Technical Memorandum
Panoche Energy Center

Supplemental Discussion of Water Supply and Wastewater Discharge Alternatives

Submitted to

The California Energy Commission

March 23, 2007

Submitted by

Panoche Energy Center, LLC

With support from

URS

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March 23, 2007

James W. Reede, Jr., Ed.D.
Energy Facility Siting Project Manager
California Energy Commission
1516 - 9th Street
Sacramento, CA 95814

RE: Panoche Energy Center – Supplemental Discussion of Water Supply and Wastewater Discharge Alternatives

Dear Dr. Reede:

On behalf of Panoche Energy Center, LLC (PEC), URS Corporation respectfully submits the attached Technical Memorandum entitled "Supplemental Discussion of Water Supply and Wastewater Discharge Alternatives." This Technical Memorandum has been developed to address comments and questions generated by the CEC staff in response to the previously submitted Technical Memorandum (*dated March 2, 2007*).

The intent of this memorandum is to provide additional information on cost and regulatory definitions that were presented in the Technical Memorandum dated March 2, 2007. This memorandum also provides supplementary information to justify the use of water from the lower confined aquifer for cooling at the PEC and the use of deep injection wells for the disposal of process wastewater generated from the facility.

PEC appreciates this opportunity to provide the CEC with this supplemental technical memorandum. Given the critical nature of water and wastewater relative to both the CEC AFC process and the overall success of the PEC project, I ask that you and Staff review this Technical Memorandum prior to our meeting on April 13, 2007. As a result, the PEC team hopes that Staff's concerns will have been answered. I appreciate your consideration of this Technical Memorandum, and look forward to our discussions in its regard.

Sincerely,

Margaret M. Fitzgerald
Program Manager

Attachment
Cc: Eileen Allen, CEC
Roger Johnson, CEC
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Supplemental Discussion of Water Supply and Wastewater Discharge Alternatives

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This Technical Memorandum has been developed to address comments and questions generated by the California Energy Commission staff in response to the previously submitted Technical Memorandum (*dated March 2, 2007*). The subsequent sections of this Technical Memorandum will address the following topics:

- A cost comparison between different water sources for use as process water for the project. More specifically, a comparison between the uses of upper-level, semi-confined aquifer water wells versus lower-level, confined aquifer water wells.
- A cost comparison between different wastewater discharge alternatives. More specifically, a comparison between the uses of deep well injection versus a zero liquid discharge system, while using confined aquifer as the water supply.
- A discussion of the definitions of fresh water and brackish water, and identification of water sources for Panoche Energy Center (PEC) based upon those definitions.

The intent of this memorandum is to provide additional information on cost and regulatory definitions that were presented in the Technical Memorandum dated March 2, 2007. This memorandum also provides supplementary information to justify the use of water from the lower confined aquifer for cooling at the PEC and the use of deep injection wells for the disposal of process wastewater generated from the facility.

Note: Follow-up information for the Technical Memorandum on this subject sent to CEC on March 2, 2007.

1.0 Background

A variety of options were examined to determine the most appropriate water source and wastewater disposal methods for the Panoche Energy Center (PEC). The various options were assessed and presented through the Application for Certification (AFC) submission and in an initial Technical Memorandum (March 2, 2007). After an evaluation and discussion of the initial Technical Memorandum (*meeting with California Energy Commission [CEC] staff on March 7, 2007*), CEC staff requested further information on the alternative water/wastewater options examined for the PEC. The basis of the CEC request is to obtain a clear determination that the requirements presented by Resolution No. 75-58 are being properly recognized and upheld by the PEC.

In order to comply with the CEC's requests for comparative cost analysis, four water/ wastewater options were examined for PEC. These different options are listed below:

- **Option A**
  - Water Source
    - 70% from the lower confined aquifer
    - 30% from Baker Farming filter backwash
  - Wastewater Disposal Method
    - Deep Injection Well
- **Option B**
  - Water Source
    - Lower Confined Aquifer
  - Wastewater Disposal Method
    - Deep Injection Well
- **Option C**
  - Water Source
    - Lower Confined Aquifer
  - Wastewater Disposal Method
    - Zero Liquid Discharge (ZLD) system
- **Option D**
  - Water Source
    - Upper Semi-Confined Aquifer
  - Wastewater Disposal Method
    - Deep Injection Well

The remainder of this Technical Memorandum is organized as follows. Section 2.0 compares the estimated cost of Option B with Options A and D using the same Deep Well Injection method as wastewater disposal. Section 3.0 compares the estimated cost of a ZLD system (Option C) with the Deep Well Injection (Option B) using the same confined aquifer water supply source. Section 4.0 discusses the further investigation that was conducted to clarify the definitions of fresh water and brackish water. Through the clarification of these terms, the PEC will demonstrate that all requirements established in Resolution 75-58, and other CEC guidance on the subject of water usage in power plants, are being adhered to. The comparisons presented below demonstrate that Option B is the most economically sound alternative for the PEC project (see conclusions in Section 5.0).

2.0 Water Supply Selection Based Upon Cost Analysis Semi-confined Aquifer Versus Confined Aquifer

The confined aquifer water is the proposed source for PEC because of its relatively lower capital and Operating and Maintenance (O&M) cost, as well as lower waste sludge generation and energy consumption. Compared to using semi-confined aquifer water or a combination of agriculture water reuse and confined aquifer, the exclusive use of confined aquifer water is the most economically and environmentally sound option. Costs for the various options are listed in the Table 2-1.

Table 2-1. Cost Comparison

	A[1] Comparative Evaluation	B Proposed	D Comparative Evaluation	Remarks
	Baker Water well backup	Confined aquifer Wells / Reverse Osmosis (RO) / Injection Wells	Semi-confined aquifer Wells / RO / Injection Wells	
Water TDS	280 ppm	1000 ppm	3000 ppm	Water in options B and D can be described as brackish (see Section 4.0)
Capital Cost				
Paid to Baker for the use of land and water	$ 500,000			
Clarifier / Filter	$ 1,500,000		$ 4,000,000	
RO/ System	$ 3,500,000	$ 3,500,000	$ 7,500,000	
Production Wells	$ 1,500,000	$ 1,500,000	$ 1,500,000	
Injection Wells	$ 3,000,000	$ 3,000,000	$ 3,000,000	
Misc filters, pumps, systems			$ 4,000,000	
Water / Waste Capital Cost	$ 10,000,000	$ 8,000,000	$ 20,000,000	Option B has the lowest capital costs
Variable Costs 5000 Hours				
Aux Power (above base) FIXED	$ 100,000		$ 400,000	600 kw, 800kw
Water Supply	$ 500,000	$ 50,000	$ 50,000	
Water Discharge	$ 100,000	$ 50,000	$ 50,000	
Chemicals (above base)	$ 100,000		$ 1,560,375	
Demin Trailers	$ 200,000	$ 200,000	$ 200,000	
Operators (Labor above base)	$ 150,000		$ 670,000	
ZLD/ lime System Maintenance			$ 300,000	
Total O&M	$ 1,150,000	$ 300,000	$ 3,230,375	Option B has the lowest annual O&M costs
Increase Capital (above base)	$ 2,000,000	$ Base	$ 12,000,000	
Increase O&M Annual (above base)	$ 850,000	$ Base	$ 2,930,375	

[1] Baker Farming recovers backwash water at a volume equivalent to about one-third of the water supply needs of the PEC, but not necessarily consistent with the operation of the PEC. Therefore, this option is the same as our base option (see Option B) with about 30% of the water provided by Baker as filter backwash water. The system requires the installation of additional equipment to treat the surface water stream as well as base equipment to treat well water. The following differences are relative to Option B.

Capital- $1.5M for clarifier and $500K payment to Baker for installation of collection piping. Estimates derived from engineering cost manuals and from experienced power plant operators

O&M – There would be water supply charges, additional chemicals, aux power to run the clarifier and two additional operators.

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Water from the semi-confined aquifer contains the following minerals that will affect plant economics:

1. Sulfate concentrations exceeding 1,500 milligrams per liter (mg/L) (i.e., three times higher than confined aquifer); and

2. Hardness greater than 1,200 milligrams (mg) equiv calcium carbonate ($CaCO_3$) (20 times higher than confined aquifer).

These water quality parameters are of particular concern for operation of the PEC. The sulfate and hardness concentration limits for the cooling tower design are 900 mg/L and 500 mg equiv. $CaCO_3$, respectively. Therefore, significant pretreatment to reduce the concentration of these constituents would be required. In addition, the total dissolved solids (TDS) concentration in the semi-aquifer is three times higher than that of the confined aquifer, which imposes a high pressure requirement of the reverse osmosis (RO) system. As a result, the total capital cost will increase by about $12M and the annual O&M will increase over $2.9M using the semi-confined aquifer compared to confined aquifer water.

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3.0 Wastewater Disposal Method Selection Criteria Based Upon Cost Analysis, Zero Liquid Discharge Versus Deep Well Injection

As discussed in the previous Technical Memorandum (March 2, 2007), the Deep Injection Well alternative is the preferred method of wastewater disposal for PEC because it meets the following hydrogeological factors:

- Isolated Zone of Groundwater Injection;
- Adequate Storage for Groundwater Injection; and
- Injection Zone formation Water is not a Groundwater Resource.

In addition, the Deep Injection Well alternative is also more economically sound than the implementation of a ZLD system. The installation cost for two wells is approximately \$3M and the corresponding O&M costs are on the order of \$100,000 per year. A breakdown of some of the associated costs with each option is provided in Table 3-1.

Table 3-1. Cost Breakdown for Each Option

	B Proposed	C(2) Comparative Evaluation
	Confined aquifer Wells / RO / Injection Wells	Confined aquifer Wells / RO / ZLD
Water TDS	1000 ppm	1000 ppm
Capital Cost		
RO/ System	$ 3,500,000	$ 3,500,000
Ground Wells	$ 1,500,000	$ 1,500,000
Injection Wells	$ 3,000,000	$ -
ZLD		$ 16,000,000
Misc filters, pumps, systems		
Water / Waste Capital Cost	$ 8,000,000	$ 21,000,000(3)
Variable Costs 5000 Hours		
Aux Power (above base) FIXED		$ 300,000
Water Supply	$ 50,000	$ 50,000
Water Discharge	$ 50,000	$ 50,000
Chemicals (above base)		$ 520,125
Demin Trailers	$ 200,000	$ 200,000
Operators (Labor above base)		$ 800,000
ZLD/ lime system Maintenance		$ 500,000
Total O&M	$ 300,000	$ 2,420,125(4)
Increase Capital (above base)	$ BASE	$ 13,000,000
Increase O&M Annual (above base)	$ BASE	$ 2,120,125

(2) This option uses a ZLD system versus Deep Injection Wells. The ZLD system requires the installation of additional equipment for lime softening/ High Efficiency Reverse Osmosis (HERO) and a crystallizer. Labor estimates and capital and O&M estimates are derived from consultation with individuals at the Magnolia power plant as well as estimates from Bibb Engineering.
(3) Capital- Bibb Engineering developed a detailed estimate for \$16.7M- attached
(4) O&M – An increase in aux power of 600 kW is anticipated. Chemicals to support the ZLD include lime soda ash and a number of specialty chemicals. This estimate is based upon actual cost from an operating power plant in Burbank, California (Magnolia Power Plant) cost of about

$2500 per day and includes sludge hauling and disposal. Labor is expected to increase by 12 operators as estimated by Bibb Engineering and confirmed by Magnolia Power Plant Project in Burbank, CA.

Operation of a ZLD system at the PEC plant requires pretreating the process water discharge to remove the mineral content and circulate the resulting liquid into the process cooling water system. Compared to the deep well injection system, ZLD is not suited to the technical or economic model of the PEC project for the following reasons:

1. It increases the capital costs of the project by about $13M;
2. It increases the annual operating cost of the plant by about $2.1M;
3. It handicaps the operating requirements of the plant by limiting plant readiness on demand; and
4. It adds to environmental issues due to increase in truck traffic and handling of additional chemicals and sludge hauling to a landfill.

A breakdown of cost estimates and assumptions for the ZLD option are presented in Section 3.1.

3.1 Zero Liquid Discharge Process Description and Cost Estimate

This section describes the conceptual design of an alternate plan for treatment of cooling tower blowdown to achieve ZLD at the PEC. The design is based on treating the maximum daily wastewater production anticipated and assumes that all plant wastewater except sanitary wastewater and discharge from the oil/water separators is routed to the cooling tower. The latter wastewater streams are assumed to be disposed of by leach field and land disposal, respectively.

The alternate design concept is comprised of two major subsystems:

- Cooling Tower Blowdown Pretreatment and Concentration; and
- Brine Crystallization and Solids Handling.

3.1.1 Cooling Tower Blowdown Pretreatment and Concentration

The cooling tower blowdown and concentration subsystem includes High Efficiency Reverse Osmosis (HERO™) for volume reduction. This process requires extensive pretreatment to remove suspended solids, hardness, and alkalinity. The first step is lime and soda ash softening of a sidestream of the circulating water. The lime and soda ash softener is unsuitable for start-stop operation. Therefore a 1,000,000 gallon capacity cooling tower blowdown storage tank is included in the plan to allow the lime and soda ash softening process to continue operating at steady state when the plant is not operating. In the event tank contents is depleted during a plant outage, the lime and soda ash softening process is shut down and will require 1 to 2 days for an orderly restart.

Approximately 300 gpm of the softened water from the side stream lime and soda ash softening process is further treated by the HERO™ system. The HERO™ system is expected to recover approximately 90% of this waste stream with the reject steam going to the Brine Crystallization and Solids Handling Subsystem.

The cooling tower blowdown and concentration subsystem is expected to consist of the following major equipment components:

- Cooling tower blowdown transfer pumps;
- One 100% capacity solids contact unit;
- One softened water clearwell;
- Two softened water transfer pumps;
- Complete chemical feed subsystems (lime, soda ash, sodium hypochlorite, coagulant, and polymer) each with two full capacity dosing pumps;
- Two 100% capacity pressure or gravity filters;
- Two full capacity air scour blowers;
- One full capacity filter backwash pumps;
- One full capacity sludge thickener;
- Two sets of full capacity sludge handling pumps;
- One full capacity filter press;
- Sulfuric acid feed subsystem;
- Sodium hydroxide feed subsystem;
- Two full capacity filtered water transfer pumps;
- Two 100% capacity weak acid cation (WAC) exchangers;
- WAC regenerant storage tank;
- Two WAC regenerant recycle pumps;
- Sodium bisulfite feed subsystem;
- Antiscalant feed subsystem;
- One full capacity degasifier with redundant air blowers;
- 1st stage HERO feed pumps;
- HERO cartridge filters;
- 1st stage HERO™ booster pumps;
- 1st stage HERO™ unit;
- 1st stage HERO™ reject tank;
- 2nd stage HERO™ feed pumps;
- 2nd stage HERO™ cartridge filters;
- 2nd stage HERO™ booster pumps;
- 2nd stage HERO™ unit;
- Permeate storage tank;
- Two full capacity permeate transfer pumps; and

- Brine storage tank (~5 days storage).

3.1.2 Brine Crystallizer and Solids Handling

The Brine Crystallization and Solids Handling subsystem will include the following major equipment components. The treatment capacity is assumed to be ~ 30 gallons per minute (gpm) based on continuous operation and 90% recovery by the HERO™ process.

- One crystallizer feed pump skid;
- One crystallizer distillate tank and pump skid;
- One crystallizer forced circulation heat exchanger;
- One full capacity crystallizer recirculation pump;
- One crystallizer flash tank;
- Antifoam dosing system with two pumps;
- One full capacity mechanical vapor compressor;
- One crystallizer brine storage tank;
- One crystallizer filter press;
- Two full capacity filter press feed pumps; and
- One filtrate tank and pump skid.

Distillate from the crystallizer is returned to the cooling tower. A portion of the recirculating slurry of salt crystals is sent to the filter press for dewatering. Filtrate from the filter press is returned to the crystallizer. The salt cake is dumped into a hopper for off-site disposal by others.

The ZLD system is complex and requires continuous operator attention while in service.

3.1.3 Waste Solids Production

The estimated volume of solids produced at maximum daily operating conditions is based on the following assumptions:

- 30 gpm HERO™ reject;
- Reject density ~9 pounds (lbs)/gallon;
- 50,000 parts per million (ppm) dissolved solids in HERO™ reject;
- Filter cake is 30% solids; and
- Filter cake density is 75 lbs/cubic feet

The "maximum day" filter cake production is estimated to be 865 cubic feet/day. The "average day" solids production is estimated to be 620 cubic feet/day. Annual solids production can be estimated by multiplying the average day production by the plant capacity factor. These estimates are preliminary and should be confirmed following final sizing of the ZLD system.

3.1.4 Space Requirements

The space required is expected to be an area of about 120' x 180". The HERO™ system and all chemical feed and pump skids are assumed to be indoors, while solids contact clarifier, crystallizer body, filter press, bulk chemical feed storage, and all large tanks are outdoors. A single-story building required to house the equipment may be on the order of 50' x 100' with 20' clear headroom. A second floor addition will be required if the filter press is to be located indoors.

3.1.5 Estimated Capital Cost

The capital cost based on the preliminary sizing described above is an engineering estimation. The accuracy of the estimate is on the order of ±30%, which is typical for such estimation. These cost estimates have been compared with vendor cost estimates and are within the range of estimates provided by equipment vendors.

Component	Equipment Cost, $	Construction Cost, $	Total, $
Blowdown Storage	1,000,000	Included	1,000,000
Cooling Tower Blowdown & Pretreatment	4,500,000	4,500,000	9,000,000
Brine Crystallizer & Solids Handling	1,500,000	1,500,000	3,000,000
Building @$40/sf	200,000	Included	200,000
Subtotal	7,200,000	6,000,000	13,200,000
Construction Indirects @ 17%	1,224,000	1,020,000	2,244,000
Contingency @10%	720,000	600,000	1,320,000
Total	9,144,000	7,620,000	16,764,000

4.0 Discussion of the Definitions of Fresh Water and Brackish Water

The purpose of this section of the Technical Memorandum is to properly define both fresh water and brackish water. By establishing a correct definition for each term, a proper distinction can be generated between each water source. This clarification is intended to aid in the justification to allow the PEC the use of water from the lower confined aquifer for its cooling tower.

4.1 Fresh Inland Water

Inland fresh water is generally identified as water that contains low concentrations of dissolved salts and TDS. It is commonly identified as water that contains less than 0.5 parts per thousand, or 500 ppm, of dissolved salts. The California Environmental Protection Agency (EPA) State Water Resources Control Board (SWRCB) generally defines fresh water as water that is free of excessive salinity concentration, as per applicable California salinity thresholds(1). Fresh inland waters are further defined by the SWRCB through Resolution Number 75-58 as those inland waters that are suitable for use as sources of domestic, municipal, or agricultural water supply and which provide habitat for fish and wildlife.

(1) Applicable California salinity threshold can be found within the California Toxics Rule or in Basin Plans.

4.2 Brackish Water

Brackish water is generally identified as water with higher salinity and TDS concentrations than are found in fresh water, but lower concentrations than those found for sea water(2). Brackish water sources are usually formed from either the mixing of sea water with fresh water or from deposits found within brackish fossil aquifers. Generally, brackish water contains anywhere between 0.5 and 30 parts per thousand (500 – 30,000 ppm) of dissolved salts. The EPA SWRCB generally defines brackish water as a mixture of fresh water and salt water. The SWRCB defines brackish waters more specifically through Resolution Number 75-58 as all waters with a salinity range of 1,000 mg/L to 30,000 mg/L and a chloride concentration range of 250 mg/L to 12,000 mg/L.

4.3 Comparison to PEC Water Sources

Based on the aforementioned definitions for brackish water and fresh water, both the water found within the upper semi-confined aquifer and the lower confined aquifer can be classified as brackish water. Neither one of these water sources can be considered suitable for use as domestic, municipal, or agricultural water (without significant pretreatment being performed to it). In addition, water found within both of these aquifers has a TDS concentration greater or around 1,000 ppm, which classifies it more as brackish water than fresh water. Therefore, the PEC's use of either the confined or semi-confined aquifer as a water source for its operations should be considered permissible by the California Water Code and the SWRCB, since both sources are brackish water.

5.0 Conclusions

Based on the results of the comprehensive evaluations of source water and wastewater disposal options conducted in the *August 2006 AFC*, the *March 2, 2006 Expanded Evaluation of Water Supply and Wastewater Discharge Alternatives*, and this *March 19, 2006 Supplemental Discussion of Water Supply and Wastewater Discharge Alternatives*, it is clear that the use of water from the confined aquifer for source water and the use of Deep Well Injections for wastewater disposal (Option B in this memorandum) is the best alternative based on economic feasibility, project performance, and environmental consequences. Further, based upon the classification of fresh and brackish water from EPA, Option B clearly adheres to all regulatory requirements. Therefore, the selection of using confined aquifer water and Deep Well Injection presents the best option for the PEC project.