308	$2,813,178	$2,774,106	$1,367,517	$1,172,158	$4,571,415	$3,985,336
Total Power Cost per year	$1,719,165	$3,262,505	$4,766,774	$4,727,702	$2,246,635	$1,953,596	$7,697,169	$6,915,730
Inspection $/cell	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
Total Cell Inspection Cost / year	$48,000	$90,000	$120,000	$120,000	$54,000	$48,000	$192,000	$180,000
Annual Cell Inspection and Pump Maintenance $/yr.	$60,000	$112,500	$150,000	$150,000	$67,500	$60,000	$240,000	$225,000
CW Treatment Chemicals $/MW/yr	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Total CW Treatment Chemicals $/yr.	$348,000	$585,000	$832,000	$832,000	$341,000	$341,000	$1,138,000	$1,138,000
Total O&M Costs ($/year)	$2,127,165	$3,960,005	$5,748,774	$5,709,702	$2,655,135	$2,354,596	$9,075,169	$8,278,730