POSEIDON WATER

Appendix S
Hydrogeologic Investigations
SDG&E Encina Power Plant
Carlsbad, CA

Renewal of NPDES CA0109223
Carlsbad Desalination Project

SDG&E San Diego Gas & Electric

DROUGHT-PROOFING THROUGH DESALTING
THE SAN DIEGO GAS & ELECTRIC APPROACH

JUNE 1995

BOYLE ENGINEERING CORPORATION

DROUGHT-PROOFING THROUGH DESALTING THE SAN DIEGO GAS & ELECTRIC APPROACH

by

Donald L. MacFarlane, Boyle Engineering Corporation
7807 Convoy Court, Suite 200, San Diego, CA 92111

and

Joseph A. Otahal, William H. Stroman, San Diego Gas & Electric
990 Bay Boulevard, Chula Vista, CA 91911

INTRODUCTION

Producing a reliable power supply is a fundamental goal of San Diego Gas and Electric Company (SDG&E). Because water is an essential element in the production of power at SDG&E's generating facilities, the reliability of their plants' water supply affects the reliability of the plants. SDG&E purchases water from the Carlsbad Municipal Water District (CMWD), a member agency of the San Diego County Water Authority (Water Authority), who in turn is a member agency of the Metropolitan Water District of Southern California (Metropolitan). This "imported" water supply is subject to shortages from droughts and other natural disasters. Both the Water Authority and Metropolitan are taking steps to improve supply reliability. In the meantime however, SDG&E has recognized the opportunity to greatly improve the reliability of their water supply. In October 1993, SDG&E selected Boyle Engineering Corporation (Boyle) to provide engineering consulting services to determine the feasibility of desalting ocean water for use at their Encina power plant.

SDG&E's Encina power plant is a gas and oil fired generating station located adjacent to the Pacific Ocean in Carlsbad, California. Ocean water via the Agua Hedionda Lagoon is used for cycle cooling. Fresh water needs are purchased from the local water district and potable uses include drinking, landscape irrigation, fire protection, and sanitation. Non-potable uses include boiler feed make up, condenser cleaning, pump sealing, boiler cleaning, and other maintenance activities. Potable and non-potable requirements are variable, and can be met with a system that is sized to provide 400 gallons per minute (gpm).

To meet SDG&E's system requirements, Boyle needed to determine the technical feasibility and costs associated with an ocean water reverse osmosis (RO) treatment plant to supply the water requirements of the Encina plant. SDG&E divided the project into two phases, a Preliminary Engineering Phase (PEP) and a Detailed Engineering Phase (DEP). This paper describes the results of the PEP, and is organized into the six (6) following sections:

- ❑ Water Supply Requirements
- ❑ Hydrogeologic Investigation

- Reverse Osmosis Treatment System
- Liquid and Solid Wastes
- Project Costs
- Conclusion

WATER SUPPLY REQUIREMENTS

Existing Supply

Presently, SDG&E purchases water from Carlsbad Municipal Water District (CMWD) for use at their Encina plant. CMWD is a member agency of the San Diego County Water Authority (Water Authority), who is a member agency of the Metropolitan Water District of Southern California (Metropolitan). Metropolitan receives water from both northern California (through the California Aqueduct) and the Colorado River (through the Colorado River Aqueduct). These sources are blended at Lake Skinner in Riverside County, treated at the Skinner Filtration Plant, and delivered to San Diego County through large diameter pipelines, known as the San Diego Aqueducts. From Metropolitan's delivery point, the Water Authority owns and operates the aqueducts (Figure 1). CMWD is supplied water through several aqueduct connections. Water is stored and delivered to their customers through a local distribution system. SDG&E's Encina power plant is connected to the CMWD system by a 12-inch primary connection pipeline, and a 10-inch backup connection pipeline. Although the plant has a single distribution system for both potable and non-potable needs, the flow requirements were studied separately in the reverse osmosis (RO) investigation.

Potable Requirements

Presently, the Encina plant's potable water uses include drinking, landscaping irrigation, fire protection, and sanitary purposes. The estimated potable flow requirement is 200 gallons per minute (gpm). The water quality must meet State and Federal Drinking water requirements.

Non-Potable Requirements

Non-potable water use is primarily for boiler feedwater make-up (BFW) water, but also includes condenser cleaning, pump sealing, boiler washing, and other maintenance activities. For BFW, SDG&E treats CMWD water with an existing, on-site reverse osmosis makeup demineralizer system. The estimated non-potable requirement is 200 gpm, making the total plant requirement 400 gpm. With a recovery rate for the RO plant of about 50 percent, a supply of approximately 900 gpm is required.

Future Water Supply for Desalting

Although ocean water is readily available at the Encina plant from the cooling water system, a groundwater supply would be a very attractive alternative due to its lower suspended solids, and resulting potential to eliminate pretreatment and associated waste disposal requirements. For this reason, a significant effort was made during the PEP to investigate and develop a groundwater supply.

HYDROGEOLOGIC INVESTIGATION

Exploratory Program

The purpose of the exploratory program was to select a site for a production well that could be pumped to test the capability of the aquifer. Initially, a review was made of available reports, maps, aerial photographs, and construction drawings. Some of this information indicated that an alluvial channel extending from under the plant site to the Pacific Ocean had been filled when the plant was constructed in the early 1950s. This information also indicated areas of alluvial deposits in and around the Agua Hedionda Lagoon. Based on the information reviewed, two possible locations were identified for exploration:

1. At the power plant site in the filled channel; and
2. North of the plant site, on a linear strip of beach deposits (sand spit) adjacent to Carlsbad Boulevard, in between the Pacific Ocean and the Agua Hedionda Lagoon where the channel had previously existed.

The three exploratory borings that were drilled are shown in Figure 2. Boring B-1 was located on the sand spit, and borings B-2 and B-3 were located in the plant's parking lot. The eight-inch diameter borings were advanced to depths of from 50 to 95 feet using a Mobile B-61 truck-mounted drill rig. The drilling operation was supervised, and the borings logged and classified by a geologist. Boring B-1 did not reveal the depth of sediments that were expected on the sand spit. A gravity survey was then employed to locate one additional boring location (B-4). At B-4 sediments were found at depths of more than 135 feet. Monitoring wells consisting of 2-inch diameter PVC pipe with 0.02 inch slots below the water table, were installed in borings B-2 through B-4 for use during the aquifer testing. Based on this exploratory program, the location for a production well was selected, 42 feet south of boring B-4.

Production Well Design and Development

To construct the production well, a 14.75-inch diameter hole was drilled to a depth of 200 feet. An 8-inch diameter schedule 40 PVC casing, consisting of alternating blank and screened sections (0.03-inch slots), was installed to a depth of 165 feet. The screened sections were aligned with the most permeable water bearing formations, as located by the geologic and geophysical logs of the hole. The annulus between the bore hole and casing was backfilled with a Lone Star No. 3 gravel pack, except for the upper 30 feet, where a Portland cement sanitary seal was provided. Figures 3 and 4 show geologic sections through the well, and Figure 5 shows the well drilling.

After the installation of the casing, screen, and gravel pack, the well was developed by using a surge block to bring suspended sediments to the surface using compressed air. Further development was done by pumping the well at its full capacity of 330 gpm. Periodic pumping was conducted for several days prior to the testing of the aquifer.

Aquifer Testing and Yield Estimate

Step-drawdown and constant discharge pumping tests were conducted for a period of 25 hours, followed by monitoring of recovery for an additional 24 hours. Drawdown was measured in monitoring wells B-2, B-4, and the production well. Drawdown in the production well ranged from 9 feet after 93 minutes, to 14 feet at the end of the test.

After interpretation of the test data, it was concluded that:

- The yield of the production well was in excess of 450 gpm;
- The yield of a larger diameter well is likely to be in excess of 600 gpm; and
- The aquifer is capable of producing the 900 gpm desired through installation of multiple wells.

Water Quality

Water samples were collected and analyzed throughout the exploratory program, well development, and aquifer testing. As expected, the suspended solids were considerably lower than surface water, and elimination of pretreatment was feasible. The analyses also indicated favorable values for temperature, silt density index, and iron, as shown below:

TSS	13 ppm
Temperature	64 to 67 Deg. F
SDI	1.0- to 5.0+ (mostly less than 3)
Iron	3.6 ppm (with entrained air)
Bicarbonate	220 ppm
Turbidity	0 NTU

Unfortunately, the total dissolved solids (TDS) in the water were on the order of 60,000 parts per million (ppm), nearly twice that of typical seawater. The geologists felt that either the water stored in the aquifer had very high TDS, or that the water moving through the aquifer was leaching chlorides from the soil. In either case, because the well is located on a sand spit between the Pacific Ocean and the Agua Hedionda Lagoon, the geologists felt that eventually the TDS would approach that of standard seawater.

The supply water TDS is a very important parameter in the design of an RO system. The higher the TDS, the higher the osmotic pressure and the lower the recovery rate. The net result is higher operating costs, shorter membrane life, a larger feedwater requirement, and a larger brine stream. The team decided that the best way to determine how long it would take for the TDS to decline would be to extend the pumping test. The pumping was extended for nearly a month at 330 gpm. The TDS did not decline significantly and no firm conclusions could be reached regarding the time required for the TDS to approach that of standard seawater.

Multiple Shallow Wells

The electric log of the production well indicated that groundwater, with a quality similar to that of seawater, is contained in the upper 50 to 60 feet of the alluvial sediments. After completing the 30-day well pumping test, grab samples were taken at various depths to characterize the well water quality between the different strata (Table 1). It is possible to install a series of shallow wells to tap just this layer. This arrangement however, would create a vertical gradient that could potentially become a pathway for the upward migration of poor quality groundwater into the well bore. The geologic log of the production well indicates that the majority of the water provided by the production well is coming from coarse-grained sediments below 145 feet. Additionally, the log of Boring B-4 indicates that the upper alluvial sediments are typically fine-grained materials. This suggests that shallow wells may not produce water in sufficient quantity to meet the plant's requirements.

It was recommended that prior to drilling other shallow wells, existing well tests be performed with the insertion of an inflatable block at various depths to isolate the effects of the lower strata, while pumping the upper well section to determine yield and water quality.

Conclusion

Until further study is completed indicating that the well supply is practical, the cooling water system is assumed to be the source of supply water for the new RO treatment system. As previously described, the total potable and non-potable requirements are 400 gpm. With a recovery rate for the RO plant of about 50 percent, approximately 900 gpm will be withdrawn from the cooling water intake system.

REVERSE OSMOSIS TREATMENT SYSTEM

Basis of Design

The process developed for the Encina seawater reverse osmosis treatment system includes pretreatment, a partial two-pass seawater reverse osmosis system, storage, and posttreatment facilities. The process will provide both the potable and non-potable water supplies for the plant. The somewhat different treatment requirements for each stream (potable and non-potable) are described below.

Feedwater

Process feedwater will be taken from the power plant's cooling water intake canal using vertical turbine pumps dedicated to that service. One pump will be located between the traveling screens and cooling water pumps at both Unit 4 and Unit 5. Seawater will be delivered to the pretreatment system, where it will be prepared for desalting. Important water quality parameters are discussed below.

Suspended Solids

The suspended solids in the intake cooling water range from 5 to 50 milligrams per liter (mg/L), depending upon many factors including weather, tides, and time of year. As a basis for design, it was assumed that the average suspended solids concentration is 30 mg/L.

Dissolved Solids

Dissolved solids in the feedwater are assumed to be typical of seawater in the San Diego area (34,400). The water quality assumed in making RO performance projections are presented in Table 2.

Temperature

Temperature has a significant effect upon the pressure requirements for the RO system and is an important RO design parameter. As temperature decreases, the RO feed pressure must increase to maintain a constant permeate production. The temperature of the intake cooling water (CW) has been measured over the years, and average temperatures for each month computed. Based upon these computations, design temperatures of 55 degrees Fahrenheit (Deg. F) for winter operation and 75 Deg. F for summer operation were chosen. The primary design point for pump selection and piping system design will be for winter operation, as this period will have higher pressure requirements.

Product Water

Two separate product streams were required from the seawater RO system. Total production requirements for both streams is 400 gpm, of which half is potable water and half is non-potable. The water quality requirements differ.

Potable water is required to meet all Federal and State health standards as established by the Safe Drinking Water Act and the California Department of Health Services. In particular, all primary standards (Maximum Contaminant Levels, or MCLs) are to be met. Maximum Total Dissolved Solids (TDS) content of the domestic water is to be 500 mg/L after posttreatment. In addition, the minimum hardness and alkalinity of the water are to be 40 mg/L (as $CaCO3$) and the Langelier Saturation Index (LSI) is to be between -0.2 and 0.2 for the water to meet the requirements of the Lead and Copper rule of the Environmental Protection Agency (EPA).

The BFW (non-potable) stream has no fixed water quality requirements. The only standard is to produce a water with TDS approximating that of the existing municipal water supply, and have a very low scaling potential. No posttreatment will be applied to reduce the corrosivity of the water.

Summary of Proposed Processes

A simplified process flow diagram is included in Figure 6.

Cooling Water Supply

The water supply intake will consist of vertical turbine pumps placed to take suction from the cooling water intake canal. The pumps will deliver water through a new pipeline to the RO island. Since this is surface water and presumably biologically active, substantial pretreatment will be required, including clarification, filtration, disinfection, and dechlorination.

Pretreatment

The pretreatment system is intended to provide a clean, relatively particle-free supply to the RO system. Requirements for the pretreatment system are to provide water with turbidity below 0.2 nephelometric turbidity units (NTU) and with a silt density index (SDI) below 4.

In addition to filtration, it is necessary to reduce the biological activity of the feedwater, as biological fouling commonly causes RO membranes to need cleaning. Chlorinating the feedwater will reduce biological activity. However, since the RO membranes under consideration for this project are intolerant to chlorine, it will be necessary to dechlorinate the feedwater immediately before entering the RO system through injection of sodium metabisulfite.

Reverse Osmosis System

The reverse osmosis system is intended to provide the design water quality under both summer and winter conditions. Spiral wound membranes were selected because SDG&E has had good experience with them, they are manufactured locally, and SDG&E has experienced good product support.

While several different types of pumps can be used to provide the necessary feed pressure, the design and cost estimates were based upon using quintuplex piston pumps as the main feed pumps because of their inherent high efficiency. These will be constant speed pumps fed by horizontal centrifugal or vertical turbine pumps with variable frequency drives (VFDs). The boost pumps are equipped with VFDs to permit variation in RO feed pressures required by temperature fluctuations in the feedwater, to accommodate changes in cartridge filter differential pressure, and to adjust to changes in the membrane net driving pressure. This proposed pumping arrangement provides the range of operating conditions required for the RO membrane system.

Posttreatment

Potable water will be disinfected by calcium hypochlorite and stabilized by chemical addition. Alkalinity will be provided by injection of gaseous carbon dioxide (CO_2), followed by passing the water through a bed of calcium carbonate (limestone). Carbonic acid produced by the CO_2 addition will dissolve the calcium carbonate, producing calcium bicarbonate. The presence of calcium bicarbonate tends to stabilize the water.

Posttreatment will not be provided for the non-potable product water.

Site Requirements

An area of approximately 65 feet by 130 feet will be required to install the reverse osmosis treatment system. This area will house the pretreatment system, reverse osmosis treatment system, posttreatment system, chemical storage and feed, and storage and delivery systems. A preliminary site arrangement is given in Figure 7 and a photograph of the proposed site is shown in Figure 8.

Pretreatment

The pretreatment system consists of two primary elements: filtration for particle removal, and chemical feed to provide disinfection and enhance particulate removal.

Filtration Systems

A prepackaged media filter and a membrane filter have been investigated for the Encina desalting system.

Prepackaged Media Filter

The prepackaged media filter is a conventional municipal-type gravity media filter, equipped with anthracite, garnet, and sand media. This filter is believed to be capable of providing suitable RO feedwater without additional clarification or filtration, except during periods of extremely high solids loading in the influent water. The filter system includes the concrete filter structure, internals, media, backwash system, chemical feed system, control system, and installation. It is not necessary to install the filters inside a building.

Microfilter

The microfilter has received a substantial amount of attention as a method of meeting filtration requirements for municipal supplies and RO feedwater. Not only has it demonstrated the ability to meet water quality requirements, but it provides a built-in method of checking the integrity of the filter elements. By measuring the pore pressures of the filter elements, it determines if any of the elements have developed leaks or tears capable of permitting unfiltered water to pass through. This capability can be of significant value in cases where stringent water quality standards must be met.

Microfilters are capable of producing substantially better water quality than multimedia filters. A much larger percentage of particles, and much smaller particles, are removed. In the case of RO pretreatment, better water quality could result in substantially reduced fouling of the membranes, reduced cleaning being required, and extended membrane life. Improved water quality is provided without using coagulant aid chemicals, which could simplify the discharge of backwash water. In addition, microfiltration could provide operational cost savings by reducing the frequency of cartridge filter replacements.

The microfilter has higher pressure requirements than a media filter; about 15 psi differential. However, since the entire system is under pressure, it is possible to use the intake pumps to push water through the entire pretreatment system from the intake canal to the pre-RO storage tank.

These filters are provided with their own control panels, and additional items necessary for operation, including a cleaning tank and backwash air system. These items are provided in the filter package. This system would require an area about 45 feet by 32 feet, or 1,440 square feet, and should be housed inside a building or under a cover to provide weather and sun protection.

Recommended Filtration System

The microfilter is more reliable in solids removal and was recommended for this reason. The media filter is a strong candidate and is considerably less expensive, but its ability to provide adequate solids removal in this application must be pilot tested. The testing would be used to determine chemical dosage rates, solids removal rates, filter rates, and overall feasibility. The selection of a filter type should be revisited in the project's DEP. In laying out the RO island and in determining liquid and solid waste volumes, the media filter was assumed.

Seawater Reverse Osmosis System

First Pass RO Pumping System

The feed pumps for the first pass RO system must be capable of varying output pressure to meet the varying temperature of summer and winter operation. This requires the pump system to produce a 120 psi variation in discharge pressure over the year, while maintaining relatively constant flow. In addition, pressure requirements will vary over time as membranes age and the required net driving pressure tends to increase.

Both positive displacement (PD) and centrifugal pumps were examined for use in the first pass RO system. PD pumps have the primary advantage of providing essentially constant flow regardless of discharge pressure. This means that the pressure difference required by temperature change will have minimal effect upon the pumping system. PD pumps also have inherently high mechanical efficiency. This type of pump tends to be more expensive than a centrifugal pump.

Centrifugal pumps produce different flows at different differential pressures. The pressure requirements of this system therefore present an operational challenge. The best way to handle this pressure variation is through the use of variable frequency drives (VFDs) to vary the motor speed and the pressure delivered by the pumps. It has been Boyle's experience that the large VFDs required for RO feed pumps (in excess of 250 horsepower) are very expensive. Rather than use only PD pumps, or only centrifugal pumps with large VFDs, the team decided to separate the pumping system into a boost pump and then a feed pump. In this system, the boost pump provides the required pressure variation.

Typically, RO systems use these boost pumps to provide the head necessary to deliver water through the cartridge filters and into the feed pumps, requiring less than 50 psig. For Encina, the boost pumps have been selected to provide 300 psig discharge and are equipped with VFDs. These pumps (and VFDs) require about 100 horsepower (HP), placing them in a much more economical size range than if VFDs were used to operate the RO feed pumps (would require several hundred horsepower). This two-stage pumping system provides a more efficient and economical system overall.

Table 3 summarizes the first pass pumping requirements for the design case (winter operation, 50% recovery). The table includes design conditions for energy recovery devices (discussed later in this report).

Boost Pumps

The boost pumps may be either horizontal split-case or vertical turbine pumps. Horizontal split-case were selected due to their expected lower cost, easier piping, higher efficiency, and lower maintenance cost. The pumps are intended to provide 185 to 300 psig discharge pressure, at a delivered flow of 400 gpm (each pump will service one RO train, with feed requirements of 400 gpm). Motor-driven VFD pumps were recommended. To withstand the corrosive effects of seawater, pumps with aluminum bronze or stainless steel construction were also recommended.

Feed Pumps and Energy Recovery

Feed pumps may be either positive displacement, vertical turbine, or high-speed centrifugal designs. The pumps must be selected to provide 690 psi differential pressure at 400 gpm flow. Several systems were developed that included a horizontal split-case boost pump and either a PD or vertical turbine feed pump. The characteristics of these systems are shown in Table 4. The high-speed centrifugal pump is only offered with an energy recovery device and is therefore not included in Table 4, but is discussed later.

Energy recovery devices are often used in seawater RO systems, since the RO concentrate contains almost half of the energy originally delivered to the feedwater. A large portion of this energy can be recovered using some type of energy recovery device.

The vertical turbine pump manufacturers quoted reverse running turbines (RRTs) to be included as a part of the pump column. This is the equivalent of mounting several additional pump bowls on the shaft, but isolating them and running the RO concentrate through them backwards. The energy in the concentrate stream is delivered to the pump shaft and thence to the RO feedwater. This reduces the amount of energy required from the pump motor. The RRTs quoted operate at 59 percent efficiency, compared to the 72-73 percent efficiency of the pumps. The RRT delivers about 61 HP to the pump.

The positive displacement pump manufacturer proposed an energy recovery turbine that would be coupled directly to the pump drive shaft. This turbine was quoted as having an efficiency of 84 percent, delivering 97 HP to the pump.

The high speed centrifugal pump manufacturer had a standalone device containing both an energy recovery turbine and a pump turbine, direct coupled. It is not attached to the primary feed pump. This device was quoted as having an overall efficiency of 58 percent. However, since this efficiency rating includes that of the pump (which for the other pumps is about 73 percent), the efficiency of the energy recovery section is about 79 percent and delivers about 87 HP. Operating characteristics of the pump systems with energy recovery are given in Table 5.

The positive displacement pump system has been chosen as the basis for this report because of its low energy requirements. However, an economic analysis based pumping scheme should be selected and incorporated into the RO procurement specifications.

Membrane Configuration

Projections of membrane performance were run using design software from several membrane manufacturers. The results are summarized in Table 6. In each case shown in the table, the vessels are loaded with six elements. Assumptions used in calculating membrane performance include the water quality and temperature data noted earlier in the report, membrane performance (and maintenance) specified by the manufacturer, and a membrane age of three years. The membrane array column indicates the number of vessels in the first stage to the number of vessels in the second.

The table shows that membrane selection can have a substantial impact upon feed pressure requirements and product water quality. After consideration of these data, a maximum membrane system feed pressure of 950 psig was selected. An additional 25 psig for manifold pressure losses, and permeate back pressure was included, yielding a design pump discharge pressure of 975 psig.

Permeate quality varies substantially, based upon membrane selection and system recovery. Permeate quality is also affected by temperature, necessitating performance projections at the maximum expected summer temperature of 75 Deg. F. Permeate quality projections for both winter and summer operation are shown in Table 7.

A 400 ppm limit was established, so that after posttreatment the TDS would be 500 or less. Only membrane "A" was capable of maintaining a permeate quality of less than 400 ppm under both winter and summer operating conditions. Membrane "C" exceeded 400 ppm under summer conditions at 50 percent recovery, and Membrane "B" exceeded the 400 ppm limit for all recoveries under summer conditions, and for 50 percent recovery under winter conditions. Preheating the feedwater was investigated and was not found to be beneficial.

Posttreatment

The function of the posttreatment process is to prepare the water for potable use. This involves disinfecting and stabilizing the water in order to meet the requirements of the California Department of Health Services (DHS) and the Surface Water Treatment Rule (SWTR). The non-potable water will not receive posttreatment. The potable water system is sized to provide a maximum flow of 200 gpm, or a maximum of 288,000 gallons per day.

The SWTR requires 4 log removal (99.99 percent removal) of viruses and 3 log removal for Giardia lamblia. These removals can be obtained either by filtration or by disinfection. The DHS has established "credits" for the amount of removal that filtration processes can provide. Microfiltration has received credit for 4 log removal of both types of organisms. Multimedia filtration is credited with 2 log removal of Giardia and 1 log removal of virus. In addition, the DHS is willing, on a case-by-case basis, to allow additional removal for RO treatment. Any remaining log removal must be provided by disinfection. As a basis for design, disinfection was assumed to provide 1 log removal of Giardia and 3 log removal of viruses. If calcium hypochlorite is injected at 1 mg/L, the required contact time to provide this level of disinfection is 1.5 hours at 55 Deg. F.

Disinfection will be accomplished by injection of calcium hypochlorite upstream of the potable water storage pumps. The existing domestic water storage tanks will provide considerably more storage volume than is required for the contact time for disinfection. However, baffles may need to be retrofitted to prevent "short circuiting" in the tank.

Stabilization of the domestic water will be required in order to meet the dictates of the Lead and Copper Rule. This rule limits the amount of lead and copper allowed in domestic water at the tap. Since a large percentage of these contaminants enter the water in the distribution system via corrosion, the Rule specifies acceptable ranges for corrosiveness of the water. Therefore, the established targets for certain water quality parameters related to corrosion include:

- Hardness is to be greater than 40 mg/L;
- Alkalinity is to be greater than 40 mg/L; and
- Langelier Saturation Index (LSI) is to be between -0.2 and 0.2.

Meeting these requirements will require the addition of chemicals to adjust pH, hardness, and alkalinity.

Alkalinity adjustment will be performed by addition of carbon dioxide, followed by passing the water through a bed of limestone. The carbonic acid formed from the dissolved CO2 will dissolve part of the limestone, producing calcium bicarbonate. The presence of calcium bicarbonate will stabilize the water, providing both hardness and alkalinity.

Liquid carbon dioxide will be stored on-site in a refrigerated tank. It will be vaporized as required for injection. Liquid carbon dioxide is stored under considerable pressure (about 300 psig). The hazards associated with carbon dioxide involve its high pressure storage and that being in gaseous form, it is capable of displacing oxygen from confined spaces.

LIQUID AND SOLID WASTES

The salt water RO process will produce several waste products, including both liquid and solid wastes.

Liquid Wastes

Liquid wastes produced by the process include pretreatment microfilter or media filter backwash water and RO concentrate. The microfilter would produce a waste stream of two to three percent of the flow. It is assumed that this could be combined with the brine stream and discharged to the cooling water discharge. If the media filter were used, backwash water would be produced on an intermittent basis. The water will contain solids removed from the influent water, as well as any coagulant chemicals injected to the filter feedwater. The accumulated debris present problems in meeting the plant's National Pollutant Discharge Elimination System (NPDES) discharge permit requirements for total suspended solids (TSS). In addition, there is a potential for problems associated with metals, grease, and oils which could occur periodically from runoff, due to influences from rain, into the lagoon and ocean.

A sludge settling pond will be required to separate the solids for land disposal and the water for low volume waste or return to the RO feed. Due to the expected problems with the pretreatment disposal, a backwash treatment process would be required to posttreat the collected sandfilter backwash. The treatment process would most likely consist of a backwash equalization tank, a backwash clarifier, and mechanical dewatering equipment.

RO concentrate will be produced in the desalting process at a rate approximately equal to that of the desalted water. Assuming the worst case operation (continuous operation of two RO trains), about 576,000 gallons of concentrate will be produced per day, at a concentration of about 68,000 mg/L. This waste stream will be discharged into the power plant cooling water discharge, where it will be diluted by flows in excess of 100 MGD, providing a dilution factor in excess of 170.

Solid Waste Disposal

Solid wastes produced by the salt water RO system will include filter backwash sludge, spent cartridge filters, spent RO membranes, damaged parts replaced during equipment repairs, and miscellaneous domestic waste. Filter backwash will produce about 675 pounds per day of solids, to be collected in a sludge settling basin. This sludge will require periodic removal and disposal. The solids are not expected to contain hazardous materials, but could if these materials are present in the lagoon. Assuming that the sludge will be removed at a concentration of 40 percent solids, about 13.5 cubic feet of sludge per day will be produced.

Cartridge filters will require periodic replacement. A two month replacement schedule has been used for costing purposes. The volume of the cartridge filters will be about 8 cubic feet. Cartridge filters are constructed of relatively inert plastic materials and are suitable for landfill. It may be possible to recycle the plastic cartridge material.

RO membranes require replacement every three to five years for the first pass, with four years being selected for this study, and about every seven years for the second pass. The volume of first pass elements will be about 1.5 cubic feet per element, with 132 elements, totaling about 198 cubic feet. RO elements are constructed of relatively inert plastic materials. A second tier membrane business is developing that reconditions and resells used membranes. SDG&E already recycles membranes from the existing plant RO facility and the saltwater membranes are assumed to be recycled in a similar manner.

Damaged parts replaced during equipment repairs will include plastic and metal parts, synthetic and natural rubber gaskets, and synthetic and natural fibrous materials. Some parts will be coated with synthetic and natural greases and oils. The quantity of this waste cannot be estimated at this time.

Domestic waste will be comprised primarily of waste paper products, with small quantities of other materials. The quantity of this waste cannot be estimated at this time. The existing cooling water intake system has a trash rack and traveling screen and the RO system benefits from this. If the intake is located elsewhere, there would be an overall increase in debris that would need to be disposed of.

Source Reduction of Hazardous Wastes

Per California Senate Bill 14 (SB14), a Source Reduction Evaluation Plan, Plan Summary, Hazardous Waste Management Performance Report and Report Summary are required for the Encina Power Plant because it generates more than 11,000 kilograms of routinely generated hazardous waste. The focus of these requirements, is to evaluate source reduction for those waste streams that are greater than 5 percent of the total routinely generated waste. The addition of the sand filter treatment sludge would increase the waste disposal by approximately 33,000 pounds annually, and would significantly impact the present amount of generated waste. Due to the new source increase, a higher baseline will need to be established and a new waste reduction plan submitted.

In addition to SB14, is SB 1726. SDG&E voluntarily set a goal of 20 percent reduction over a four-year period for specific routinely generated hazardous wastes streams to meet SB 1726. They have also established a corporate goal to reduce total routinely generated hazardous wastes by five (5) percent for all SDG&E facilities.

PROJECT COSTS

With pretreatment, the desalted oceanwater was estimated to cost between $1,200 and $1,800 per acre-foot. If the pretreatment could be eliminated, this range would drop to $900 to $1,400 per acre-foot.

CONCLUSION

The Preliminary Engineering Phase of the Encina Salt Water Reverse Osmosis System Project reached several important conclusions:

1. The Encina Plant requires an average water supply of about 400 gpm, half for potable and half for non-potable uses.

2. The local aquifer can supply at least 900 gpm, but the TDS is too high for practical reverse osmosis treatment. Extended pumping, or a series of shallow wells could produce water with acceptable TDS.

3. The cooling water system can supply the RO system, but pretreatment will be required for solids removal.

4. Reverse osmosis treatment with spiral wound membranes is technically feasible. A partial two-pass system is efficient for meeting both potable and non-potable needs.

5. The cost of the water from the RO system is estimated to be between $900 and $1,800 per acre-foot. Imported water currently costs $660 and is projected to cost $840 per acre-foot in the year 2000.

6. Depending upon the value assigned to the reliability of the water supply and the future cost of the imported supply, the project may be economically feasible.

REFERENCES

1. "Hydrogeologic Investigation SDG&E Encina Power Plant, Carlsbad, California," dated March 23, 1994, prepared by Apex/Group Delta Consultants for Boyle Engineering Corporation.

ACKNOWLEDGMENT

The authors would like to thank Ian Watson, Chris Martin, and Barbara Bartholomae for their valuable comments on this manuscript.

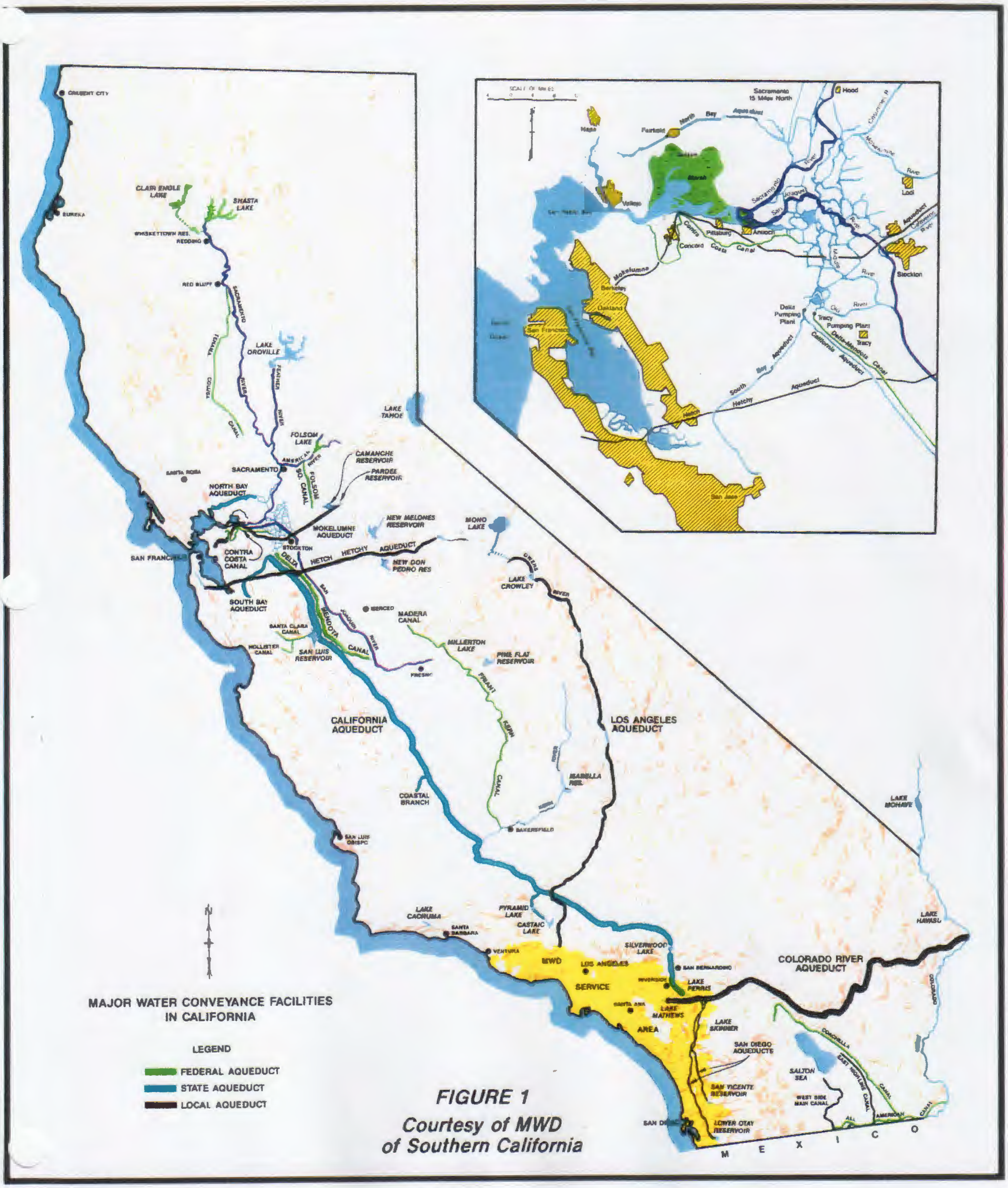
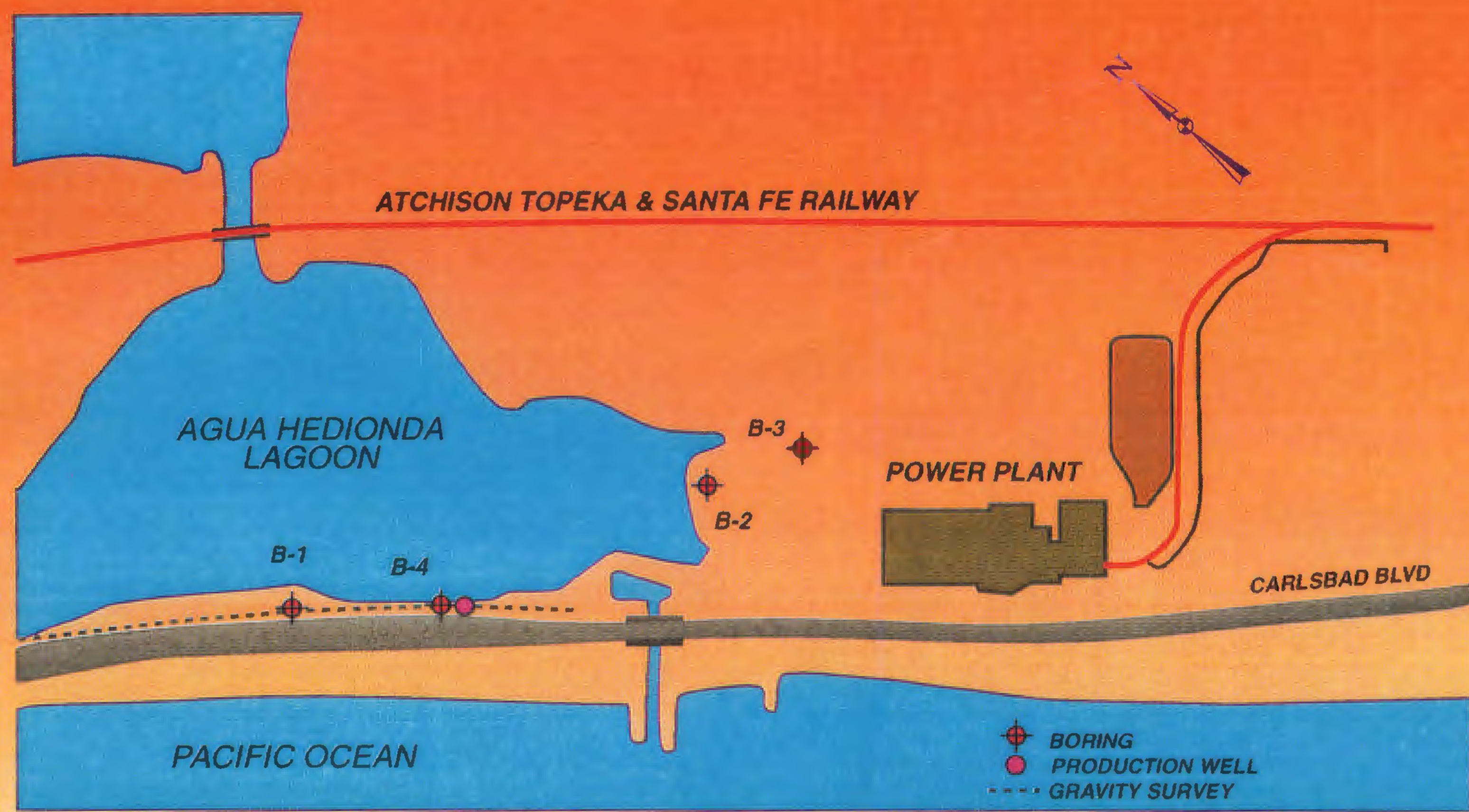


FIGURE 1

Courtesy of MWD of Southern California



SDGE

FIGURE 2

WEST-EAST GEOLOGIC SECTION THROUGH WELL-1

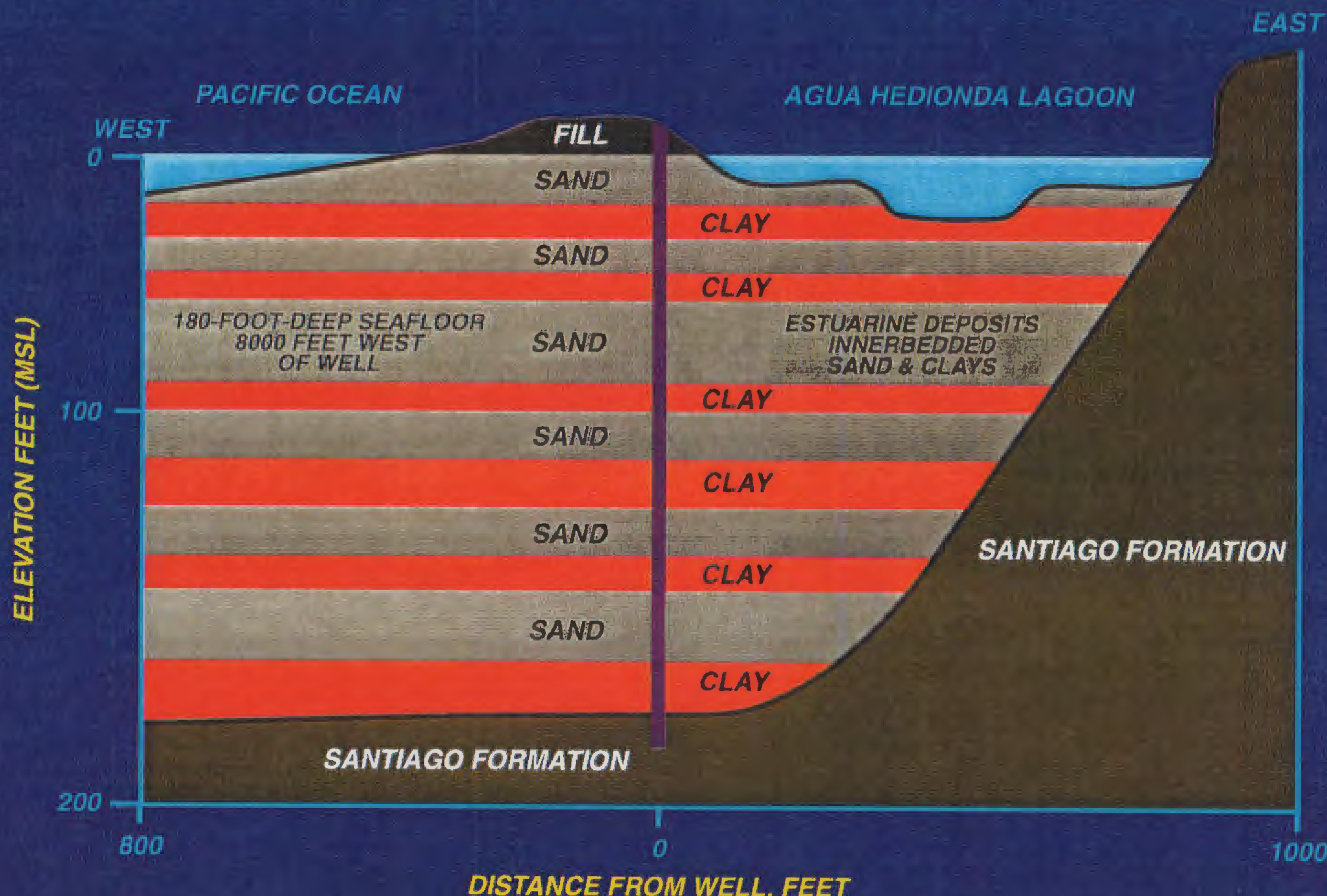


FIGURE 3

NORTH-SOUTH GEOLOGIC SECTION THROUGH WELL-1

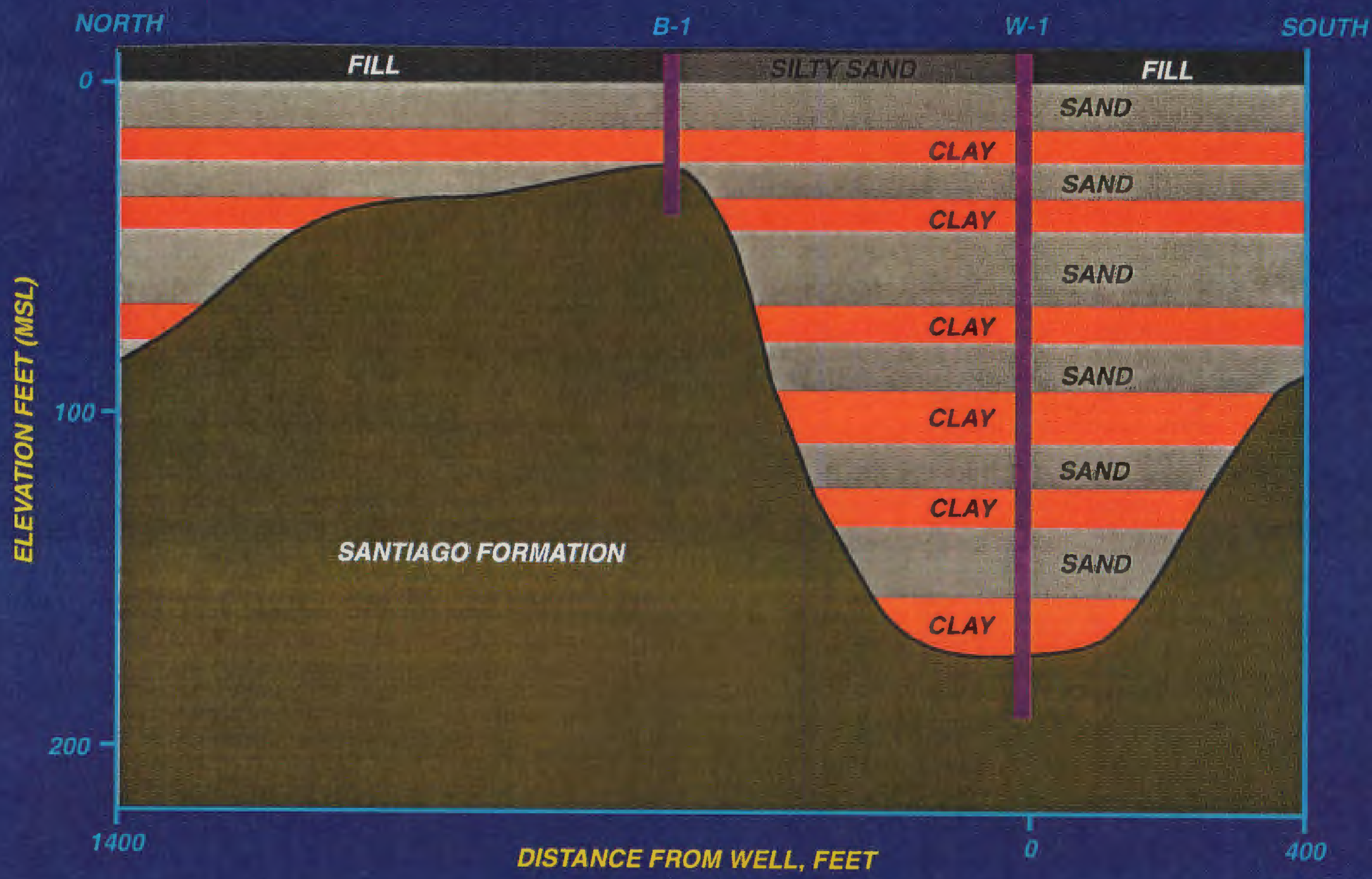


FIGURE 4


FIGURE 5

PROCESS FLOW DIAGRAM

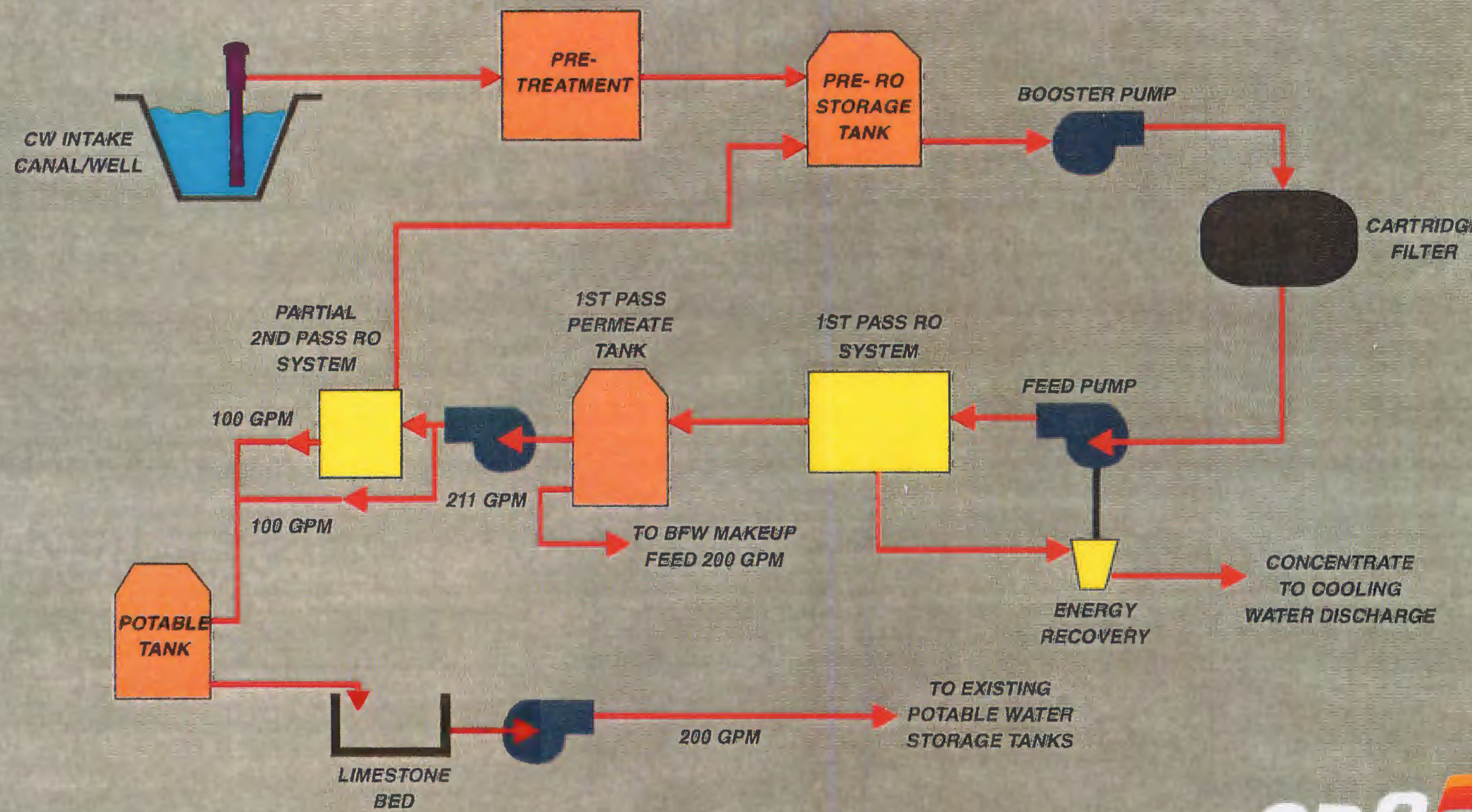


FIGURE 6

SDGE

RO PLANT LAYOUT

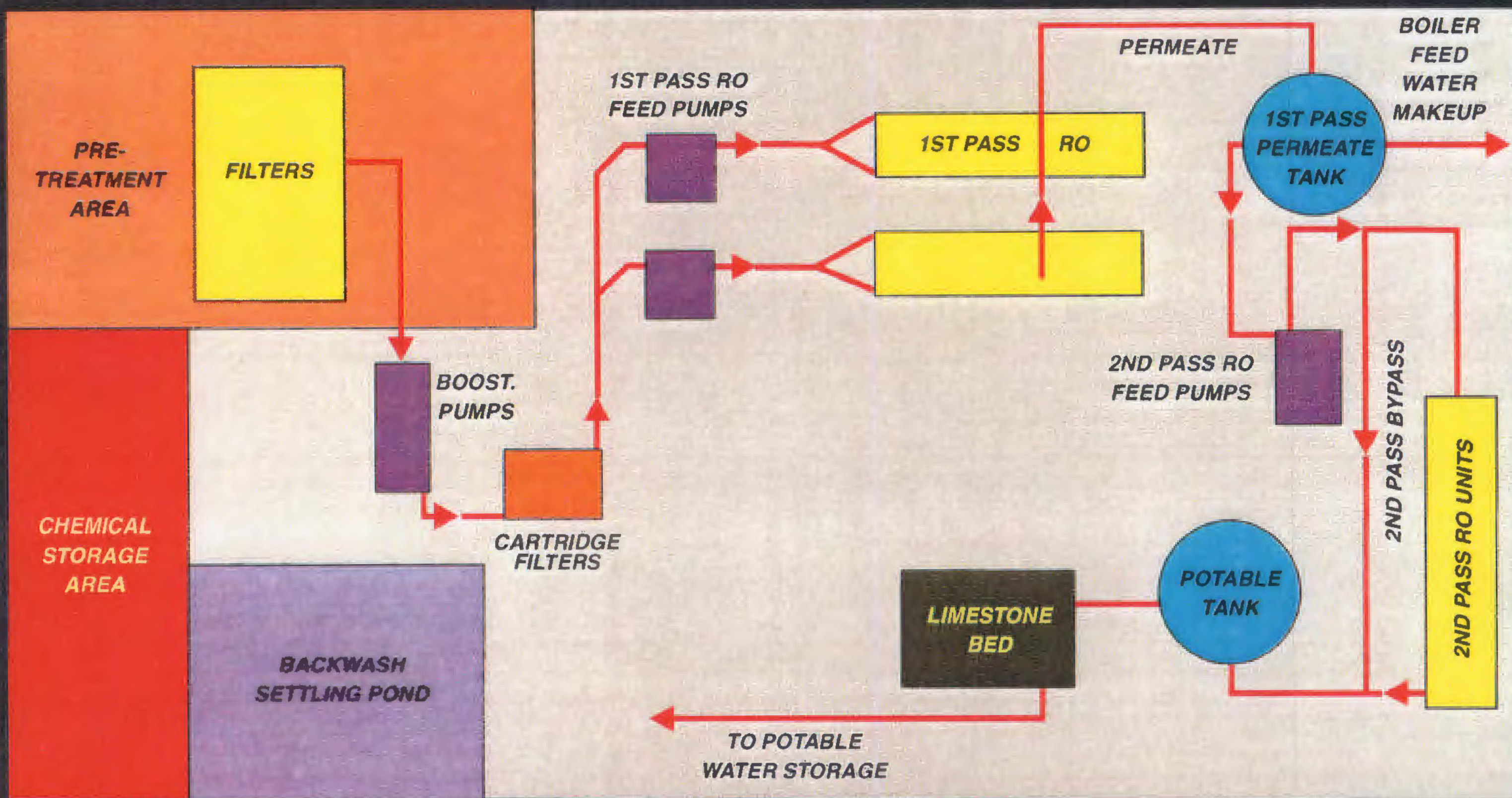


FIGURE 7

FIGURE 8

Table 1
Well Depth (Feet)
Versus TDS (Mg/l)

Well Depth	Total Dissolved Solids
Lagoon	35,000
10	33,464
42	35,064
59	38,583
73	61,426
97	72,303
150	84,781

Table 2
Basis of Design
Water Quality

Parameter	Unit	Quantity
Calcium	mg/L	400
Magnesium	mg/L	1272
Sodium	mg/L	10,561
Potassium	mg/L	380
Bicarbonate	mg/L	142
Sulfate	mg/L	2,662
Chloride	mg/L	19,010
Silica	mg/L	9
TDS	mg/L	34,427
pH	Units	8
CO2	mg/L	19

Table 3
Pumping Requirements

Pump	Flow	Suction Pressure	Discharge Pressure
RO Boost	411 gpm	0 psig	300 psig
RO Feed	411 gpm	285 psig	975 psig
Energy Recovery Device	211 gpm	940 psig	5 psig

Table 4
RO Pumping System Summary

System	Total Hp Required	KWH per 1000 Gallons Product	Pump Manufacturer
Positive Displacement	312	20.8	A
Vertical Turbine	316	21.1	B
Vertical Turbine	315	21.0	C

Table 5
RO - Energy Recovery Pumping System Summary

System	Total Hp Required	ER Type	ER Hp	Net KWH per 1000 Gallons Product	Pump Manufacturer
Positive Displacement	312	PD	97	14.4	A
Vertical Turbine	316	RRT	61	17.0	B
High-Speed Centrifugal	316	RRT	87	15.3	C

Table 6
RO System Projections
Winter Temperature Operation

Recovery (%)	Membrane	Feed Pressure (psig)	Permeate TDS (mg/L)	Membrane Array
50	A	990	265	15:7
	B	957	464	15:7
	C	951	324	15:7
45	A	982	224	14:6
	B	956	395	14:6
	C	944	276	14:6
40	A	967	201	13:6
	B	974	313	12:5
	C	928	248	14:5
	D	877	506	11:5

Table 7
Permeate Quality Projections (TDS) - Single Pass

	Winter - 55 Deg. F			Summer - 75 Deg. F.		
Recovery - %	40	45	50	40	45	50
Membrane A	201	224	265	289	324	385
Membrane B	313	395	464	451	564	678
Membrane C	248	276	324	351	392	463